

# Lessons from a Hurricane: Supply Chain Resilience in a Disaster

An Analysis of the US Disaster Response to Hurricane Maria

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Matthew Kunkel  
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*Signature below of Paper Supervisor certifies successful completion of oral presentation and completion of final written version:*

---

**Amy Kircher**

*Co-Director, Strategic Partnerships and Research  
Collaborative*

*Senior Advisor, Food Protection and Defense  
Institute, University of Minnesota*

*Paper Supervisor*

---

Date

Oral Presentation

---

Date

Paper Completion

---

**Kevin Gerdes**

*Director of MPA and Capstone Projects, Humphrey  
School of Public Affairs*

*Paper Committee Member*

---

Date

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## Executive Summary

This paper examines the US response to Hurricane Maria in Puerto Rico. It takes a specific look at how the supply chains failed, focusing on the three key aspects of (1) essential workers, (2) medical supply chain fragility, and (3) food availability. It goes on to identify potential causes of those failures and then identifies lessons that might have mitigated the supply chain breakdowns. Finally, the paper reviews how similar supply chain challenges are being faced in the current COVID-19 pandemic and explores how lessons observed during Hurricane Maria may be applicable in the present-day.

Maria struck Puerto Rico as a category 4 hurricane on 20 September 2017 and caused widespread damage. The electrical grid was completely destroyed, communications were knocked out, roads were blocked, and access to clean water was limited. Supply chains were severely disrupted.

Key failures of the supply chain included the following:

- 1) A lack of essential workers prevented key goods from being distributed. A shortage of logistical personnel, contracts personnel, translators, debris removal workers, and truck drivers severely compromised the ability to track and distribute important emergency goods on the island.
- 2) Fragility in the medical supply chain led to national and localized shortages. A shortage of saline, saline bags, and medical drugs disrupted the medical supply chain at a national level and uncovered the US's reliance on the large medical industry in Puerto Rico. At the local level, most hospitals were completely inoperable following the storm. Without access to doctors, dialysis machines, oxygen, and ventilators, mortality in Puerto Rico increased.
- 3) Damage to key infrastructure and low food security restricted access to food. Ahead of the hurricane, levels of food insecurity in Puerto Rico were much higher than the rest of the US. The island depended on imports for 85% of its food supply. After the storm, distribution networks were severely compromised, and both local and relief supply chains struggled to meet the need. The result was an island-wide food shortage.

During a disaster, the ability of a supply chain to function relies on characteristics of the chain itself, as well as factors external to the supply chain (e.g. infrastructure, emergency

preparedness, leadership, and coordination). The cascading effects of failed infrastructure or unprepared leadership will severely compromise the ability of a supply chain to deliver the right supplies at the right time. Lessons observed from the Hurricane Maria response—both internal and external to the supply chain—include:

- 1) The Federal government should have been better prepared to assume a frontline leadership role in the disaster response.
- 2) The Federal Emergency Management Agency (FEMA) should have established stronger public-private partnerships through collaboration with local government leaders and organizations.
- 3) The US should have taken steps to strengthen its medical supply chain and reduce susceptibility to single point failures.
- 4) The White House should have conveyed a clear and unified response strategy that was consistent with the on-the-ground reality.
- 5) The US should have taken swift action to quickly assemble a team, assess the needs, and deploy resources.
- 6) The federal government should have had an expanded workforce surge capacity that accounted for concurrent disasters.
- 7) Investment should have been made to increase the resiliency of Puerto Rico's infrastructure.
- 8) Emergency plans should have accounted for the severity of the threat and have honestly assessed local resiliency.
- 9) Food security should have been strengthened through an increase of local food production and a strategic stockpiling of emergency food supplies.

In its review of COVID-19, the paper finds that—although of a different scale and nature—many of the challenges encountered in Maria are also being faced during the pandemic. Similarly, the lessons observed during Maria—especially around supply chain resilience, preparation, leadership, and strategy—are quite applicable today. This underscores the notion that, even faced with the uncertainty each disaster might bring, there are foundational steps that need to be taken to increase preparedness and resilience.

## Introduction

The hurricane season of 2017 was one of the most destructive on record. Hurricanes Harvey, Irma, and Maria resulted in \$276 billion dollars of damage and over 2,900 lives lost (Larson et al., 2020; Santos-Burgoa et al., 2018). The hurricanes, along with the California wildfires, pushed the U.S. emergency response apparatus to its limit. By the time Maria struck the heart of Puerto Rico, the emergency response workforce was already stretched thin and supply warehouses were empty. The overwhelming destruction caused by Maria would have tested any local government, but the weak infrastructure in Puerto Rico—coupled with the country's staggering debt crisis (Sullivan, 2018)—made Puerto Rico especially vulnerable.

The United States has developed an emergency management structure to respond to catastrophic disasters like Hurricane Maria. A central concern of emergency planning is the positioning and distribution of critical supplies and services. Thus, supply chain management is an essential component to a successful response. The ability to deliver food, water, shelter, and medical supplies in the aftermath of a disaster can often mean the difference between life and death.

All supply chains are subject to disruption. A natural disaster, like a hurricane, will most certainly disrupt the supply chain and the emergency team's ability to get relief supplies to disaster victims. The resilience of a supply chain will determine how much of an impact the disruption will have on the affected population (National Academies of Sciences, Engineering, and Medicine [NASEM], 2020).

In the aftermath of Hurricane Maria, the challenges of distributing critical supplies to the population were overwhelming. The country's infrastructure was completely decimated. The entire island was without power, communication towers were down, and roads were blocked. The ability to deliver key medical help, food, and water was severely hindered. Supplies were

often slow getting to the island, and when they did arrive, they got stuck at the seaport and couldn't be distributed by the territory's incapacitated supply chain.

This paper examines the US response to Hurricane Maria in Puerto Rico. It takes a specific look at how the supply chains failed, focusing on the three key aspects of (1) essential workers, (2) medical supply chain fragility, and (3) food availability. It goes on to identify potential causes of those failures and then identifies lessons that might have mitigated the supply chain breakdowns.

At the time this paper is being written, the world is confronting and responding to a completely different type of emergency: the COVID-19 pandemic. While obviously different than a hurricane, there are clear similarities in the supply chain challenges faced in Hurricane Maria and those encountered during coronavirus. Those parallels, along with the applicability of lessons observed from Hurricane Maria, will be also discussed.

## Background

### Puerto Rico

Puerto Rico is a U.S. territory located in the Caribbean Sea, 1000 miles off the coast of Florida. Its 3.4 million inhabitants live on an island that is 100 miles long and 40 miles wide. Compared to its neighbors, it is one-fifth as large as the Dominican Republic, one-third the size of Haiti, and slightly smaller than Jamaica. The capital is San Juan (Wagenheim, 2019).

The United States invaded Puerto Rico during the Spanish-American war in 1898. Spain ceded the island to the US in the Treaty of Paris, ending 400 years of Spanish rule.



**Figure 1 Map of Puerto Rico**  
SOURCE: usgs.gov

Puerto Rico is the largest of the US's 16 territories. Native born residents are American citizens and, as citizens, can move freely between the mainland and the island with no passport. They do not, however, have a vote in congress and cannot vote in general presidential elections. Puerto Ricans do have a member within the House of Representatives, but that member does not hold a vote.

In 1976, the US enacted section 936 of the Internal Revenue Code which exempted mainland companies from paying federal taxes on income earned in Puerto Rico. This, along with other policy measures, enticed hundreds of companies to establish manufacturing operations on the island. By the late 20<sup>th</sup> century, much of the island's poverty had been eliminated and many Puerto Ricans enjoyed a modest middle-class standard of living (Wagenheim, 2019)

In 1996, Congress and President Bill Clinton eliminated Puerto Rico's corporate tax exemption under pressure that it made too many concessions to private business (Deibert, 2019). This contributed to the island sliding into recession over the course of a decade (Puerto Pobre, 2013). Rather than cut spending, the government took on enormous amounts of debt, selling bonds pushed by New York bankers. By 2012, the island's debt had ballooned to \$70 billion,

exceeding its gross national product (Sullivan, 2018). In 2015, then-governor Alejandro García Padilla conceded that Puerto Rico could not pay its debts (Santos-Burgoa et al., 2018).

The financial crisis had serious implications for the island's critical infrastructure. Components of the power grid were decades old and in dire need of replacement. Other critical infrastructure—water pumping stations, bridges, levies, roads—had been neglected and were in terrible need of investment (Deibert, 2019). The crippled infrastructure and lack of strong local government left Puerto Rico dangerously vulnerable. It was in no position to withstand one, much less two, category 5 hurricanes.

## The 2017 Hurricane Season

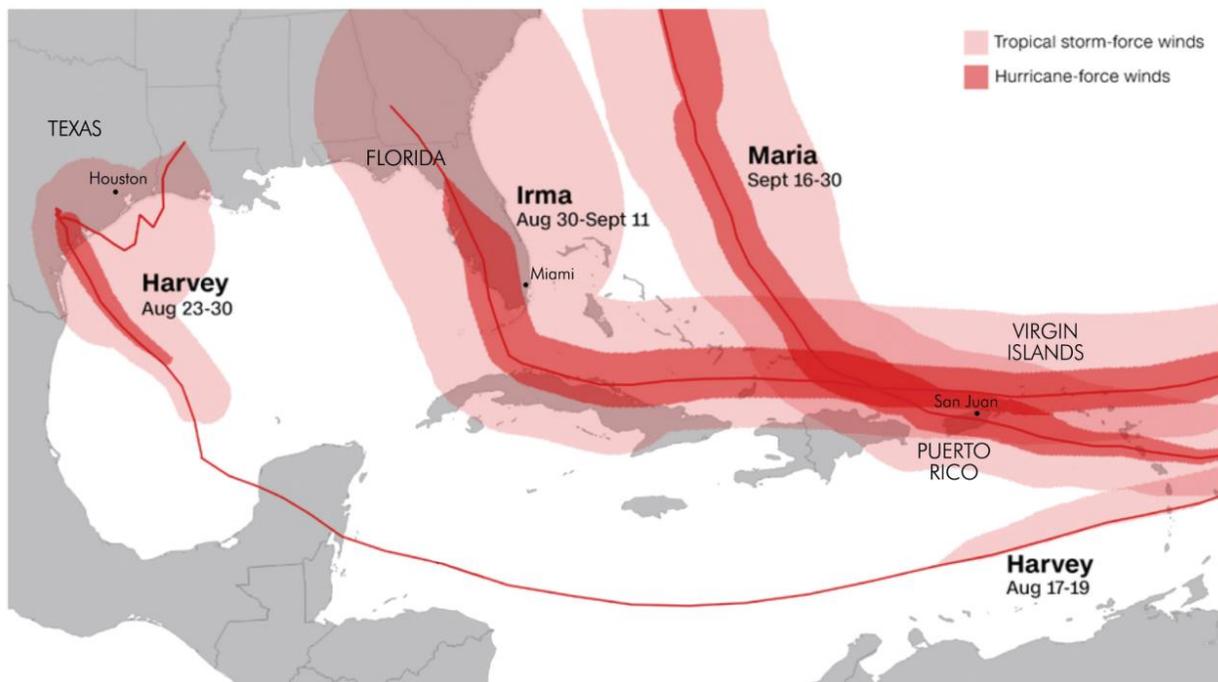
The 2017 Atlantic hurricane season was one of the most destructive on record. Five major hurricanes struck the US. The most consequential of these hurricanes—Harvey, Irma, and Maria—struck the US within one month each of other. **Harvey** made landfall on 25 August 2017 at Rockport, Texas as a category 4 hurricane. It caused catastrophic flooding, especially in the Houston area, and is one of the costliest storms on record, incurring about \$126 billion in damage (Larson et al., 2020).

Hurricane **Irma** made landfall in the Caribbean as an extremely powerful category 5 hurricane. It struck Barbuda on 6 September and continued on to San Martin. Puerto Rico was spared a direct hit, but the storm knocked out power to over half of the territory as its eye skirted north of island. It continued through the Bahamas and onto Cuba before making landfall on Florida as a category 4 storm on 10 September. Flooding was also an issue in Florida and the storm caused about \$50 billion dollars in damage (Larson et al., 2020). It weakened considerably as it moved up Florida's spine and eventually dissipated over the US mainland (Blake, 2018).

Hurricane **Maria** intensified rapidly as it crossed the Atlantic and approached the Caribbean. On 18 September it became a category 5 hurricane and made landfall on the island of

Dominica, devastating the small country. It turned northwest and made landfall on Puerto Rico on 20 September. It had sustained winds of 155 mph (category 4), although many parts of Puerto Rico likely experienced category 5 winds (greater than 156mph) (Blake, 2018).

Maria followed similar paths as Irma and Harvey, but unlike those storms, it plowed directly through the heart of Puerto Rico, its center just 25 miles south of San Juan. It dropped 30" of rain in one day (compared to Harvey's 32" in 3 days) and moved slowly (9 mph), which prolonged the island's exposure. It was the worst hurricane to hit Puerto Rico since 1928 and it was the tenth strongest Atlantic hurricane on record (A. Thomas, 2017). It caused about \$100 billion dollars in damage (Larson et al., 2020).



**Figure 2 Hurricane Paths of 2017**

Source: National Academies of Sciences, Engineering, and Medicine. (2020).

While the amount of damage, from a dollar perspective, was higher in Harvey, the destruction in Puerto Rico was staggering in both scale and scope. The entire island was affected: the roads, the grid, the communication, homes, everything. In Texas and Florida, the basic infrastructure

was still intact and a functioning core remained to organize a response. In Puerto Rico, the island was completely decimated (Larson et al., 2020).

Maria knocked out 100% of the electricity on Puerto Rico. Nearly all communication was lost as 95% of the cell networks were down. More than 70 percent of Puerto Rico's water treatment and distribution system was compromised, leaving nearly half of the population without potable water (A. Thomas, 2017). The island was still reeling from the glancing blow of Irma. When Maria hit, 70% were still without power, and 34% without water. In some towns 80-90% of the structures were destroyed (Meyer, 2017).

The damage to the aging power grid was especially devastating. While damage to power generation infrastructure was relatively minor, it was the transmission and distribution portions that were especially hard hit (Kwasinski et al., 2019). Over 60,000 electrical power lines were knocked down or destroyed. The result was the longest blackout in US history. It would be 7 months before power was restored to Puerto Rico (Young et al., 2019).

Initial government reports attributed 64 deaths to Maria (Kishore et al., 2018). But that number was proven to be a gross underestimate. A study conducted by researchers at George Washington University indicated a total of 2,975 deaths (Santos-Burgoa et al., 2018). And a Harvard study put the numbers even higher (Kishore et al., 2018). In comparison, Hurricane Harvey resulted in 103 deaths and Hurricane Irma, 93 (Willison et al., 2019). The high number of deaths and the overwhelming destruction clearly set Maria apart from the other storms that struck in 2017.

## The US Emergency Response Framework

Successful response to a hurricane—or any disaster—requires a coordinated effort between governments, private business, utilities, and non-governmental organizations (NGOs).

Interaction within the government alone requires vertical coordination between local, regional,

state, and federal levels. And it requires horizontal coordination across agencies, regional leaders, relief organizations, businesses, and emergency responders. The extent to which all these different groups can coalesce around common goals, share and communicate information, manage limited resources, and prioritize and execute tasks will often determine how successful a response is and could very literally mean the difference between life and death.

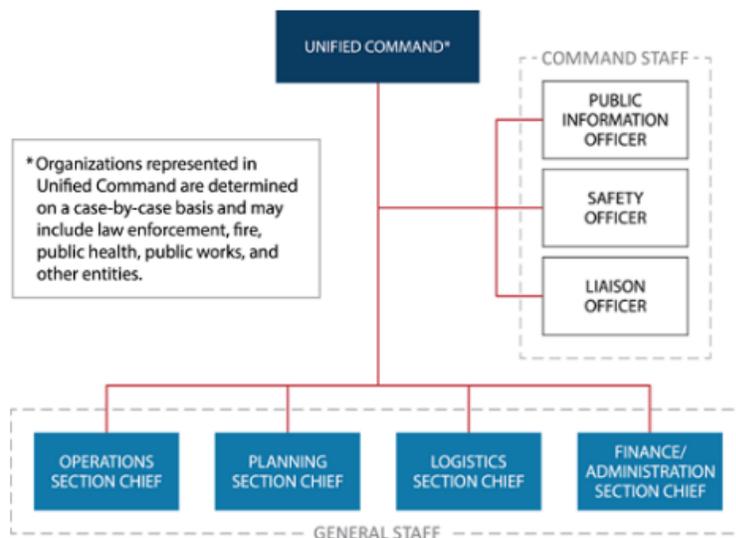
The United States has developed the National Response Framework (NRF), a systematic emergency management structure, to organize responses to catastrophic disasters like Hurricane Maria. This section gives a brief overview of the NRF and its history.

The NRF has evolved over time and is the product of several iterations. The 1988 Stafford Act established the processes by which the federal government would administer assistance following a disaster. It also directed FEMA to create the Federal Response Plan, which was released in 1992. The Federal Response Plan consisted of not one, but several separate response plans. Following the September 11<sup>th</sup> attacks, the Homeland Security Act of 2002 and Homeland Security Presidential Directive 5 (HSPD-5) directed the Department of Homeland Security (DHS) to create a single, unified national response plan. The result was the National Response Plan (NRP), released in October of 2003. Shortcomings of the NRP observed during the Hurricane Katrina response, along with mandates in the Post-Katrina Act, led to revisions of the NRP and its release in its present-day form as the NRF in January 2008 (Congressional Research Services [CRS], 2011).

The NRF describes what the federal government response will be to all types of disasters and emergencies (McEntire, 2015). It, along with the National Incident Management System (NIMS) and the Incident Command Structure (ICS), defines the strategy, structure, and methods the government will employ to respond to a disaster.

FEMA, an agency within DHS, has the primary responsibility for coordinating disaster response (U.S. Government Accountability Office [GAO], 2018). A key tenet of the NRF is that the incidents will be managed at the lowest level of government that can handle the situation. It is expected that local governments will be unified with the private sector and lead the disaster response. When the ability to respond is beyond the capabilities of state or local governments, the governor can initiate a request to the federal government. At that point, the president can, under the Stafford Act, declare a major emergency. Such a declaration is the mechanism by which the federal government gets involved in funding and coordinating response and recovery activities (GAO, 2018).

The ICS defines a common command structure that can be used during an emergency response. The five functional areas of ICS are command, operations, planning, logistics, finance/administration. The incident commander may be a single individual or team of people who are part of a unified command. A typical ICS command structure is shown in Figure 3.



**Figure 3 ICS Command Structure**  
SOURCE: FEMA (2017)

Resource management is a key element of any response. The functional areas work together to procure, track, deploy, and use resources within the relief supply chain. In general, finance monitors resource cost, logistics procures resources, planning tracks resources, operations puts

resources to use, and command sets the objectives that drive resource needs (FEMA, 2018b). During larger incidents, a dedicated emergency operation center (EOC) may be established to act as a “one-stop shop” for disaster resources (FEMA, 2017).

## Supply Chains in a Disaster

Disrupted supply chains can prevent victims from getting much-needed resources. A central focus of any response framework is the distribution of critical supplies after the crisis.

In normal times, supply chains facilitate the timely flow of products from suppliers to the end users. Elements of a supply chain include raw material suppliers, manufacturers, distributors, retail outlets, delivery vehicles, equipment, buildings, information systems, and the people required to operate and maintain those elements.

The ongoing challenge of a supply chain is to match supply with demand. Central challenges to achieving that aim are: (1) fluctuations in demand, (2) fluctuations in cycle time (i.e. the time required for the chain to process and deliver a product), and (3) maintaining communication flow between supply chain nodes. Demand, even in normal times, changes. And cycle-time also changes as the ability to procure, manufacture, distribute, and transport goods also changes. Likewise, the ability to respond to those changes requires reliable communication channels.

Maintaining information flow is critical to keeping a supply chain functioning. End-users communicate demand up the supply chain, and producers use that information to guide production and distribution decisions. Information-exchange between the different elements of the supply chain also ensures a coordinated response to bottlenecks and supply challenges.

A disaster can disrupt a supply chain in three ways: (1) Demand shifts: large spikes in demand for relief items (e.g. generators, fuel, water, food, medicine, tarps); (2) Capacity reductions: loss of capacity due to factory damage, road closures, lack of workforce, etc.; and (3)

Communication loss: inability for information to flow up and down the supply chain due to loss of communication infrastructure (NASEM, 2020).

In a disaster, if the normal steady-state supply chain and pre-existing flow of goods is unable to meet the population's need, then relief supply chains are often established by FEMA and other emergency organizations to temporarily replace or supplement the pre-existing flow of goods. The normal supply chain is almost always better positioned, however, to meet the volume of demand. Consequently, every effort should be made to repair the elements of and reinstate operation of the normal supply chain (NASEM, 2020).

The **resilience** of a supply chain is the degree to which severe disruptions affect lead-time and bottlenecks. The objective of supply chain resilience is to minimize the impact of such disruptions on the affected population (NASEM, 2020).

## Supply Chain Failures and their Consequences

Supply chains in Puerto Rico suffered severe disruption following the destruction of Hurricane Maria. Capacity to produce goods, move goods, and to communicate was severely restricted. This section examines the ways supply chains failed following Maria, with a specific focus on (1) essential workers, (2) medical supply chain fragility, and (3) food availability. It also describes some of the consequences endured by victims unable to attain critical supplies or services.

### A Shortage of Essential Workers

People are an essential component of any supply chain. People are required to run the machines, manage the processes, coordinate between players, operate the equipment, and move the goods within the supply chain.

The damage from Hurricane Maria was widespread across the entire island. Almost every member of the Puerto Rican workforce was somehow impacted by the hurricane and many had damaged or destroyed homes. Following the storm, these people were busy attending to the urgent needs of their families and neighbors (Larson et al., 2020). Government officials, utility workers, factory workers, and contractors—overwhelmed by personal emergencies or impeded by blocked roads—were unable to return to work. The unavailability of these workers was an enormous disruption to the normal flow of goods, which, in the days following landfall, came to a virtual standstill (NASEM, 2020).

The island's transportation network was especially hard hit by the worker shortage. By the end of September, only about 20% of Puerto Rico's truck drivers had reported back to work (Gillespie et al., 2017). Furthermore, a lack of local debris removal contractors significantly delayed the effort to clear the island's roads. As a result, the island's transportation network remained blocked by trees, power lines, and building wreckage. This shortage of these essential workers (exacerbated by lack of fuel, electricity, and communication), severely impaired the ability to move goods on the island and created a huge bottleneck at the Port of San Juan. Food, water, relief supplies, and medical equipment all piled up. At one point over 10,000 shipping containers were stuck at the port (Gillespie et al., 2017).

Movement of goods was only one issue. Lack of factory workers in Puerto Rico's enormous medical supply industry led to significant production slowdowns, creating shortages nationally and on the island itself (discussed further in the next section). Lack of utility workers to repair infrastructure delayed the restoration of communication networks and the electrical grid. Two weeks following the storm only 12 percent of the island's cell phone towers were operational (Meyer, 2017). Information flow, critical to the successful functioning of any supply chain—not to mention a disaster response effort—proved an enormous challenge following the storm.

The extent of the damage from Maria was so overwhelming that even if all of Puerto Rico's essential workers had been available, outside help would have still been required. As mentioned above, when normal supply chains cannot meet the population's need, then FEMA or other response organizations create temporary relief supply chains to facilitate the flow of goods. Even the relief supply chains faced worker shortages in Puerto Rico. When hurricane Maria hit, FEMA had already deployed relief workers to Texas and Florida in response to Harvey and Irma. The number of remaining qualified relief workers was critically low. And over half of the relief workers deployed were serving in a role they were not trained for. The fact that FEMA had entered the 2017 hurricane season with an existing 37% staff shortage only exacerbated the problem (GAO, 2018).

Implications of FEMA workforce shortages were far-reaching. Lack of trained logistics personnel, for example, contributed to the agency's inability to comprehensively track resources moving to and throughout the island. Relief commodities arrived at the port of San Juan but were not well-tracked and not efficiently distributed. Lack of contracts personnel delayed the procurement of key relief resources for the island. In the wake of Harvey and Irma, pre-staged supplies and pre-negotiated contracts were completely exhausted (FEMA, 2018a). This created a need for FEMA to rapidly solicit, close, and monitor contracts with vendors outside of their standard system. The burden on contracting personnel was severe, and it contributed to a delay in essential supplies being delivered to hurricane victims. These included tarps, critical to providing safe and temporary shelter (A. Thomas, 2017), as well as generators. Only 31 generators were on the island 3 days after landfall (FEMA, 2018a) and there were long delays in procuring more (Sullivan & Schwartz, 2018).

FEMA also lacked a sufficient number of bilingual employees to communicate with local residents. FEMA's region II Hurricane Annex states that information in Puerto Rico must be communicated in Spanish (FEMA, 2014). After Hurricane Maria, however, there was a lack of translators to communicate with the island's residents. And unlike the continental United States,

most individuals could not apply for individual assistance online or at disaster centers, so they were much more reliant on the door-to-door visits by relief workers (GAO, 2018). Lack of qualified relief workers to conduct those door-to-door visits meant that there was a less accurate picture of the true need (demand). It also meant that many residents—with no means to request assistance and communicate their demand up the supply chain—never received the relief they needed. The shortage of essential workers—seen in both the normal and relief supply chains—prevented critical supplies from reaching victims when they needed them most.

## A Disrupted Medical Supply Chain

Hurricane Maria disrupted the medical supply chain at the national level and at the local level. This section describes the nationwide medical supply issues as well as impacts on the ground in Puerto Rico.

### Nationwide Shortages

The pharmaceutical and medical device manufacturing industries have come to represent a huge portion of Puerto Rico's overall gross domestic product (GDP). In 2016, these industries represented 30% of the island's GDP and accounted for \$800M of worker's wages (Food and Drug Administration [FDA], 2017). The island also represented a significant portion of the US's medical supply chain: almost 10% of the US's pharmaceutical expenditures were spent in Puerto Rico. And eleven of the top US 20 pharmaceutical companies had a presence on the island.

Hurricane Maria brought manufacturing in Puerto Rico to an abrupt halt. Lack of factory workers, physical damage to manufacturing plants, and loss of electricity took production facilities completely offline. Consequently, a critical piece of America's medical supply chain was nearly inoperable. The result was a nationwide shortage of saline bags and intravenous (IV) saline solution. These are commonplace items, but they are vital to the delivery of

medications and fluids (Barrera et al., 2018). They are also required for virtually every patient who is hospitalized. Both the IV bags and the saline solution were produced by the same manufacturer in Puerto Rico. Consequences of these shortages impacted both patients and hospitals alike. Without these supplies, healthcare providers had to use alternative delivery methods to administer medications. These alternative methods (e.g. an “IV push”) generally took more time, posed higher risk to the patient, and had a higher cost than traditional methods. Besides IV bags and saline solution, the storm also interrupted production of medical devices and key pharmaceutical drugs. Responding to the concern of drug shortages, the Food and Drug Administration (FDA) created a watch list of about 30 drugs that were made on the island (K. Thomas, 2017).

### Disruptions in Puerto Rico

While disruptions to the medical supply chain were felt across the United States, they had dire consequences to on-the-ground relief efforts in Puerto Rico. The interdependent nature of the island’s medical supply chain meant that disruptions to communications, electricity, and water severely compromised the ability to deliver medical supplies and services (Kishore et al., 2018). And many clinics and hospitals had themselves sustained damage from the storm. After the hurricane, only 3 of the island’s 95 hospitals were operational (Michaud & Kates, 2017). Hospitals and clinics that came back online struggled to provide basic medical services, lacking basic supplies, water, electricity, and fuel. A study published in the *New England Journal of Medicine* reported that over 30 percent of households reported problems accessing health care after the hurricane; issues included the inability to get medications, inoperable 911 service, closed healthcare facilities, and unavailable doctors (Kishore et al., 2018).

The obvious and tragic result was that victims injured by the hurricane struggled to find the medical treatment they required. And those who became ill over time—due to lack of food, contaminated drinking water, poor living conditions, or infectious disease—had limited access to health care. The slow restoration of the island’s basic infrastructure meant that access to health

care would remain a problem for some time. In the same study mentioned above, households reported that one third of post-hurricane deaths were caused by an inability to access medical care (Kishore et al., 2018). Furthermore, Puerto Rico already had its share of health concerns before the storm arrived: a high percentage of people were living with a disability, cases of diabetes were 50% higher compared to the rest of the US, and the HIV death rate was four times higher (Michaud & Kates, 2017). The higher number of diabetes cases in Puerto Rico made dialysis centers a particularly important part of the health care system. But the hurricane had created a critical shortage of operable dialysis machines. Some dialysis centers had generators, but fuel supply was not consistent and generator power was not reliable. And while some patients were flown to dialysis centers to get the needed treatment, the frequent trips took a toll on already-weak bodies (Coto, 2019b). Besides dialysis machines, the hurricane created a critical shortage of oxygen and ventilators. In the coastal town of Río Grande, the mayor reported several deaths due to lack of oxygen (Deibert, 2019).

The ability of public health workers to identify and diagnose health hazards was also compromised after the hurricane. A shortage of functioning public health laboratories meant that collecting data on mosquito-borne illnesses, Zika, leptospirosis, and respiratory illness was interrupted or delayed. The lack of data prevented health care workers from effecting a timely health care response in the midst of the crisis. And without a clear picture of which threats were most prominent, future efforts at increased preparedness were compromised (Michaud & Kates, 2017).

While it is difficult to characterize the precise impact the medical supply shortages and facility closures had on the island's population, a study of excess mortality conducted by George Washington University put the death toll from hurricane at almost 3,000—over 45 times greater than the initial estimate of 64 (Santos-Burgoa et al., 2018). Another study by researchers at Harvard put the estimate even higher (4645 excess deaths as a *conservative* estimate) and

directly links the cascading effects of broken infrastructure and interrupted access to health care to increased mortality (Kishore et al., 2018).

## A Lack of Food

Even before Hurricane Maria, Puerto Ricans were experiencing a high level of food insecurity: 1.5 million of the island's residents were food insecure and 56% of children—3 times the US average—were experiencing food insecurity (Bread for the World, 2019). Contributing to this problem was the fact that the median income in Puerto Rico was only one-third of the US average (\$19,775 vs \$61,372). Furthermore, food entering the island was subjected to the Jones Act: a merchant marine rule requiring that all imports from sea be processed through the United States (Mares, 2019). This increased the price and the delivery time for food entering the island. Puerto Rico's anti-hunger program, the Nutrition Assistance Program (NAP) could help close some of the gaps in hunger and nutrition. But unlike the program in the 50 states—the Supplemental Assistance Nutrition Program (SNAP)—federal funding for NAP was not allocated based on need but was a fixed-amount block grant whose amount did not change, even during emergencies such as hurricanes (Bread for the World, 2019).

These issues were compounded by the fact that Puerto Rico is heavily reliant on food imports. Ahead of the hurricane, the island only produced 15% of its own food, relying on imports for 85% of the overall food supply (Dietrich & Garriga-López, 2018). Thus, ahead of the storm, the population was more vulnerable than their mainland counterparts and had a food supply chain extremely sensitive to disruptions. When the hurricane struck and paralyzed the island's transportation network, food shortages around the island became a problem almost immediately. Long lines formed outside grocery stores and store shelves were quickly emptied. Many stores and restaurants closed and ones that stayed open often placed restrictions on critical goods (e.g. cooking gas and water) that were running low (Dietrich & Garriga-López,

2018). A survey of some residents, a month after the storm, found that 59% were facing challenges acquiring food (Rodríguez Cruz & Niles, 2018).

With Puerto Rico's normal food supply chain in such disarray, help was clearly needed from the outside. FEMA's relief supply chain was facing its own challenges, however. There were not enough food supplies pre-staged in the Caribbean to handle the relief demands of several storms. The agency's after-action report (AAR) recommended increasing meal and water supplies in the region by six-fold (FEMA, 2018a). And, as discussed above, the lack of workers, loss of electricity, loss of communications, and blocked roads, made moving food and other goods around the island an enormous challenge. Air support helped but lagged substantially compared to the efforts in Texas and Florida (Vinik, 2018). FEMA claimed to be providing 200,000 meals a day but acknowledged that there was a shortfall of 2 million meals per day, highlighting the massive gap in food relief (Garcia-Lopez, G. A. 2018).

There was also a lack of coordination between FEMA and relief agencies to provide food to victims. This was accentuated by the fact that World Central Kitchen, a small non-profit led by Spanish chef José Andrés—and not part of any formal emergency response effort—became the largest food provider on the island: outpacing the Red Cross, the Salvation Army, and any government agency (Severson, 2017). Andrés' unconventional approach and disdain for bureaucracy often created tension between him and federal authorities, but it was difficult to ignore his results. Where the relief supply chain was failing, Andrés was having success, and he was helping to alleviate hunger in a population devastated by a storm and already struggling with food insecurity.

The scope of destruction following the hurricane was immense and it presented enormous challenges to groups like World Central Kitchen and to FEMA. Still, some have suggested that shortcomings in the disaster response itself prevented victims from getting the supplies they needed and delayed the recovery of the island's normal supply chains (Garcia-Lopez, G. A. 2018).

## Analysis – Factors Contributing to Supply Chain Failures and Lessons Observed

FEMA's response to hurricane Maria was the largest in the agency's history. It committed over \$12 billion dollars for response and recovery and tasked over 1,000 individual response missions (GAO, 2018). Still, the response has been roundly criticized as slow, uncoordinated, and insufficient given the scale of the disaster.

The ability of a supply chain to function during a disaster relies on characteristics of the chain itself: resilient manufacturing facilities, robust transportation networks, and clear communication channels. Factors outside the supply chain also affect its ability to respond: the condition of the existing infrastructure, the level of emergency preparedness, and the level of leadership and coordination (or lack thereof). The cascading effects of failed infrastructure or unprepared leadership will severely compromise the ability of a supply chain to deliver the right supplies at the right time (Dolinskaya et al., 2018).

This section will examine some of the factors that contributed to the failures described in the previous section. It will also discuss some potential lessons that could have helped to improve the response.

### The Federal Role and the Response Framework

The National Response Framework is predicated on the assumption that local officials will lead the emergency response. According to the National Disaster Response Framework:

The local government has primacy in preparing for and managing the response and recovery of its community. Individuals, families, and businesses look to local governments to articulate their recovery needs. The local government leads pre-disaster recovery and mitigation planning efforts and has the primary role of planning and managing all aspects of a community's recovery post-disaster. (FEMA, 2016)

The federal government, according to the framework, will serve a primarily supportive role when the disaster exceeds the capacity of state, local, tribal, and territorial (SLTT) entities to respond. It is up to state and local governments to articulate their recovery needs to the federal government (FEMA, 2016).

The problem with Maria was that the territorial government of Puerto Rico was completely overwhelmed and incapacitated. The infrastructure of the island was decimated.

Communication was nearly impossible. There was not a robust emergency response structure in place ahead of the storm. And many of the officials, leaders, and response workers were themselves victims of the storm and attending to their own urgent family emergencies.

The inability of territorial and local leaders to characterize the extent of the damage, stand up a response, and communicate specific needs to federal leaders created a leadership vacuum that limited the ability of early responders to quickly stage and organize a response. It would take several days before FEMA would cease looking for a state-led solution and take over the operation itself (Larson et al., 2020). This required—according to FEMA’s own after-action report—that FEMA assume “a more active role in coordinating whole community logistics operations” (FEMA, 2018a). FEMA and other federal personnel had to take on first-responder type roles they were not familiar with and not trained for (Larson et al., 2020).

A guiding principle of the NRF is that response efforts be scalable, flexible, and adaptable (FEMA, 2019a). This would suggest that, while local control and leadership is desirable, there should be sufficient dexterity within the federal response to adapt to the needs of the situation and assume those functions more typically performed at the local level. While that did happen—to a degree—eventually in Puerto Rico, it caught FEMA unprepared and exposed a gap between the strategic vision expressed in the NRF and the tactical reality on the ground.

According to the FEMA AAR:

FEMA strategic doctrine calls on the Agency to assume the responsibilities of SLTT governments, the private sector, and NGOs when the effects of a major incident incapacitate those organizations' ability to perform their functions effectively and efficiently until they can resume operations. However, FEMA's operational plans did not include these planning assumptions [emphasis added] and thus did not account for continuing commodity distribution beyond the handoff to the state or territory. (2018a)

**The Federal government should have been better prepared to assume a frontline leadership role in the disaster response.** The US's plan assumed the state authorities would retain the ability to guide and lead the response, but in the case of Maria they could not (Larson et al., 2020). This should not have come as a big surprise. A 2011 exercise AAR for Puerto Rico anticipated that, following a disaster, the territory would require extensive federal support to move commodities throughout the island (FEMA, 2018a). Through the lens of the supply chain, there was no channel or structure for information to flow. Victims could not communicate their needs up the supply chain, creating high levels of demand uncertainty. And since demand was not clearly defined, it was not obvious what resources—in terms of people and material—were required to effectively respond.

The destruction of key infrastructure had cascading effects that prevented critical lifelines (water, food, healthcare) from being delivered to the storm's victims. Restoration of that infrastructure was complex since ownership of it resided across private and public sectors. Without federal leadership to prioritize and coordinate between the different partners, the response efforts were delayed. The leadership-vacuum created a lack of situational awareness and an inability to form a targeted action plan (FEMA, 2018a). The FEMA AAR acknowledged that following the hurricane, the agency was not prepared to assume SLTT functions. It also admitted that the national response was not integrated well with the private sector or critical infrastructure owners. The AAR recommended that the NRF be updated to prioritize the restoration of key lifelines and to emphasize the importance of cross-sectional coordination both

ahead of, during, and after a disaster. As a result of these recommendations, the NRF was updated in 2019 to establish seven key community lifelines (see Figure 4). The intent was to establish a plain-English way to quickly assess community needs and then prioritize and deploy resources (FEMA, 2019a). The revised NRF also established a new emergency support function: Cross-Sector Business and Infrastructure to facilitate coordination between businesses, infrastructure owners, and government partners (FEMA, 2019a).

These changes to the NRF would—on their own—not likely have solved the leadership vacuum in the Hurricane Maria response. By its own reckoning, FEMA was not prepared to assume frontline leadership and had not taken into account lessons from previous exercises in the region. Still, incorporating the lifeline concept and improving cross-sector collaboration may have helped mitigate that lack of preparedness. It certainly would have accelerated the restoration of normal supply chains and the efficacy of relief efforts.



**Figure 4 NRF Community Lifelines**  
SOURCE: FEMA (2019a)

## Partnership with Local Actors

When José Andrés' World Central Kitchen became the largest food supplier on Puerto Rico, it highlighted the dysfunction of the US response effort and FEMA's inability to establish a working relief supply chain. A private chef, head of a non-profit with modest resources, landed on the island via commercial aircraft and was able to coordinate a feeding effort that outpaced the government and huge NGOs.

At the same time, however, his success lent credence to the value the NRF places on local response. While Andrés was not from Puerto Rico, he had relationships with local

restauranters and food supply vendors. And as a renowned chef he obviously had the knowledge to understand what it would take to cook food for a lot of people at once. Those assets, along with a creative determination to cut through bureaucracy, allowed him to mobilize a grassroots effort that would not likely have been possible for a government agency. He was able to close gaps the formal relief supply chain could not. Furthermore, Andrés' efforts were more integrated with existing community resources. He used local restaurant kitchens (eventually a stadium kitchen) and local workers. He also created a response that was more culturally appropriate, recognizing that the food served more than the functional purpose of providing nourishment; it also had the potential to empower and instill value to those receiving it. (Andrés, 2018)

Andrés' success demonstrated how local individuals and local entities are in a strong position to respond to disaster. They have up-close understanding of the need; they have knowledge about what resources might be mobilized; they can identify potential obstacles, and they understand the cultural nuances.

Andrés' involvement also demonstrates that, regardless of what is written in a formal plan or strategy, disaster response is not contained to formal government action. Local actors will often rise to fill in the gaps left by the formal government response.

The ability of Andrés' team to conduct such a successful feeding operation underscores the importance of strong relationships and strong coordination with local businesses and entities. While Andrés' team did eventually become partially funded by a FEMA contract, it was not for some time after the disaster struck.

As mentioned above, in a disaster, if the normal supply chain and pre-existing flow of goods is unable to meet the population's need, then relief supply chains are often established by FEMA and other emergency organizations to temporarily replace or supplement the pre-existing flow of goods. The normal supply chain is almost always better positioned, however, to meet the

volume of demand. So, every effort should be made to repair the elements of and reinstate operation of the normal supply chain (NASEM, 2020). Doing this effectively requires that relationships between public and private stakeholders be cultivated ahead of the disaster. The relationships enable stakeholders to come together, establish plans, conduct exercises, and form a strategy for maintaining the flow of critical goods during an emergency (FEMA, 2019b).

Had plans been in place in Puerto Rico to strategically position emergency food supplies and rapidly distribute them following a crisis, the need for Andrés' group would not have been so acute. But it would have required those public-private relationships to be in place ahead of the disaster.

In one instance, Andrés pointed out to a FEMA official that there were functioning bakeries on the island that were eager to help. The problem was that they lacked fuel to deliver their goods. When Andrés suggested that the bakeries be supplied with gasoline, he was told FEMA had “other priorities” (Andrés, 2018). These local businesses could have been a great asset to the response effort, but their value was not fully recognized. FEMA would later acknowledge in its AAR that public and private efforts to restore the island’s supply chain were “too ‘stove-piped’ to share timely information, too slow to consult, and as a result, often too late to synchronize stabilization efforts” (FEMA, 2018a). In Puerto Rico, **FEMA should have established stronger public-private partnerships through collaboration with local government leaders and organizations.** In Texas, strong pre-existing relationships between volunteer organizations and FEMA facilitated the ability of volunteer partners to contribute to the response. And in Florida, information from prior exercises was critical in that state’s ability to efficiently execute mutual aid agreements (GAO, 2018). Had the same emphasis on strong networking and preparedness activity been in place in Puerto Rico, response efforts could have better leveraged local resources and more quickly restored the flow of critical goods.

## The Medical Supply Chain

At the national level, shortages of drugs, saline, and IV bags after the hurricane exposed the vulnerability of the entire US medical supply chain. **The US should have taken steps to strengthen its medical supply chain and reduce susceptibility to single point failures.** An outage of Puerto Rico's factories led to nation-wide shortages and revealed that the island's medical industry represented a single point of failure within the national medical supply chain network. Supply chain resilience for critical drugs and medical supplies should be strong enough to withstand disturbances and respond to large-scale disasters. The US should enact policy to expand the capacity of and diversify its medical supply chain. This could be achieved by offering tax-breaks to medical manufacturers, creating laws requiring redundancy, streamlining and simplifying regulatory requirements, and stockpiling critical medical equipment and drugs. Domestic production capacity should also be increased so that the US medical supply chain is less susceptible to disruption abroad. Admittedly, these policies could come with a price tag, but they could dramatically reduce the cost (and lives lost) associated with a shortage in a disaster.

At the local level in Puerto Rico, the "final mile" of the medical supply chain, the hospitals and clinics where patients receive care, were almost completely inoperable after the storm and took weeks to restore operational capacity. It's true that a disaster the scale of Maria would have challenged any system and any level of preparedness. Still, steps could have been taken to make hospitals and clinics more resilient. Key supplies—generators, fuel, water, oxygen, ventilators, medications—could have been stockpiled at hospitals and clinics. Mobile dialysis machines could have been procured and strategically placed around the island, instead of scrambling to procure them post-storm (Coto, 2018b). And redundancies could have been built in so that if one facility was destroyed, a nearby one could step in and fill the gap. Even before the storm, Puerto Rico's healthcare system was facing capacity challenges (Michaud & Kates, 2017). An expanded capacity to meet the needs of island residents, along with the ability to

surge during emergencies, would have better positioned the health care system to respond to the hurricane.

## Presidential Leadership: Message and Focus

Hurricane Maria struck Puerto Rico on Thurs, 20 September 2017. The next day President Trump acknowledged how dire the situation was, saying that Puerto Rico had been “totally obliterated” and “practically leveled”. He went on to say that rebuilding would begin with “great gusto” (Associated Press, 2017).

Yet as the next few days unfolded, the response coming from the White House did not seem to reflect this same level of urgency. On the same day the President offered his stark assessment on the situation in Puerto Rico, he departed for one his golf clubs for the weekend. And over the next several days, despite several public events, he made no mention of Puerto Rico (Phillip, 2017). The governor of Puerto Rico, Ricardo Rosselló publicly urged the federal government to take “swift action” to “prevent a humanitarian crisis” (Walsh & Liptak, 2017). Yet the President’s first Situation Room meeting on the response in Puerto Rico wasn’t held until 26 September, 6 days after landfall (Meyer, 2017).

As context, after the 2010 earthquake in Haiti, 8,000 US troops were en route to the island within two days. And after two weeks, 22,000 troops, 33 ships, and over 300 helicopters were positioned in country (Davis et al., 2017). In comparison, only 7,200 military personnel had made it to Puerto Rico two weeks after landfall (Meyer, 2017). Lt. Gen. P.K. Keen, the general who commanded the US military effort in Haiti, questioned the lack of response in Puerto Rico, “The morning after [the earthquake], the president [Obama] said we were going to respond in Port-au-Prince . . . robustly and immediately, and that gave the whole government clarity of purpose. I think it’s a fair ask why we’re not seeing a similar command and response” (Davis et

al., 2017). All of this when, unlike Haiti, Puerto Rico was a US territory. And unlike an earthquake, a hurricane could be predicted (Meyer, 2017).

Aside from an apparent lack of urgency, the White House's characterizations of the situation did not agree with messages coming from Puerto Rico's own leadership. Eight days after landfall, acting DHS secretary Elaine Duke told reporters that she was "very satisfied" with the Puerto Rico response and went on to say "I know it is really a good news story in terms of our ability to reach people and the limited number of deaths that have taken place in such a devastating hurricane" (Victor, 2017). Responding to Duke's comment, Carmen Yulín Cruz, the mayor of San Juan said, "Well maybe from where she's standing, it's a good news story. When you're drinking from a creek, it's not a good news story. When you don't have food for a baby, it's not a good news story. When you have to pull people down from buildings—I'm sorry, that really upsets me and frustrates me" (Victor, 2017). The next day the mayor appeared on the Cable News Network (CNN) wearing a t-shirt that said, "Help us, we are dying," and made desperate pleas directly to the President for help (CNN, 2017). Clearly there was a disconnect in the message being articulated by the administration and the one being articulated on the ground.

Besides this disconnect, the rhetoric from the President was often confrontational and marginalized the challenge faced by the Puerto Ricans. In response to Mayor Yulin Cruz's comments the President tweeted, "Such poor leadership ability by the Mayor of San Juan, and others in Puerto Rico, who are not able to get their workers to help. They want everything to be done for them when it should be a community effort. 10,000 Federal workers now on Island doing a fantastic job" (Trump, 2017, September 30, 6:26am & 6:29am). During his visit in Puerto Rico, President Trump seemed to suggest that Hurricane Maria didn't represent a true disaster when he said, "Every death is a horror, but if you look at a real [emphasis added] catastrophe like Katrina... You can be very proud" (Johnson & Parker, 2017).

The president did have positive words of support for the Puerto Rican response effort and for the relief workers (Trump, 2017, September 20, 10:13pm), but those messages were spoken alongside divisive and confrontational messages. This inconsistency in messaging, along with an apparent lack of urgency, resulted in a fragmented vision for the response in Puerto Rico. **The White House should have conveyed a clear and unified response strategy that was consistent with the on-the-ground reality.**

According to the NRF, “Regardless of the type of incident, the President leads the Federal Government response [emphasis added] effort to ensure that the necessary resources are applied quickly and efficiently to large-scale and catastrophic incidents” (FEMA, 2019a). White House support is critical in ensuring that the FEMA response can be effective, and the lack of urgency communicated by the President did little to encourage other agencies to make the response in Puerto Rico a priority (Farber, 2018).

Bureaucracy became a major challenge during Maria. There were delays in lifting the Jones Act to allow non-US flagged vessels to dock in Puerto Rico (Meyer, 2017). There were contracts debacles that prevented much-needed tarps from arriving on the island in a timely manner (Young et al., 2019). And there were difficulties getting much-needed generators (Young et al., 2019). Presidential focus is essential in removing these roadblocks, prioritizing resources, and achieving alignment between responding organizations. A clear sense of mission with a focused “get it done” mentality—from the top—could have empowered responding agencies to remove bureaucratic obstacles, more quickly restore normal supply chains, and accelerate the work of relief supply chains (A. Thomas, 2017).

## Prioritization: Comparison to Other Responses

On 30 Oct 2007, the Office of the UN High Commissioner for Human Rights (OHCHR) issued a news release which stated,

Puerto Rico remains without an effective emergency response more than a month after Hurricane Maria devastated the island.

With winter approaching, we call for a speedy and well-resourced emergency response that prioritizes the most vulnerable and at risk – children, older people, people with disabilities, women and homeless people.

The Special Rapporteur on the right to housing, Leilani Farha, added: “We can’t fail to note the dissimilar urgency and priority given to the emergency response in Puerto Rico, compared to the US states affected by hurricanes in recent months.” [emphasis added] (United Nations [UN], 2017)

The statement was damning of the emergency response in its entirety but also highlighted the discrepant response between Maria and the two hurricanes that preceded it, Harvey and Irma.

Nine days after Harvey, FEMA had approved \$141.8M in individual assistance in Texas versus just \$6.2M in Puerto Rico. Within one week of Harvey’s landfall, seventy-three helicopters were deployed in Houston. It took over three weeks to reach that same number in Puerto Rico. FEMA provided 5.1 million meals, 4.5 million liters of water and over 20,000 tarps to Houston; but in the same period, it delivered just 1.6 million meals, 2.8 million liters of water and roughly 5,000 tarps to Puerto Rico (Vinik, 2018).

Besides Harvey and Irma, the response also lagged behind past US disaster responses.

Retired Lieutenant General Russell Honoré, former commander of the Joint Task Force during Katrina, said that 20,000 federal troops, 240 helicopters, and 40,000 national guard troops were committed within 5 days of Katrina’s landfall. This, in comparison to just 12,000 federal workers in Puerto Rico (Coto, 2018a). One lawmaker offered this stark observation, “We’ve invaded small countries faster than we’ve been helping American citizens in Puerto Rico” (Phillip et al., 2017).

It wasn't just the UN that noticed less urgency seemed placed on Puerto Rico. A disaster response expert from Refugees International said, "We were pretty surprised to see how slow the response was." And she noted that the response in Puerto Rico was much slower than the US response in the Philippines after Typhoon Haiyan (Einbinder, 2018). It seems that the federal government simply chose not make Puerto Rico a priority.

Although the administration acknowledged that Puerto Rico was "obliterated," it did not take action commensurate with that assessment. **The US should have taken swift action to quickly assemble a team, assess the needs, and deploy resources.** Even though operational plans did not account for a non-functioning SLTT (as discussed above), if troops and federal personnel had been deployed immediately, valuable time would have been saved that was instead squandered. Urgency should have been conveyed with immediate—not delayed—action.

The FEMA AAR acknowledged that FEMA entered the 2017 season already short of its workforce target (FEMA, 2018a). **The federal government should have had an expanded workforce surge capacity that accounted for concurrent disasters.** An expansion of surge capacity requires an increase in the number of FEMA relief workers, an increase in the number non-FEMA surge capacity force, and an expedited training program to ensure that those workers are prepared for their assigned task.

Workforce capacity is not measured in numbers alone. The efficiency of that workforce depends on strong private-public relationships prior to the disaster. According to a GAO report GAO-18-472, the pre-existing relationships with voluntary organizations played a key role in the disaster response in Florida and Texas. It goes on to say that that same level of coordination did not exist in the Caribbean (2018). Establishing relationships with private business stakeholders is essential. In terms of supply chain resilience, private partners needed to include factory owners, trucking companies, and fuel suppliers. Even if workers are short in one area,

coordination between federal and private entities could have ensured that that shortage was, at a minimum, communicated upwards. Then, relief agencies would have been positioned to respond to the shortage (rather than not knowing about it at all). Emergency response is indeed a “whole community” effort. Standing up a crisis response workforce and a relief supply chain is more than a head-counting activity. It requires active coordination before, during, and after the incident.

Obviously, resources were stretched after several storms had hit at once. But lack of federal priority and an insufficient workforce capacity led to further (and unnecessary) delays in Puerto Rico.

## Preparation and Resilience Ahead of the Storm

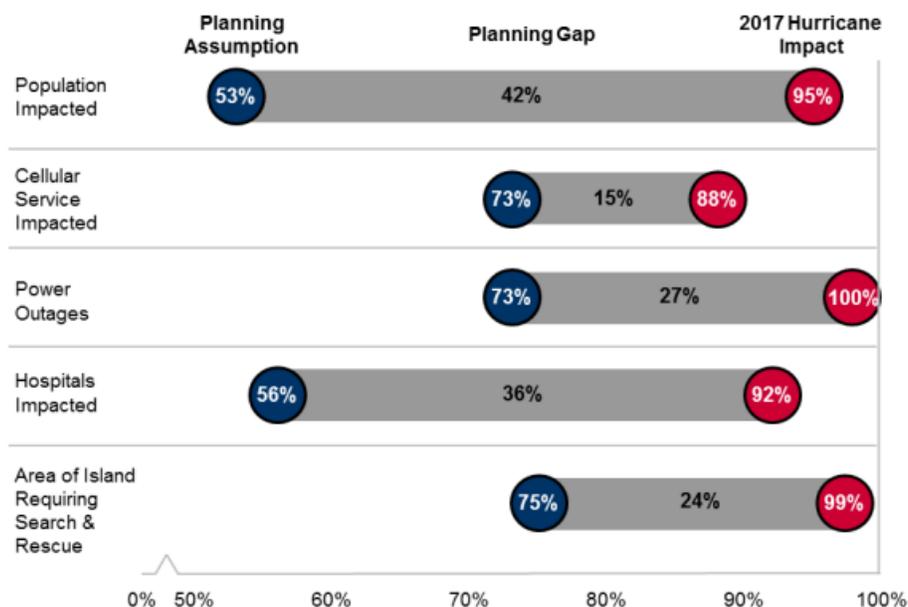
Nearly all after action reports include findings about the need for increased preparation and increased resilience. And for better or worse, it’s after a disaster strikes that building resilience receives the most attention and the most resources. In a sense, that is not hard to understand. Building infrastructure and stockpiling resources is usually an expensive endeavor. And it’s one that does not yield an immediate payback. Prevention is a tough sell.

Yet it’s clear that the lack of prevention made the supply chains of Puerto Rico much more vulnerable to a disaster like Maria. Ahead of the storm, the financial crisis limited the investment in and maintenance of critical infrastructure. Components of the power grid were decades old and in dire need of replacement. Other critical infrastructure—water pumping stations, bridges, levies, road—had been neglected and were in terrible need of investment (Sullivan, 2018). Furthermore, investment in emergency management had waned: response plans were outdated, unapproved, or non-existent. And Puerto Rico’s Emergency management agency (AEMEAD) had failed to conduct simulations to test readiness measures (Rivera, 2019).

FEMA’s own AAR acknowledges that the agency was not sufficiently prepared for Hurricane Maria:

FEMA leadership acknowledged that the Agency could have **better anticipated** that the severity of hurricanes Irma and Maria would cause long-term, significant damage to the territories’ infrastructure. Leadership also recognized that emergency managers at all levels could have better leveraged existing information to **proactively plan** for and address such challenges, both before and immediately after the hurricanes. (2018a)

Figure 5 below, extracted from the AAR, shows the gaps between planning and the actual storm impact. The report explains how the agency’s preparations did not anticipate the cascading impacts resulting from a failed infrastructure. And it did not anticipate the added burden FEMA would need to bear (for providing air and sea transportation services, for rebuilding infrastructure, etc.) The report further acknowledged that the Puerto Rico region did not have a Resource Phasing Plans (RPP) plan in place ahead of Maria (unlike the Texas and Florida regions). This undoubtedly encumbered response workers with additional work and slowed the delivery of critical emergency supplies (FEMA, 2018a).



**Figure 5 Hurricane Planning Assumptions vs Actual Impacts in Puerto Rico**  
SOURCE: FEMA (2018a)

Government documents often tout the response in Puerto Rico as the largest in US history, but the large scale of the response should not be considered a measure of success. Had sufficient investment been made into Puerto Rico's infrastructure ahead of the storm, the response would not have been so costly. **Investment should have been made to increase the resiliency of Puerto Rico's infrastructure.** Furthermore, **emergency plans should have accounted for the severity of the threat and have honestly assessed local resiliency.** While not common, a hurricane of this size hitting an island in the Caribbean should not have been unexpected. The state of Puerto Rico's infrastructure was not an unknown, and emergency plans should have anticipated a high impact, low probability event: especially a large hurricane.

The objective of supply chain resilience is to minimize the impact of disruptions like large hurricanes. While any supply chain would have been tested by a storm the magnitude of Maria, had increased investment and planning been in place in Puerto Rico, both normal and relief supply chains would have had a higher level of readiness, been better positioned to respond, and would have required less time to recover (NASEM, 2020).

## Food Security

Heavy reliance on outside sources of food meant that when distribution networks in Puerto Rico were cut off, so was access to food. As mentioned earlier, the island imports 85% of its food supply. And after the hurricane, this number rose to 95% (Mares, 2017). All of this on an island that—due to a myriad of economic and political factors—was already facing higher levels of food insecurity (Bread for the World, 2019). Ahead of Maria—and still today—the population of Puerto Rico was quite vulnerable to disruptions in the food supply chain (Bullido, 2014). In Puerto Rico, **food security should have been strengthened through an increase of local food production and a strategic stockpiling of emergency food supplies.** Ahead of the storm, a move towards increased food production was already emerging, and Hurricane Maria brought even more awareness to the fragility of the island's food chain (Mares, 2019). Efforts to

reduce dependency on imported food should continue. While it may not be possible to eliminate all need for imported food items, increased local production would improve food access and food availability (Bullido, 2014). And it would make the food supply chain less susceptible to external disruptions. Government incentives and agricultural movements are already underway following Hurricane Maria (Acevedo, 2018), but government policy should continue to protect agriculture lands and promote local food production.

Increased local food production alone would not likely close all the gaps were another disaster to strike Puerto Rico. Increased stockpiling is also an important component of preparedness. Ahead of Irma, pre-positioned supplies in the US Virgin Islands helped facilitate the response effort after the storm (GAO, 2018). And the FEMA AAR acknowledged the importance of pre-positioned supplies by recommending a six-fold increase of food and water ahead of the 2018 hurricane season (FEMA, 2018a). Strategically placed stockpiles—especially given Puerto Rico’s island geography—help ensure food access even if imports were cut off or local crops were destroyed.

## Applications in a COVID-19 Environment

Every disaster is different. And a global pandemic is obviously much different than a hurricane. Still, there may be practical lessons from the disaster in Puerto Rico that could have been (or can be) applied in the current COVID-19 environment.

This section explores the parallels between the Hurricane Maria disaster and the COVID-19 pandemic. It describes how similar supply-chain challenges have been encountered, and it discusses the extent to which lessons observed during Hurricane Maria are applicable in the COVID response.

## Supply Chain Challenges in COVID-19

### **Essential Workers Shortages**

The coronavirus pandemic will permanently change the lexicon of (at least) an entire generation. Phrases like “social distancing” and “flatten the curve”—previously unknown outside of public health circles—are now commonplace terms throughout all of society. Among these is the term “essential worker,” describing workers who are “needed to maintain continuity of operations of essential critical infrastructure sectors” (State of California Public Health Officer, 2020). It identifies those workers who can (must) return to work while many others are under stay-at-home orders. These include the obvious: doctors and nurses, but it also includes information technology workers, factory workers, check-out cashiers, truck drivers, defense industry workers, and bankers.

Throughout COVID, a shortage of medical workers has accompanied regional spikes in the virus. During a recent spike in the southern US, 39 hospitals in Florida requested help from the state for front-line nurses and respiratory therapists (Stead Sellers & Hauslohner, 2020). In South Carolina, the National Guard sent 40 medical professionals to five hospitals in response to rising cases. In Texas, short-staffed hospitals turned away patients or sent them to facilities hundreds of miles away (Walter, E. et al.,2020). They also delayed elective surgeries and converted lobbies and conference rooms into healthcare spaces. And in one striking example the governor of Michigan tweeted a video saying, “If you’re a health professional anywhere in America, Michigan needs you. We’re calling on doctors, and nurses, and respiratory therapists, and other health professionals to sign up and help us fight Covid-19 and save lives.” (Whitmer, 2020). Some have expressed concern that regional staffing shortages will lead to higher mortality rates. This fear echoed by a senior policy researcher at the RAND Corporation who said that the backlog of patients “will cost lives, not just for COVID patients, but for everyone else in the hospital” (Stead Sellers & Hauslohner, 2020).

The pandemic has also exposed the criticality of workers outside of healthcare. Workers within the food system have been thrust to the frontline of the pandemic. Cashiers and grocery store workers have become frontline workers during COVID-19, often working with limited personal protective equipment (PPE) and at high risk to themselves (Parks et al., 2020). Workers in meat processing plants, working in close quarters are especially susceptible. Between the US and Europe, 30,000 employees in meat processing facilities have contracted the disease (Laborde et al., 2020) and in the US, at least 48 have died (Parks et al., 2020). While food supply chains were largely able to keep up with consumer demand (Laborde et al., 2020), the pandemic underscored the necessity of including these workers in any future plans for supply chain resilience. These workers—often lower paid and lower skilled—represent key nodes in the supply chain, the final “link” between consumers and their goods. Unlike many healthcare workers, they did not “sign up” to be on frontlines of a global pandemic (Parks et al., 2020) and have had to grapple with whether their paychecks were worth the risks. Several retailers have increased worker’s wages, to increase the probability of retention and acknowledge the risk these workers are taking (Cain, 2020). Still, the potential for labor shortages among the food distribution and processing sectors should remain a watch item (Hobbs, 2020).

Outside of the food system, transportation workers are also essential to keep supply chains functioning. Long-haul trucker shortages have not become a pervasive problem during the pandemic, but a spike in the demand for home delivery services could create a labor shortage for short-run drivers (Gray, 2020). Public transit workers have been especially hard hit in some areas. In New York City, 120 have died due to COVID-19, and nearly 4000 have tested positive (Lancet, 2020). While a decrease in demand for transit services may mitigate the impact of sick workers, further protections for workers may be required as demand returns.

### **Medical Supply Chain**

During the COVID crisis, producers of PPE such as N95 masks and face shields, have been unable to keep up with the surge in demand (World Health Organization [WHO], 2020).

Additionally, there have been shortages in ventilators, gowns, and gloves. The consequences of a PPE shortage are especially pronounced for healthcare workers. Inadequately protected workers can infect patients, co-workers, or get sick themselves and need to quarantine (Park et al., 2020).

Contributing to the shortage is the US's dependence on international suppliers: 95% of surgical masks and 70% of respirators are produced overseas; and much of the production is located in China (Park et al., 2020). Disruptions in Chinese production from the virus have contributed to a worldwide shortage. The surge in demand has also led to shortages in raw materials and production equipment. Export bans between countries have complicated the flow of goods across international borders. And transportation and shipping due to quarantine restrictions has slowed the flow goods once made (Park et al., 2020).

Like Hurricane Maria, private and non-traditional suppliers have stepped in to fill some of the gaps. In cities large and small, private residents with sewing machines volunteered to sew masks for fellow residents and medical workers. Initially viewed as little more than sweet gestures, the efforts of these home-based producers have created a much-needed supply of masks, especially in areas where residents have limited access to transportation and as mask mandates become more common. On a larger scale, manufacturers like Rolls Royce, Raytheon, and General Motors have volunteered to convert portions of their production facilities to manufacture face shields and ventilators (Park et al., 2020 & Raytheon 2020).

As in Maria, hospitals and clinics in COVID have been overwhelmed by patient need. While not completely decimated like those in Puerto Rico, the ability of the hospital system—already taxed prior to the pandemic—to surge in capacity was very limited (Osterholm & Olshaker, 2020). Now, with a shortage of workers and key equipment, many systems are ill-prepared to deal with spikes. A central objective of “flatten-the-curve” policies is to prevent healthcare systems from

becoming overwhelmed (Ranney et al., 2020). Reducing the flow of patients into the hospital helps control demand on the system and limits the need for medical supply chain surges.

## **Food Shortages**

In the early days of the pandemic, runs on toilet paper, long lines at grocery stores, and panic buying of non-perishable items highlighted the volatile nature of consumer demand (Hobbs, 2020). The closure of restaurants and increased number of people working from home also drove an increase in demand on grocery stores. And while panic-buying did cause a few short-term shortages, food supply chains were largely able to keep up with consumer demand (Laborde et al., 2020).

There were, however, some supply-side challenges that followed flare-ups of the virus. Work environments especially vulnerable to virus spread, meat-processing plants for example, were especially hard hit by widespread breakouts of the virus (Lancet, 2020). These nodes of the food supply chain were especially vulnerable to a virus that could lead to a massive loss of laborers and the type of essential worker shortage described above (Hobbs, 2020). The closure or diminished capacity of these plants had both upstream and downstream impacts. In Minnesota, 10,000 pigs were being euthanized a day after meat-processing plants closed due to a large number of positive COVID cases (Lussenhop, 2020). With the processing facilities closed, farmers had no option but to euthanize the animals, even though demand for pork was high in grocery stores.

Unlike Maria, where there was an immediate food shortage due to a loss of distribution capability, global food supply chains have largely been able to keep up with increased demand, and even profit from it (Laborde et al., 2020). Yet in the long-term, loss of income, production chain disruptions, and export complications will continue to pose risks to food security (The World Bank, 2020).

## Lessons Observed in a COVID-19 Context

This section lists each of the lessons observed from Hurricane Maria (as described above) and examines the extent to which they are applicable in the current COVID-19 context.

### **The Federal government should have been better prepared to assume a frontline leadership role in the disaster response.**

State and local governments are clearly intact during the COVID crisis. And rather than FEMA, the Department of Health and Human Services (HHS) and Center for Disease Control (CDC) have a more prominent role in the response. The fact that the pandemic is a *national-level crisis*, however, means that the federal government needs to establish a *national-level response*. States have the authority to protect the health of citizens within their borders and the federal government controls movement at international borders and between states (CDC, 2020). In COVID-19, the president has issued confusing statements around authority, one day claiming to have “total authority” (White, 2020) to open up states and two days later telling states they would “call their own shots” (Miller, 2020). In addition to the confusion coming from the White House, there were missed opportunities for leadership at the federal level. As soon as the coronavirus was identified, the federal government could have ramped up efforts to develop test capabilities and production of PPE (Osterholm & Olshaker, 2020). It could have appointed a supply chain coordinator to help distribute and track resources, rather than telling states to “buy it on their own” (Martin, 2020). Lack of direction in these areas has led to shortages and unequal distribution of resources (Ranney et al., 2020). The changing nature of the pandemic has challenged most countries but clearly, elements of frontline leadership—like in Maria—have been missing in US COVID-19 response.

### **FEMA should have established stronger public-private partnerships through collaboration with local government leaders and organizations.**

Partnership with private industry will be critical in filling the shortages of PPE encountered in the COVID pandemic. The president has employed the Defense Production Act (DPA) to direct certain companies to produce PPE (CRS, 2020). While that is a start, there is not enough coordination at the federal level to allocate and distribute resources (Osterholm & Olshaker, 2020). States and health care systems are competing for the same resources and those resources are not necessarily being distributed on the basis of need (Ranney et al., 2020). Had stronger relationships and tighter coordination with the private industry existed before the pandemic, then some of the shortages could have been avoided. Like Maria, weaknesses in the supply chain could have been mitigated by strategic planning with private partners.

**The US should have taken steps to strengthen its medical supply chain and reduce susceptibility to single point failures.**

The COVID pandemic—like Maria—has clearly uncovered weaknesses in the medical supply chain. The heavy reliance on international suppliers means the US is susceptible to disruptions abroad and will compete with other countries for PPE and other critical supplies (Osterholm & Olshaker, 2020). The US should increase domestic production of critical medical supplies. Government incentives to that end would improve national preparedness and serve to stimulate the economy. Furthermore, “just-in-time” production practices by private business elevate the importance of stockpiling so that there is contingency should supply chains become overwhelmed (Park et al., 2020). Maria showed us that critical supply chains need to have built-in redundancies, and COVID has made that even more painfully clear.

**The White House should have conveyed a clear and unified response strategy that was consistent with the on-the-ground reality.**

President Trump has repeatedly contradicted the medical experts in his own COVID-19 task force (Trump, 2020 August 1). He has dismissed the seriousness of the threat (Trump, 2020 February 24) and then backtracked (White House, 2020 March 16). He has advocated for remedies not backed by medical professionals (Lenzer, 2020). He has undermined governors’

authority (Trump, 2020 April 17). He has, in an apparent attempt to place blame, consistently referred to the coronavirus as the “China virus” (Trump, 2020, July 21). The message coming from the President has been confusing and contradictory. The lack of clarity has real-life consequences. Lack of focus equates to loss of efficiency as states develop their own strategies and own supply chains in lieu of a coordinated federal effort (Ranney, 2020). And when the president does not follow the guidelines issued by his own team (e.g. refusing to wear a mask), it does not encourage compliance with the general population (Goodwin, 2020). As seen in Maria, the president’s voice is critical in setting the tone, aligning objectives, and clearing obstacles. In the case of COVID, the same contradictory and confrontational themes have permeated White House messaging.

**The US should have taken swift action to quickly assemble a team, assess the needs, and deploy resources.**

Crises are unexpected and have high stakes. And crisis managers rarely have all the information they need in the moment. Yet the urgency of the situation typically demands quick action is taken. As seen in Hurricane Maria, lack of urgency and action slowed the response and likely cost lives. And the COVID-19 response also suffered delays, especially early on. According to Dr. Anthony Fauci, a member the White House Coronavirus Task Force, the early inability to test was “a failing” of the administration’s response to the pandemic (Shear et al., 2020). And according to a former commissioner of the Food and Drug Administration, the lapse enabled “exponential growth of cases” (Shear et al., 2020). While it’s easy to criticize a disaster response with the benefit of hindsight, the inability or unwillingness to take swift action can have serious consequences.

**The federal government should have had an expanded workforce surge capacity that accounted for concurrent disasters.**

2020 has required emergency workers across the country to deal with multiple crises at once. In June, the state of Mississippi, for example, was contending with the COVID-19 response,

protests following the death of George Floyd, and the looming threat of tropical storm Cristobal. National Guard troops and emergency response staff were spread thin. Furthermore, each of these crises were not happening in a vacuum; one affected the other. Protests and associated gatherings raised fears of increased coronavirus transmissions. And social distancing requirements created space constraints for storm shelters. Like 2017, 2020 has demonstrated the necessity for a surge workforce and the ability to coordinate concurrent crises.

**Investment should have been made to increase the resiliency of Puerto Rico's infrastructure, and emergency plans should have accounted for the severity of the threat and have honestly assessed local resiliency.**

FEMA officials acknowledged that there was insufficient planning and investment in Puerto Rico ahead of Maria. They pointed to the successes in Texas and Florida due to thorough planning, pre-positioning of supplies, and exercises but said the same effort was not leveraged in Puerto Rico. The threat of a serious hurricane in the Caribbean was known, but that knowledge did not drive the needed preparation. The situation has not been much different with COVID-19. The threat of serious pandemic has been acknowledged by health officials for years. In 2005 Dr. Michael Osterholm of the University of Minnesota wrote, "The reality of a coming pandemic cannot be avoided. Only its impact can be lessened. Some important preparatory efforts are under way, but much more needs to be done by institutions at many levels of society" (Osterholm, 2005). The article goes to describe with some chilling accuracy the challenges being faced today with COVID-19. Lack of preparation was certainly not due to lack of information. Like Maria, the consequences of the crisis could have been mitigated had investment and planning been commensurate with the threat.

**Food security should have been strengthened through an increase of local food production and a strategic stockpiling of emergency food supplies**

While global supply chains, as mentioned above, have largely been able to keep up with global demand, there is ongoing risk that shocks to food production during COVID, loss of incomes,

and increased international tensions could result in food shortages (The World Bank, 2020). So, while food shortages are not acute (yet) as they were in Maria, food security should remain a focus of policy makers. And at the consumer level, there is already momentum towards the “local food” movement given the perceived health, social, and economic benefits. Localized shortages experienced during COVID may spur consumers towards local suppliers who are less susceptible to cross-border disruptions (Hobbs, 2020).

Lessons observed in Hurricane Maria have direct application to our current day crisis and demonstrate that core tenets of preparedness and resilience are broadly applicable, despite the varying nature of disasters. Still, every disaster is unique. The relatively localized effects of Hurricane Maria pale in comparison to the enormous reach of COVID-19. The COVID-19 crisis has shown us how exceedingly interdependent our economies and political systems have become. Conflicting policies and approaches to the virus have strained diplomatic relationships, especially with our transatlantic partners (Donfried & Ischinger, 2020). And interconnected global supply chains mean that a viral outbreak in Asia can cause shortages in the US.

## Conclusion

It's no doubt that there were heroic efforts following the disaster that was Hurricane Maria. FEMA, the military, NGOs, and private entities adapted to an incredibly dynamic situation by improvising during a shortage of resources, assuming unfamiliar roles, collaborating with unfamiliar partners, and identifying creative solutions. And there are likely hundreds or thousands of untold acts of heroism by individuals stepping up to support their community and save lives. The problem is that a lot of challenges encountered and overcome need never have had existed in the first place. If the infrastructure of the island would have been given the attention it deserved early on; if emergency plans would have been right-sized to anticipate and make provisions for a disaster the magnitude of Maria; if there would have been strong leadership to guide and prioritize the response, then things in Puerto Rico would not have been as devastating. The disruptions to critical supply chains, lifelines during a disaster, would not

have been nearly as crippling. Normal supply chains would have been better positioned to withstand the storm and relief supply chains would have been better prepared to respond. Recovery would not have been nearly as daunting. The storm was of epic proportions, and some level of calamity was without a doubt unavoidable. But a stronger and more organized response would have saved lives.

While outside the scope of this paper, a deeper look at US policy towards its territories would be a worthwhile study. Several parties—including the UN—have suggested the diminished standing of US territories contributed to a lack of priority and response in Puerto Rico (UN, 2014). Antiquated laws restrict the flow of goods to and from the island. Puerto Ricans cannot vote for president and do not have a voting member in congress. And much of the population in the continental US is not even aware that Puerto Ricans are US citizens.

Regardless of political status or geography, disasters are unpredictable and unique; none is exactly like the one that preceded it. Yet the fact that lessons observed in Maria—a wildly different type of disaster than a global pandemic—can be applied to the COVID crisis, underscores the fact that there are things we can do to increase supply chain resilience and preparedness for whatever the next crisis might be, even in the face of much uncertainty. Lessons learned and knowledge gained from previous experiences can guide preparation and policymaking in the present. Yet preparation is a long-term game. It requires investment today without an immediate return. Characterizing “return on investment” requires a future-oriented vision and getting buy-in from political and business leaders can be a challenge. In our current climate—where questions of stability, readiness, and safety are front and center—the notion of preparedness seems more pertinent than ever. The question will be whether the will exists—politically, in private industry, and with the population at large—to invest in what experience tells us we need to invest in.

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