

A CNA CASE STUDY IN SUPPLY CHAIN RESILIENCE

Retail Resilience in Puerto Rico

Hurricane Maria made landfall just south of Yabucoa, Puerto Rico, at dawn on Wednesday, September 20, 2017. It was a strong Category 4 storm with winds exceeding 150 miles per hour. With Thursday's dawn Jose Perales, manager of [Ralph's Food Warehouse](#), made it through flood and debris to check the store. His typically 20-minute drive took over 40. In several places the store's roof was gone. He guessed that 30 percent of his inventory had been ruined by rain. But the diesel generators had kicked in as intended.

By early Wednesday afternoon, the [Mi Gente](#) grocery, 2,000 feet high in the mountains of [Naranjito and Comerio](#), south of San Juan, was reeling from hot wind and rain. The owner, Rene Lopez, had locked up on Tuesday as word spread that landslides had already closed Route 167 along the Rio de la Plata into San Juan. Sometime after he left, the wireless tower connecting the ATM and credit card machine to the outside world fell hard. Eventually the store went dark. It would not be reconnected to the grid for another six months. The store stayed locked through that first day and night.

Both Ralph's and Mi Gente—and many more—are supplied from the state-of-the-art warehouse and distribution center¹ operated by [B. Fernandez & Hnos.](#) in [Bayamon, just west of the Port of San Juan](#).² On Tuesday, they consolidated their trucks, trailers, and containers in the freight yard. The same steel phalanx was organized at [Puerto Rico Supplies Group](#) immediately to the north, [Jose Santiago Food Service Distributors](#) immediately to the south, and at [V. Suarez](#) just across Route 5. The [Goya](#) processing and distribution center was just a few hundred feet south across Route 28. As he supervised preparations, Angel Vasquez, President of B. Fernandez, wondered how many people could be fed with the food being held just by his company and those of his neighbors (and competitors).

Less than 500 feet behind the B. Fernandez freight yard is the [Puma](#) fuel terminal and racks. Tuesday morning, scores of tankers had refueled by moving smoothly through 12 bays. But

¹ In contemporary supply chains, there is typically a distinction between a warehouse and a distribution center, but at B. Fernandez, the two functions have arguably been hybridized.

² See the Case Study 1 Appendix for an overview map of all of the referenced facilities.



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Wednesday morning was as quiet as Christmas. Trucks and truckers bunkered down at home. More than two million barrels of gasoline and diesel were ready,³ but the racks were closed until Maria finished her whirlwind visit. Wednesday morning, Maria made an especially violent call on the fuel terminal and racks at Yabucoa, disrupting the source for roughly 20 percent of Puerto Rico's fuel until October 3, 2017. [1] Wednesday afternoon, Rodrigo Zavala, Puma's CEO Americas, looked out his home windows at the destruction descending around him. His house was shaking. Rodrigo worried about Puma's glass-encased headquarters overlooking the terminal. Could even the hurricane glass resist this?

Far away in Washington, DC, the night watch gave way to the day watch at the FEMA National Response Coordination Center (NRCC). The NRCC had stood up as Hurricane Harvey popped up in the Western Gulf of Mexico on August 25, 2017. It continued operations as Hurricane Irma hit, Hurricane Jose had threatened, and now as the island of Puerto Rico was swallowed whole into Maria's maw. Jeff Dorko, FEMA's Assistant Administrator for Logistics arrived early to catch the departing chief of the night watch. "What are you seeing?" Jeff asked. His colleague responded, "Mostly the whole place go dark. The grid is going down hard."

Along the north shore of Hispaniola, three ocean-going barges four days out of Jacksonville anchored as close to land as they could. This is where they would ride out the powerful waves extending for hundreds of miles in front of the hurricane's forward movement. The forecast called for Maria to turn northwest; if so, the cargo of "FEMA freight" would be safe and ready for unloading at San Juan. On board were tons of water, shelf-stable food, blue tarps, and more. The same complement of supplies had been delivered by fleets of trucks to survivors of hurricanes in Texas and Florida. What a month.

GRID UNRELIABILITY AND SUPPLY CHAIN RESILIENCE

Contemporary supply chains are dependent on—and usually interdependent with—the electrical grid, telecommunications systems, road and fuel networks, and other sometimes-surprising aspects of push and pull factors. Grocers, for example, depend on power systems for lighting, payment processing, climate control, and refrigeration. The Puerto Rican electrical grid is not reliable. Since 2014, Puerto Rican electricity consumers have experienced service interruptions at a rate of four-to-five times the average for the US mainland. [2] A November 2016 "Experts Report" stated that the Puerto Rican electric utility's "generation and transmission facilities are in a state of crisis." [2]

³ Before the storm, Puerto Rico usually consumed about 155,000 barrels of fuel per day, according to EIA.

Grocery stores, food processing, and many other elements of consumer demand and supply require reliable water service, but the water sector itself needs power to operate. Over 95 percent of Puerto Ricans are public water customers. The network consists of over 20,000 miles of pipe and 114 filtration plants. In some areas, the water system benefits from large surface reservoirs and gravity feeds. But the island's mountainous interior also features long pipelines that climb over 2,000 feet from water treatment facilities. Water is heavy. Significant power is needed to pump volume up and sometimes over mountains. Most mainlines include back-up electrical generation. Prior to Hurricane Maria, 1,348 emergency generating units (EGUs) were deployed across the system. Another 269 EGUs were deployed during the long-term grid outage. Expenses associated with EGU deployment and operations equaled more than 60 percent of total 2017 water authority expenses. [3]

Shippers, wholesalers, and retailers rely on communications systems for logistics management, order fulfillment, inventory management, and processing payments. Puerto Rico has been an early adopter of wireless technologies for personal communication, Electric Data Transfer and business-to-business transactions. Since 2008, the number of wireless subscribers in Puerto Rico has grown from 2.54 million to 3.23 million (out of a current population of 3.4 million). More than 50 percent of internet traffic in Puerto Rico is generated by mobile devices, compared to a US average that has recently ranged from 32 to 42 percent. [4] This widespread adoption of mobile internet has facilitated significant business-to-business digital processing. Puma, for example, now facilitates bulk fuel purchases through an entirely digital process.

Most telecommunications infrastructure in Puerto Rico is engineered to persist with temporary loss of the electrical grid. Following Hurricane Irma (two weeks prior to Maria) approximately 63 percent of Puerto Ricans experienced several days without electricity. [5] But the Federal Communications Commission reports that in the area of Puerto Rico hardest hit by Irma, 45 percent of cell towers continued to operate and in less than four days, the outage had been reduced to 26.9 percent of cell sites in the impact zone. [6] Since the advent of mobile communications, quick recovery has been the common experience. This was not the case in the aftermath of Hurricane Maria.

In contemporary supply chains, demand pulls supply. Since the 1980s, pull signals have become mostly telecommunications signals. In the last 7 to 10 years, the signals have increasingly become bits and bytes flowing across the internet. In calendar year 2016, Puerto Rico recorded \$37.4 billion in total retail sales. Approximately 20 percent of retail sales are transacted using credit, debit, or electronic benefit transfers. In 2016, roughly \$5.6 billion was expended at food stores. [7] Approximately 40 percent of all food purchases are made with the Department of the Family's Electronic Benefit Transfer (EBT) card, also known as the PAN card. [8] There are more than 35,000 point-of-sale terminals in Puerto Rico. Even

most cash transactions eventually depend on telecoms (which depend on electricity). In 2015, there were 1,064 ATMs in Puerto Rico. [9]

Responding to consumer pull, the commercial sector exchanges its own business-to-business digital signals. For example, when a fuel distributor places a digital order with a fuel supplier, it is digitally scheduled to receive fuel and digitally pays for fuel. This seamless processing keeps the flow of trucks moving smoothly through the racks and pushes supply toward demand.

Over the years, as the Puerto Rican grid incrementally deteriorated, key elements of demand and supply networks attempted to mitigate their dependence on the grid. Many residential and commercial customers invested in back-up power generation. Residential back-up typically takes the form of 250-watt gasoline-fueled generators sufficient for a few essential services, especially home refrigeration. Much larger diesel-powered generators are utilized by grocery stores, fuel retailers, and other commercial operations. None of these back-up systems are designed to operate continuously over many weeks. Many of the largest diesel generators require regular maintenance every 500 hours or so. [10] Continuous operation also requires regular refueling. Without continuous fuel and appropriate maintenance, generators fail and require specialized expertise to repair or restart.

Puerto Ricans have experienced and expect annual hurricanes. They have grown accustomed to occasional loss of the grid. When the Category 3 Hurricane Georges hit in 1998, less than 20 percent of Puerto Ricans utilized mobile phones. Today it is over 88 percent and business-to-business communications has followed.

As Hurricane Maria toppled power transmission towers crossing south to north through the mountains of Puerto Rico, a wide web of dependencies fell with them.

FIRST WEEK AFTER LANDFALL: FUEL, TRANSPORT, AND CASH COMPLICATIONS

On Saturday, September 23, 2017, Jose Perales stood inside his hot, dim, but once-again clean and dry store. The roof was patched, the spoiled stock removed, and three generators were humming (well, one was growling). Most employees were back at work. The line of customers waiting in the parking lot extended the length of a football field. Local police stood by, but the crowd was patient. The assistant manager unlocked the doors at about 7:30 a.m. Customers purchased water and canned meat, and they especially wanted Coca-Cola. The demand for Coca-Cola surged and stayed high for weeks after the storm. “Something sweet for a sour time,” Jose decided. The Coca-Cola supply truck was the first vendor to show up after the storm.

Other suppliers—including B. Fernandez—began delivering to Yabucoa on Monday and Tuesday. “We were prepared to load trucks on Sunday, but most of our customers could not receive until Tuesday and several were not able to receive until Thursday,” Angel Vazquez explained. On Monday, Ralph’s Food Warehouse headquarters in Las Piedras sent one of their procurement staff to Caguas, where they had heard a cell signal was available. She was able to tell B. Fernandez and other wholesalers that the Ralph’s in Yabucoa was ready to receive. In Puerto Rico, most grocery products are Direct Store Deliveries (DSD) from wholesalers. Most of the wholesalers are in the San Juan metro area almost 50 miles from Yabucoa.

“As a rule, the smaller the store, the quicker the recovery,” Angel Vazquez (B. Fernandez) observes. “Our largest customers have the most sophisticated systems and were, as a result, the most disrupted by long-term outage of the grid. Our smallest customers, up in the mountains—even though they had been hit really hard—were the first to open. They also immediately adapted their orders. Less beer. Lots of canned meat. We sold more Spanish canned fish than ever before.”

As a year-round cost-containment procedure, B. Fernandez purchases fuel for its independent truckers from the nearby Puma fuel rack. It is dispersed at the warehouse from its own 10,000-gallon tank and sold to the delivery fleet at cost. As a result, the wholesaler’s trucking partners did not experience any fuel shortages during the post-storm period. Many others did experience significant fuel shortages.

The island-wide failure of the electrical grid resulted in simultaneous population-wide initiation of back-up generators. Luis Sanchez, President of the Puerto Rican Licensed Electricians Association, estimates there were more than 100,000 residential electrical “plants” in place pre-Maria. [11]

Most of these are smaller, under-5,000-watt generators with fuel tanks of less than 10 gallons designed to run for 10 to 12 hours with enough power to operate a refrigerator, house lights, small appliances and recharge cell phones. Even many larger commercial EGUs have fuel reservoirs only sufficient for three-quarters of one day.

“Most generator back-ups were installed to mitigate short-term spot outages. Very few were consciously trying for long-term grid replacement.” Rodrigo Zavala, CEO of Puma Americas, (and a resident of Puerto Rico) explained, “There was plenty of fuel, but there was not sufficient fuel storage at the point-of-consumption. Almost everyone needed daily refueling. Suddenly refueling one million additional households once or even twice a day is not feasible.”

In recent years, Puerto Rico has consumed roughly 2.5 million gallons of gasoline per day [12]. In the immediate aftermath of Maria, demand jumped more than 40 percent. Even as

late as December, when more than 60 percent of grid customers had been restored, average daily gasoline consumption was more than 25 percent above normal. [13]

The increase in fuel demand was essentially simultaneous across the entire island. By Monday, September 25, 2017, a few more than 100 (of 1,100) gas stations were open. Nearly 10 percent of available National Guard troops were assigned to several San Juan metro area stations to encourage calm and public order. Observers counted 91 fuel tankers making deliveries on Monday, usually with security escorts. [14] Two of five major fuel racks were closed. The other three were operating at less than prior capacity, due to the loss of digital processing capabilities and a reduced number of tanker trucks arriving to be loaded.

Attempting to extend available retail supplies and treat customers fairly, many gas station operators rationed purchases to \$10 or \$15 per person. While this may well have defused social tension in the long lines, it also made the lines longer, as many consumers would empty their jerry cans and quickly return to the line, increasing and accelerating expression of demand.

On September 29, 2017, the Secretary of Consumer Affairs (DACO) made retail rationing illegal. "Now there is even more need for gasoline for power plants. The most common hold very little gasoline, to operate eight or 10 hours, and people have to replenish almost daily," Secretary Pierluisi explained. [15] Removing arbitrary limits on consumer purchases reduced overall consumer cycling. Curfew was also extended by two hours, giving the system more time to meet demand, and by the end of the first week almost 700 gasoline stations had opened. On September 28, the governor exempted fuel distributors from the curfew, allowing nighttime deliveries. By the beginning of the second week after landfall, the lines at gas stations were much less dramatic. The increasing range of consumer options and operating hours allowed the fuel distribution system to achieve much more balanced, sustainable, and assured through-put. By October 3, 2017, the Puerto Rican fuel distribution system had reclaimed preexisting capacity and was distributing roughly 30 percent more than it was before the storm. [1]

According to the US Census Bureau, there are about 19,000 people in Puerto Rico involved in moving material of all sorts. [16] There are about 13,000 truck drivers. [17] According to the US Bureau of Labor Statistics, there are roughly 8,000 drivers of heavy trucks and 5,000 drivers of light trucks and delivery vans. [18] All were in some ways victims or survivors of Hurricane Maria. Most took two or three days to do immediate repairs and attend to personal priorities. By Monday, September 25, 2017, many truckers were prepared to return to work, but there were serious impediments.

Many roads remained impassable. In urban areas, even where roads were clear, traffic lights no longer functioned. Communications were minimal or non-existent, so what was open,

what was closed, and the condition between here and there was very uncertain. Many independent truckers surveyed the long lines at the small number of operating gas stations, worried about running out of gas, and often decided they needed to know more before restarting their regular routes. There was plenty to do at home.

Not much moved—not nearly enough moved—for the first five days after landfall. The regular flow of food, fuel, and much more was seriously disrupted by lack of electricity, lack of communication, debris in the road, bridges out, complications with fuel distribution and the myriad challenges of immediate recovery. But by the end of the first week, each of these impediments was gradually overcome. On Thursday, September 28, 2017, B. Fernandez and its trucking partners moved seven times the ordinary daily volume. It was the beginning of a surge that continued through mid-December and beyond.

By the close of the first week after landfall, the pre-existing supply chain demonstrated considerable resilience under duress. But some places were entirely cut off. The Mi Gente grocery store, owned by Rene Lopez, stands at a rural crossroads between mountainous Comerio and Naranjito. It is usually less than 20 miles to the wholesalers in Bayamon. Looking northeast with binoculars from nearby high ridges, you can find the warehouses. But for the first few weeks following Maria's rain and wind, those 20 miles seemed to be 200 or more. Roads into San Juan were blocked by multiple landslides and wash-outs until September 28, 2017 (eight days after landfall).

Friday is usually the big day for food deliveries. Trucks could not get through on September 22, 2017. But customers did. They mostly purchased canned goods and ice. The store limited each family to three cans and two bags of ice. Still, by the end of Friday the ice was gone. The store had frozen meat to sell until Thursday, September 28, 2017, when the generators ran out of diesel. Rene was unable to refuel his generator for two days. Over \$30,000 worth of meat and other perishables was lost. In late September, he did not imagine depending on his generator for six more months.

With fuel, Rene's diesel generator supplied power. The cash register kept track of sales. But for the first month, only cash could be used. The ATM and the point-of-sale terminal depend on a rooftop tower to exchange EBT and other digital signals. The antenna had blown down in the storm. After a few days it was erected again, but the relay tower in Barranquitas did not respond. On Friday, September 29, Rene was able to drive into Bayamon to place orders and bring back cases of essential products in his own truck. He continued this process of personal pick-up and self-delivery for over two weeks.

Most people paid cash. But over 60 percent of the Mi Gente's customers usually pay for groceries with their PAN card⁴. Many of these customers quickly ran out of cash. In some cases, Rene Lopez resurrected the practice of "fiao" or "Don Fiao," [19] the granting of temporary credit. During the first month, regular customers without cash made small purchases using store-credit to be repaid when PAN cards could be accepted again, or other resources were available.

At 8:00 a.m. on Saturday September 23, 2017, the US Coast Guard reopened the Port of San Juan. Shortly after 10:00 a.m. one of the barges that had anchored off Hispaniola began to unload. Over the next six days, over 700 loads of FEMA freight—including more than 1.3 million shelf-stable meals and huge quantities of bottled water—arrived. The *El Rey*, another vessel, would arrive on October 2, 2017 with 100 fuel trucks loaded with 275,000 gallons of diesel and 75,000 gallons of gasoline. As FEMA relief supplies arrived at port, they were quickly trucked to 11 staging areas around the island where they supplemented emergency supplies already stored in Puerto Rico. [20]

In Washington, Jeff Dorko and his FEMA Logistics colleagues worked to enable a minimum of 1.5 million meals per day in Puerto Rico. They aimed to feed, water, and provide essential life-saving services to 20 percent of the population. Some were arguing that even this was not enough. On September 25, 2017, the Puerto Rico Department of Housing and Governor's office requested six million meals per day for the following three weeks, with gradual reductions over the following nine weeks. [21] This request anticipated 60 percent of the population would not be supported by preexisting supply chains. In any case, FEMA was pushing every calorie and ounce of water it could procure toward the Port of Jacksonville and any other place there was a vessel sailing or an airframe flying into Puerto Rico.

No one in Washington knew about the Ralph's store opening in Yabucoa or the Mi Gente store in the mountains. Had anyone at FEMA Headquarters ever heard about B. Fernandez, a 125-year-old fixture of the Puerto Rican food chain? At the Joint Field Office (JFO) opened at the San Juan Convention Center, local emergency management personnel recognized B. Fernandez and even knew its warehouse location. But they did not know it was making food deliveries at seven times the normal rate eight days after landfall. The JFO was more likely to know that Puerto Rico Supplies, next door to B. Fernandez, had lost its warehouse roof. They were more likely to know which stores could not open because they had no diesel. The JFO was focused on hospitals with no fuel for back up generation. Bad news travels fast. Good news tends to be much more discreet, especially in a crisis.

⁴ The analogous mainland program is SNAP (Supplemental Nutrition Assistance Program) AKA as food stamps.

ONE MONTH AFTER LANDFALL: NETWORK RECOVERY, REDUNDANCIES, AND INTERVENTIONS

"Sistema! Sistema! Sistema!" Ana shouted. Carlos and Rene came running. Every day since they had repaired their antenna the Mi Gente grocery had checked to see if they had signal. On Wednesday morning, October 18, 2017, there was a return pulse from Barranquitas. Ana danced behind her check-out counter. Carlos laughed. Rene's eyes teared up. Finally, customers could use their bank cards and PAN cards again. The ATM would recognize them again. Many were glad to get reacquainted. Well before the end of the day, the ATM was out of cash.

There was still no ice. No more fresh or frozen meat. No fresh vegetables. But the bread trucks were delivering again. The B. Fernandez truck brought cases of Spam, canned chicken, and previously unknown canned products from Mexico and Spain. Deliveries were not yet predictable. There were new drivers behind the wheels of the trucks. They told Ana that several of the usual truckers had taken higher-paying routes delivering relief supplies between the docks and government staging areas. Some were even working as translators and navigators for electrical repair crews from the mainland.

The Mi Gente store could now exchange electronic data, but Rene was still driving several miles to use his cell phone to place orders. One month after the storm, 16 of 18 cell towers in Comerio were non-operational. In Bayamon and San Juan, about half of the cell towers were back online. Island-wide, about 33 percent of cell sites had come back. This provided mobile connections for about 61 percent of the population. [22]

Thirty days after landfall, roughly 20 percent of Puerto Ricans were reconnected to what was being called the grid. But the south-to-north transmission system was still in tatters, several substations were barely operational, and for many parts of San Juan the source of electricity was not any of the long-time public power plants but temporary, recently installed mega-generators.

Those reconnected did *not* include Ralph's Food Warehouse in Yabucoa, the Mi Gente in the mountains, B. Fernandez in Bayamon, or even the Puma Terminal next door.

Connected to the grid or not, by mid-October, all the major fuel terminals were operating at or well above prior output: Puma and Total in the San Juan metro area, Buckeye in Yabucoa, Corco, and Peerless in Tallaboa. Eighty percent of gas stations had reopened. There were still some lines. Consumers were still sensitive to keeping their gas tanks close to full. The private generator set still had to be refilled daily. But in most places, most of the time, supply and demand had found a new equilibrium.

"Fuel demand spiked and remained at far above normal into November. We—meaning the entire fuel sector—always had sufficient fuel on the island. But our distribution capacity was not sufficient for the new demand. Even worse, in the first several days, some of our competitors could not dispense fuel. We had an enormous challenge creating a paper-based replacement for our digital queuing and purchasing process. So system throughput was significantly constrained just when demand was loudest," is how Rodrigo Zavala summarized the first two to three weeks.

The fuel supply chain in place before Maria focused on fulfilling demand for electric generation by the Puerto Rico Electric Power Authority (PREPA) and for surface transportation. These two requirements accounted for roughly 90 percent of all fuel products consumed in Puerto Rico. [12] In the aftermath of the hurricane, demand by PREPA precipitously declined while demand by thousands of residential and commercial back-up generators soared.⁵ The equipment, personnel, and schedule required to service the prior source of demand was not identical to that required by the new source of demand. Prior demand was a predictable pull by a single source. New demand was an unprecedented level of need being expressed at hundreds of local gasoline retailers, even as those same retail locations continued to supply the fuel needed for surface transportation. Two previously separate "pulls" were now combined. The lack of sufficient storage by the private generator set produced rapidly cycling demand that drained retail stocks much more quickly than the surface transportation pull. This required distribution assets to refill the retail locations much more often, perhaps three times as often, than previously. Refilling capacity is especially limited by the number and volume of fuel delivery trucks, number of drivers, and number of fuel racks (and truck bays) available.

In the first several days after the hurricane at least three of five major racks were not operating. Driving time for fuel trucks was limited because it is unwise to operate large vehicles full of fuel after sunset where streetlights are dead and roads have been seriously damaged. These space and time constraints were further narrowed by the loss of digital processing at the fuel racks, which required much more time to serve each truck.

"But by one month in," Zavala says, "there was already excess capacity on the island, both in terms of supply and distribution. On September 21 (the first day after landfall) the system probably needed 100 more fuel distribution trucks to meet the surge requirement. Thirty

⁵ PREPA uses fuel oil, diesel and natural gas for generation. The private generator set is mostly gasoline and diesel based. As a result, some of the assets used to fulfill demand for PREPA could not be immediately converted to new demand.

days later, 250 to 300 trucks had been delivered. Impressive response. But over-supply creates its own difficulties and distortions.” In early October, the Public Service Commission of Puerto Rico offered a five-hour course that awarded over 2,000 provisional certificates to transport fuel. [23] But according to Rodrigo Zavala, 200 would have been entirely sufficient. That ten times as many earned the temporary certificate highlights the wild gyrations that several parts of the demand and supply network experienced.

To ensure movement of relief supplies, FEMA contractors were ready to pay premium prices to truckers. This expedited the movement of the relief supply chain even as it complicated, and arguably slightly suppressed, the ability of the grocery and construction supply chains to surge. Even other public-sector supply chains were affected. Carlos Contreras Aponte, Secretary of the Highway and Transportation Authority complained to Reuters that his agency was facing serious limitations repairing the road network because “our truck drivers, many have been hired by other companies.” Reviewing his repair requirements, the President of the Water Authority said, “We’ll never have enough trucks.” [24]

Having lost some of their trucks and truck drivers while trying to respond to demand well above normal, many beverage, grocery, and other wholesalers could not keep shelves fully stocked. Seeing empty shelves reinforced the consumer’s sense of uncertainty and increased demand. Seeing empty shelves where there should have been water was especially disconcerting. [25]

By October 20, one month after landfall, more than 70 percent of Puerto Ricans had access to public water. [26] But water quality was widely questioned. Even before the hurricane, many Puerto Ricans preferred to drink bottled water. [Coca-Cola](#), PepsiCo, and Cristalia all maintain large capacity bottling plants in Puerto Rico. Before the storm, these and other on-island operations had supplied nearly all local demand with DSD.

During the first month after landfall, while many of these water companies doubled production, they found that demand had more than doubled [27]. Some of this demand came courtesy of FEMA contracts. “In retrospect we should have stayed away from local bottled-water producers and focused on bulk water and bringing in supplies from the mainland,” one FEMA official commented. “While the on-island contract made some financial and logistical sense, it screwed up local supply and demand. We basically took product out of the commercial channel, moved it into the relief channel, and probably ended up distributing it less widely—and at a much greater overall expense—than if we had sourced elsewhere for emergency needs and let the preexisting channel respond to retail demand. We contributed to empty store shelves and this had predictable effects on consumer behavior.”

Faced with scarcity and uncertainty, consumers hoard [25]. Automobile drivers fill up their tanks when they are already three-quarters full. Grocery shoppers purchase six cans of Spam

because they are not sure of future supplies. Hospitals nervous about running out of diesel call three commercial providers, their local mayor, and the governor's office, trying to increase their odds that one supplier will show up in time. "In effect, many hospitals were sending pull-signals into the supply chain that multiplied actual need by three or four or more. No distribution system will ever catch-up with that kind of false signaling," Zavala notes. A 2018 study of Puerto Rican consumer behavior found that for 12 weeks after the hurricane, the frequency of grocery shopping soared from an average of slightly more than one store visit per week to 11 shopping trips per week [28]. Part of this is explained by the loss of at-home refrigeration and cooking capability. But it also reflects a fear of missing out in a time of profound uncertainty.

"Given the cost of repairs, the extra expense of diesel, and all the extra hours worked, the store probably lost money in October," the manager of Ralph's Food Warehouse in Yabucoa says quietly more than six months later. "I really don't recall. That was not my priority. I was just trying to keep things running. We've done fine since. There has been huge customer demand from the very beginning. Our customers are happy to come here."

Unlike the Mi Gente in the mountains, the roads connecting Yabucoa to San Juan were quickly reopened. The store is less than one mile from the intersection with the four-lane Route 53 toll-road. Regular deliveries resumed the week after the hurricane. Ice and meat were the most difficult to get. But in early October, the Yabucoa store was the first of 12 Ralph's stores to receive big deliveries of both high-demand products. "I hugged my assistant manager when he told me about the meat," Jose Perales said. "Ralph, the owner, did not believe me at first."

"Toward the end of the second week, maybe Thursday, our fuel delivery did not arrive as scheduled," Mr. Perales remembers. "I was worried we would lose all the progress we had made. But the mayor, he gave us some diesel from the truck FEMA had sent to Yabucoa. So, we made it through okay."

The day after the emergency fuel delivery, a team from [Osnet](#) in Humacao came to install a new piece of technology that allowed the Yabucoa store to once again process bank cards and PAN cards. "So, in just one day I went from fearing everything was falling apart to being very happy. Using their cards again allowed customers to get what they needed."

Only two weeks after landfall, the Ralph's in Yabucoa restored the power of plastic sooner than many other grocery outlets. The Mi Gente was more typical in not being able to conduct electronic data transfers before the fourth week. But in any case, by October 24, 2017, 95 percent of PAN beneficiaries were purchasing food with their EBT benefits. [29] Four thousand new families had also applied to participate in PAN since landfall. [30]

PAN beneficiaries have incomes that fall below the federal poverty threshold. Over 65 percent of PAN beneficiaries have zero monthly income. Another 31 percent have monthly incomes that are less than half the federal poverty threshold. Food costs in Puerto Rico have been estimated at 9 percent higher than the US mainland average. In 2015, the monthly benefit ranged from \$112 for a single-person household to a maximum of \$776 for a household of eight. [31]

Jesse Levin is a founder of [Tactivate](#) and an “expeditionary entrepreneur” especially committed to effective proactive disaster response. He arrived in Puerto Rico on September 26, 2017. “My task was to get out into the field and listen to understand the systemic challenges hindering effective recovery and look for a solution that would support local capacity to solve the discovered challenge.” He initially headed for the mountainous interior and eventually spent extended time in both Oracorvis and Barranquitas. “While most of the resources in the response were directed at remedying the effects of Maria, we were looking for the system failures leading to causation. In Puerto Rico it happened to be the EBT food accessibility challenge.” Jesse recognized that long before Maria, more than 40 percent of the population depended on their PAN card to eat. The grocery retail network was coming back fast and seemed to have access to product. The only thing standing between that food and hungry people was loss of electronic data transfer connections.

Jesse was acquainted with Steve Birnbaum, a communications specialist who was already working with FEMA and others in Puerto Rico. Steve considered several workable solutions, pitched a couple of possibilities to FEMA, the Puerto Rico Department of the Family (which administers PAN), and other response players. Trying to move fast, Jesse used his credit card to buy the necessary equipment. Jesse and Steve recruited a technical crew from [Focused Mission](#) to install satellite-in-the-box units at 13 grocery stores.

From Jesse’s arrival to completing the initial installations took about three weeks. Once the equipment was in hand, each installation required less than two hours. “It would have gone a lot quicker if we didn’t try to shop the solution to the appropriate channels and just acted ourselves sooner,” Jesse says. The satellite connection allows the point-of-sale machine to communicate with the transactions processor, bypassing the usual grid-dependent terrestrial networks. Total direct costs were roughly \$33,000. Other work-arounds were also deployed. Osnet gave Ralph’s the ability to connect through a private terrestrial network. [SkyTec](#) provides connections using radio frequencies.

By the second week in October the grocery supply chain in Puerto Rico was well on its way to restoring demand pull. Once point-of-sale terminals could be used, the over 45 percent of the population who use PAN EBT cards was immediately reengaged. The same work-around systems allowed other consumers to use their credit and bank cards. As was the case with the

Mi Gente in the mountains, ATM networks were also coming back, even while the grid remained mostly down.

By the end of October, about five percent of PAN beneficiaries remained outside the reach of grocery and related private sector supply chains. That equates to 85,000 to 90,000 people detached from their regular source of food, which is a significant challenge anywhere...at any time. Further, there was another segment of the population that was in need even if they were next door to a fully operating grocery store. PAN serves the poorest of the poor. Restoring the ability to use PAN was a huge strategic step. But in the aftermath of Maria, many self-sustaining Puerto Ricans were suddenly not employed.

The median annual household income in Puerto Rico is \$19,606. Just over 40 percent of households make under \$15,000. These are almost all served by PAN. Another 29 percent of households make over \$35,000 (more than 16 percent make over \$50,000). This leaves roughly 30 percent of households that are not part of the PAN system and who probably have limited cash reserves. [16] Fifty-seven percent of Puerto Ricans have no savings. [32] The longer the crisis—and loss of employment—the more likely this 30 percent will need food assistance. As noted, just in the first month after Maria, there were 4,000 new applicants for PAN.

In the first 30 days after Maria's landfall FEMA procured, shipped, and provided an average of 600,000 meals and 742,000 liters of water *per day*; delivered more than 3.6 million gallons of diesel and nearly 129,000 gallons of gasoline; provided 42,000 tarps and installed 439 blue roofs plus providing financial, personnel, and logistical support for the power restoration, debris removal, health delivery, and other critical response missions. [33]

These resources were delivered at the request of the Commonwealth of Puerto Rico. "They ask. We do everything we can to respond. That's our mission," is how Jeff Dorko describes FEMA logistics. In many cases, Puerto Rico's "ask" originated with one or more of the 78 mayors. The mayor of Yabucoa was not the only one who got a fuel truck. The mayor of Comerio specifically asked for help with water purification. The US Army Corps of Engineers dedicated a team to help with this task and set up operations just a few curves down the mountain road from the Mi Gente grocery.

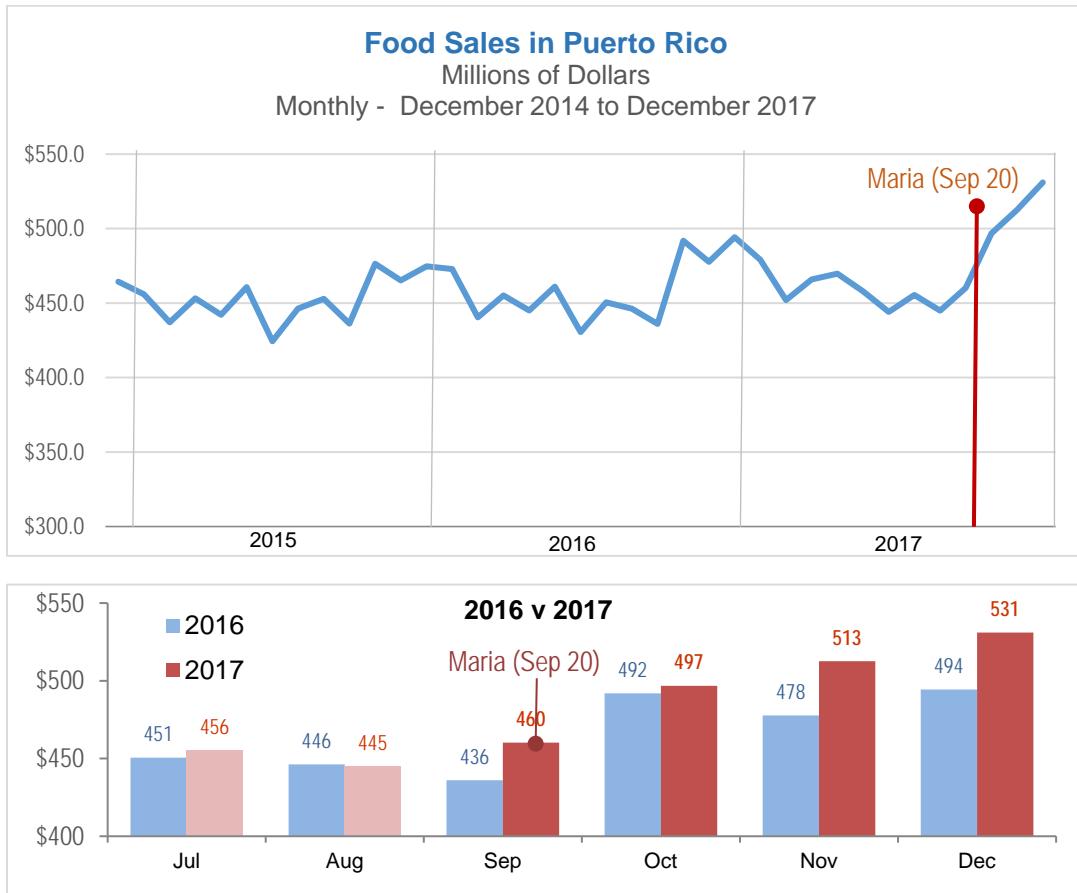
At the JFO in San Juan, any indication of private sector recovery was welcome news. But mostly they heard about impediments. There was very little strategic sense that one month after landfall, the Puerto Rican grocery supply chain was about 90 percent recovered and, by volume-sold, was operating at well above pre-storm throughputs. The government-to-government pull and push of the relief channel does not necessarily reflect the pull and push of preexisting—or recovering—demand and supply chains. Often the two networks are separate and parallel. Occasionally they collide.

THREE MONTHS AFTER LANDFALL: A FUNCTIONAL SYSTEM ENGAGING DEEP UNCERTAINTY

Puerto Rico has experienced negative or flat economic growth since 2005. [34] Puerto Rico's population had declined by roughly 10 percent in the 14 years *before Hurricane Maria*. [35] Relocation to the mainland and elsewhere has continued. [36] Given this context, for the last decade many broad measures of economic activity have tended to produce a sense of *déjà vu*. For example, total retail food sales for July 2008 were \$454.8 million. In July 2017, retail food sales were \$455.5 million. [7] There are seasonal and monthly variations. As in the remainder of the United States, retail sales are usually highest in November and December. For Calendar Year 2016, the strongest grocery retail results were in December, with \$494.2 million.

Before 2017's stormy September—do not forget Irma—comparative food sales were just slightly stronger than in 2016. Then, in the aftermath of two hurricanes, grocery sales surged [7] (See Figure CS1-1). December 2017 food sales were the strongest month since December 2009. This commercial pull and push was happening despite most of the grid still being out and the rest unreliable, even with challenges sourcing product, various distribution bottlenecks, much higher unemployment, the impact of fuel purchases on consumer disposable income, and tons of free food flowing.

Figure CS1-1. Monthly food sales in Puerto Rico spiked after Maria. Overall trend (top), and 2016 versus 2017 monthly comparison (bottom).



Source: CNA, Government Development Bank of Puerto Rico (2017) [7]

The retail fuel sector experienced similar results: August: \$857 million; September: \$856.5 million; October: \$912.7 million; November: \$838.2 million; December: \$967.8 million. [7] December sales for the retail fuel sector were the best in three years, even with historically low pump prices. Consumer confidence in the Puerto Rican fuel sector was so strong that in early November, the Commonwealth stopped providing regular updates on fuel supplies. [37] No one was worried anymore.

Despite its own very strong sales, many in the grocery industry believe even better was possible. “The supply chain was very uneven, rough, unpredictable all through November. We could not get many of the products we wanted or the volume we needed,” Jose Perales

reports. "Too often our customers were buying what we had to sell, not what they wanted to buy."

"I could not get vessel space for goods I regularly bring from the mainland," Angel Vazquez explained. "FEMA food and more had higher priority. So, we (B. Fernandez) increased buying from Mexico and Europe where I could surge flow with much more confidence. Because we regularly buy and sell many international products, it was easier for us than others to diversify our inventory mix."

"We also lost up to 10 percent of our trucking capacity," the President of B. Fernandez reports. "Several independent truckers went to work moving relief supplies. To fill the gap and increase volume, we helped a small trucking company purchase eight pre-owned trucks. In exchange he hired drivers and guaranteed long-term service to B. Fernandez and our customers."

"Consumer uncertainty was so high that I perceive almost everyone was ready to buy almost anything until sometime in mid-December. There were just too many signals of ongoing disruption. But once the water aisles in the grocery stores were regularly restocked, the market finally began to calm down. Lots and lots of water in the aisles was the signal shoppers finally found to be reassuring," Vazquez suggests.

Many wholesalers report the available flow of products from the mainland has remained well-below pre-hurricane levels even into the new hurricane season. "It is still difficult for us to get products. Before Maria, we had inventory for 14 to 20 days, but now only 7 or 8," Ricky Castro, owner of Castro Cash & Carry told the *El Nuevo Dia* newspaper. [38] The newspaper reporter adds, "Demand has skyrocketed and is higher than the capacity of the ships... the struggle to find vessel space is shared with dozens in the construction and other industries."

Problems persist. Preparedness for the new hurricane season is weakened. But it is also worth recognizing that even with all the disruption, the grocery supply chain delivered many more calories in the fourth quarter of 2017 (and since) than it has at any time in the last decade (even when there were many more customers).

Ana had shouted, "*Sistema! Sistema! Sistema!*" The cashier at the small grocery store on a mountain in central Puerto Rico shouted, "The system! The system! The system! We are once again connected to the system." Then she danced.

Ana does not know many of the technical details. But she does understand consumer behavior signaled through that data link pulls supplies to the mountaintop. Until that critical connection was fixed, the Mi Gente was excluded from the system of demand and supply. Outside that system, expressing demand and receiving supplies is difficult and probably not

sustainable given current structures. Once that connection was healed, the Mi Gente store and its customers were also on the mend.

A big part of the “system” in Puerto Rico is [Evertec](#). When Osnet reconnected the Ralph’s in Yabucoa, every PAN transaction and most other bankcard transactions were processed by Evertec. Same story when Jesse, Steve, and the Focused Mission team reconnected their baker’s dozen of grocery stores. Evertec was Ana’s ghostly dancing partner.

Here is how Evertec describes itself [39]:

Our broad suite of services spans the entire transaction processing value chain and includes a range of front-end customer-facing solutions such as the electronic capture and authorization of transactions at the point-of-sale, as well as back-end support services such as the clearing and settlement of transactions and account reconciliation for card issuers.

These include: (i) merchant acquiring services, which enable point of sales (“POS”) and e-commerce merchants to accept and process electronic methods of payment such as debit, credit, prepaid and electronic benefit transfer (“EBT”) cards; (ii) payment processing services, which enable financial institutions and other issuers to manage, support and facilitate the processing for credit, debit, prepaid, automated teller machines (“ATM”) and EBT card programs; and (iii) business process management solutions, which provide “mission-critical” technology solutions such as core bank processing, as well as IT outsourcing and cash management services to financial institutions, corporations and governments.

We provide these services through scalable, end-to-end technology platforms that we manage and operate in-house and that generates significant operating efficiencies that enable us to maximize profitability.

While Puerto Rican grocery and fuel sales increased in the fourth quarter of 2017, most other retail sectors saw a significant decline in volume. This was reflected in Evertec’s performance. “Total revenue for the quarter ended December 31, 2017 was \$99.6 million, a decrease of 2 percent compared to \$101.9 million in the prior year. The decrease in the quarter was driven primarily by the impact of reduced volumes caused by the significant hurricanes in the third quarter of 2017 partially offset by the acquisition of PayGroup.” [40]

On May 2, 2018 Evertec reported: “Total revenue for the quarter ended March 31, 2018 was \$110.3 million, an increase of 9 percent compared to \$101.3 million in the prior year. Revenue growth in the quarter reflected the impact of the acquisition of PayGroup as well as elevated sales volumes in Puerto Rico driven by post-hurricane recovery activity, federal relief and benefit programs and insurance proceeds. [41]

Data from Evertec gave Department of the Family what it needed to work with Jesse and Steve to identify grocery stores that had historically been major PAN transaction sites but

were still dark in the aftermath of Maria. That's where the satellite-in-the-box installations were targeted.

Evertec data was also indirectly being used at the JFO. Shortly after landfall, the JFO established a Business Emergency Operations Center. There was no preexisting structure, but a full-blown private-public function quickly emerged. Early on, FEMA developed a Food Availability Index to help assess specific status in each one of the 78 municipalities. The index consisted of the following information:

- Each community's Social Vulnerability Index
- Percent of people pre-storm using PAN Cards
- Whether or not PAN transactions are currently being made.
- How people accessed food prior to Maria
- How many gas stations were open?
- How often are they refueled?
- How many grocery stores are open?
- Do the grocery stores have refrigeration?
- Are the grocery stores on grid or generator?
- If on generator, how often are they refueled?
- How often are the grocery stores resupplied?

"Because the Federal Coordinating Officer was concerned about the amount of funding being spent on food, and because we did not want a false dependency on FEMA supplied food, and because we wanted to support the private sector in Puerto Rico, we created this "Food Acquisition Index" to determine how much and where food needed to go on the island. Prior to this, FEMA was operating under pressures from the media, political pressure, and the requests from the government of Puerto Rico—all at the detriment of the private sector," said Rob Glenn, FEMA's Director of Private Sector. He added, "FEMA was able to have fact-based conversations with the mayors to discuss the decision to stop sending FEMA food into their municipalities. Having this data-driven knowledge was incredibly helpful."

By statute and policy, FEMA's relief channel responds to pull as expressed by state and local governments. Strategy and operations have been organized around this government-to-government pull. FEMA logistics and NORCOM and other federal players want to push as much as they can as quickly as they can to fulfill this pull. A previous FEMA Administrator is often quoted as crystalizing this strategy as, "Go Big, Go Fast." The full quote is actually, "Go Big. Go Early. Go Fast. Be Smart." [42]

The Food Availability Index is an example of trying to be smart by moving beyond government-to-government pull to understand what is happening in the whole community,

the real economy, the preexisting and—hopefully—recovering or effectively adapting demand and supply network.

PRELIMINARY ANALYSIS – TOWARD UNDERSTANDING SUPPLY CHAINS

In the midst of enormous and persisting challenges, water, food, and fuel supply chains in Puerto Rico demonstrated considerable—some might say amazing—resilience. The speed, scope, and scale of both recovery and adaptation meant that within four weeks of landfall, over 90 percent of residents were fulfilling fundamental needs through the strategic capacity of preexisting systems.

There was, however, no systematic process by which municipal, commonwealth, or federal authorities could be confident of this recovery and adaptation—or accurately map where and when the recovery and adaptation was not happening—or strategically target public sector interventions to facilitate recovery and adaptation.

Instead, federal, commonwealth, and local authorities focused primarily on deploying an effective relief channel for mass feeding and other direct assistance to all survivors. As a matter of statute, policy, and strategy, this relief channel assumed the failure or near-failure of the preexisting demand and supply chain. The relief channel was organized to replace, not to supplement or gap-fill preexisting strategic capacity. It did not have—and probably cannot have—this replacement capacity; fortunately this capacity was not needed. The relief channel did deliver vital water, food, and other assistance to hundreds of thousands of Puerto Ricans.

In contrast with contemporary demand and supply networks—Ana's *Sistema*—the relief channel is a “push” function that only vaguely perceives consumer or system pull signals. The receiving government is the source of pull for the relief channel. Often, the receiving government does not know the capacity, capabilities, or status of preexisting supply chains. On September 25, 2017, when the request for six million meals per day was generated, very little was moving in Puerto Rico. But within three days of that request, commercial movements surged. Within three weeks, the transformation of preexisting demand and supply chains was dramatic. But these changes are—especially in the fog of crisis—not always obvious. As a result, the predetermined relief channel push continued, regardless of its effective response to human needs or network effects.

FEMA professionals who had served or are serving in Puerto Rico—many of whom are military veterans—occasionally say something like, “We are doing a messy job of saturation bombing when we need more effective precision targeting.” The Food Availability Index was the most consumer-oriented aspect of the relief channel, and it was applied more to reduce or

stop push, rather than decide where, when, and what to push. Some FEMA professionals—and others—are, in retrospect, especially concerned that the energy and attention given to “saturation bombing” could have been much better applied to filling other needs where there was insufficient preexisting strategic capacity. Blue roofs, satellite communications, and fuel racks are often mentioned as examples.

Rapid assessment teams are deployed to impact zones. But their mission is often less to assess the status of preexisting supply chains and much more often to determine where and how to direct the relief channel. There could be a process by which the relief channel is guided to where preexisting networks have failed. There could also be a process by which the relief channel extends support to restoring key elements of the preexisting network.

In Puerto Rico—as in any extreme event—several bottlenecks were created or amplified. Post-Maria, the capacity and capability to push groceries recovered quickly. The capability to pull groceries with the PAN card (and other bank cards) was mostly lost. Once this bottleneck was recognized, several comparatively quick and inexpensive solutions were deployable. But the relief channel did not seem able to recognize—or respond to—this strategic opportunity.

In Puerto Rico—as in many prior disasters—fuel distribution emerged as a fundamental problem to be solved. As a matter of statute, policy, strategy, and operations, the “fuel mission” has mostly been defined as fuel for the relief channel. Significant efforts are made to avoid complicating commercial recovery. But little attention is given to helping preexisting fuel distribution capacity or capabilities recover or adapt. Again and again, long lines of fuel tankers form around the racks rather than making their deliveries. Can this recurring pattern be effectively understood and operationally engaged?

How can the relief channel⁶ develop sensing capabilities that would allow it to track and target where the preexisting supply chain’s strategic capacity has failed or is failing? Is there a role for local, commonwealth, and federal authorities to gap-fill and reinforce the pull and push capabilities of preexisting strategic capacity? Rather than behaving only as a relief channel, can the public sector role be reconceived to be more of a strategic adaptation function?

The experience in Puerto Rico suggests that this non-traditional role could be a crucial capability-multiplier for serving dense populations surviving an especially hard-hit and an extended period of failed critical infrastructure. Puerto Rico has demonstrated several strategic soft spots where non-recovery of preexisting capacity was experienced or

⁶ See Case Study 2 for a much more complete examination of the relief channel in Puerto Rico.

threatened. Electronic data transfer, trucks and truckers, and fuel distribution were especially threatening. Are these—and other—threats particular to post-Maria Puerto Rico or systemic? Based on the outcomes of Harvey, Irma, and other large-scale disasters, there is evidence to suggest systemic implications.

Contemporary demand and supply networks are complex, adaptive systems and, in many ways, common-pool resources. [43] There are large numbers of stakeholders. No one is in charge and, in a typical meaning of the word, no one can be in charge. But there are opportunities for shared understanding, strategic intention, and operational influence.

Monitoring Flows, Applying Filters, and Choosing Targets

How is shared understanding cultivated? How is strategic intention formulated? How could operational influence be exercised?

Because the situation after Hurricane Maria in Puerto Rico is an especially extreme event, it is potentially an especially helpful case study. Vulnerabilities, dependencies, and interdependencies that can remain obscure in less extreme contexts are much more obvious in Puerto Rico.

This case study—focusing mostly on food and fuel in post-Maria Puerto Rico—is only one of many potential angles of analysis. But based on multiple experiences in Puerto Rico, and after Irma in the Caribbean and Florida, and after Harvey in Texas and Louisiana, and informed by many prior events, CNA research teams believe it would be helpful for every jurisdictional level and major stakeholder to have the following:

An accurate (and regularly updated) strategic understanding of the volume of pull and push for water, food, and fuel being delivered by the private, pre-existing (i.e., not relief channel) demand and supply networks. This would necessarily involve the role of transportation and workforce components across these elements. We are calling this **flow**.

An ability to recognize significant changes in flow and the source of such changes. There are preexisting data and information resources. There are key players who can report these changes. There are observable outcomes that could be combined to provide this strategic insight. We are calling these **filters**.

A practical ability, cultural predisposition, and legal authority to target actions that would maximize flow of water, food, and fuel to support survivors of a catastrophic event by facilitating restoration of private supply chains and strategic capacity and gap-filling where flow from preexisting strategic capacity cannot be restored or is insufficient to fundamental human needs. A strategically informed process of choosing **targets** is most likely to ensure those in need are served and that preexisting strategic capacity effectively recovers or adapts.

Flows, filters, and targets would considerably enhance whole-of-nation readiness for New Madrid, Cascadia, or San Andreas events.⁷ In each of these crises—or when a CAT-5 hits Miami, a pandemic swirls, or in a host of catastrophic contexts—having a strategic grasp of flows, filters, and targets will allow the system to maximize surviving capacity and capabilities. We do not have this ability today.

A powerful destructive force hit what was essentially the entire *sistema* serving Puerto Rico. A dense population dependent on distant supplies and interdependent technologies survived to face months of grid unavailability, system unreliability, recurring network-disruption, and—as of late June 2018—a new hurricane season. It was—and remains—a precarious situation.

There are good reasons to argue that the situation in Memphis is at least as precarious in the aftermath of a New Madrid seismic event. There are reasons to argue that the situation is even more precarious for the Puget Sound region in the aftermath of a Cascadia event. In each of these and many other densely populated places, there is not a current readiness to perceive changes in demand and supply, recognize the implications of such changes for near-term population health (or long-term economic recovery), and take effective strategic action.

Even now, with the results of post-Maria Puerto Rico fresh in our minds, there is a tendency for preexisting concepts and procedures to reassert their authority. Especially with the urgency of the crisis now superseded, there is a tendency to focus on what can be controlled and to increase the resources under control, even if—maybe especially because—we just went through an experience where catastrophic risk was mostly outside our control and supply networks surged in ways we barely understood.

While the accumulating evidence from Harvey, Irma, Maria, and more suggests there is good cause to be skeptical of prospects for control, there are plenty of opportunities for enhanced understanding. The CNA research team especially recommends the following lines of inquiry:

Is it possible to accurately characterize the complex, dynamic, interdependent network of demand and supply on which dense populations depend? Can this characterization practically inform the conception, preparation, and implementation of effective system-supporting—even system-amplifying—strategies? Based on our recent research related to Harvey, Irma, and Maria, we perceive this is possible, but specifying and building such a characterization is non-trivial.

⁷ Three catastrophic earthquake scenarios in Missouri, the Pacific Northwest, and California, respectively that the emergency management community is preparing for with exercises and simulations.

While engaging the first question, **who or what are the most valuable indicators of network fitness and output?** Are there recurring categories of vulnerability, failure, or constraints that can be identified in advance for specific attention and potential mitigation? Based on our recent research, we believe there is particular potential in identifying the persistence or loss of consumer “pull” and the current status of distribution or “push” for water, food, and fuel. Other network elements should be engaged, but these two aspects of pull and push seem especially promising.

To the extent these first two lines of inquiry have authentic strategic value in serving human needs in catastrophic contexts, **what statutory, policy, doctrinal, fiscal, and strategic shifts are needed to incorporate and implement the implications of flows and filters?** What is needed to do effective targeting? Potentially even more difficult, are there cultural predispositions within the emergency management profession or more broadly within the public-private domain that must be changed to make real progress?

This case study was developed by the Institute for Public Research at CNA, a not-for-profit research organization that serves the public interest by providing in-depth analysis and result-oriented solutions to help government leaders choose the best course of action in setting policy and managing operations.

Additional case studies related to issues of Supply Chain Resilience emerging from the 2017 Hurricane Season are available at: www.cna.org/supplychainresilience

CASE STUDY 1 APPENDIX: MAPS AND FIGURES

Figure CS1-1. Area map of Puerto Rico with Key locations labeled, and inset of the Bayamon Food Corridor.

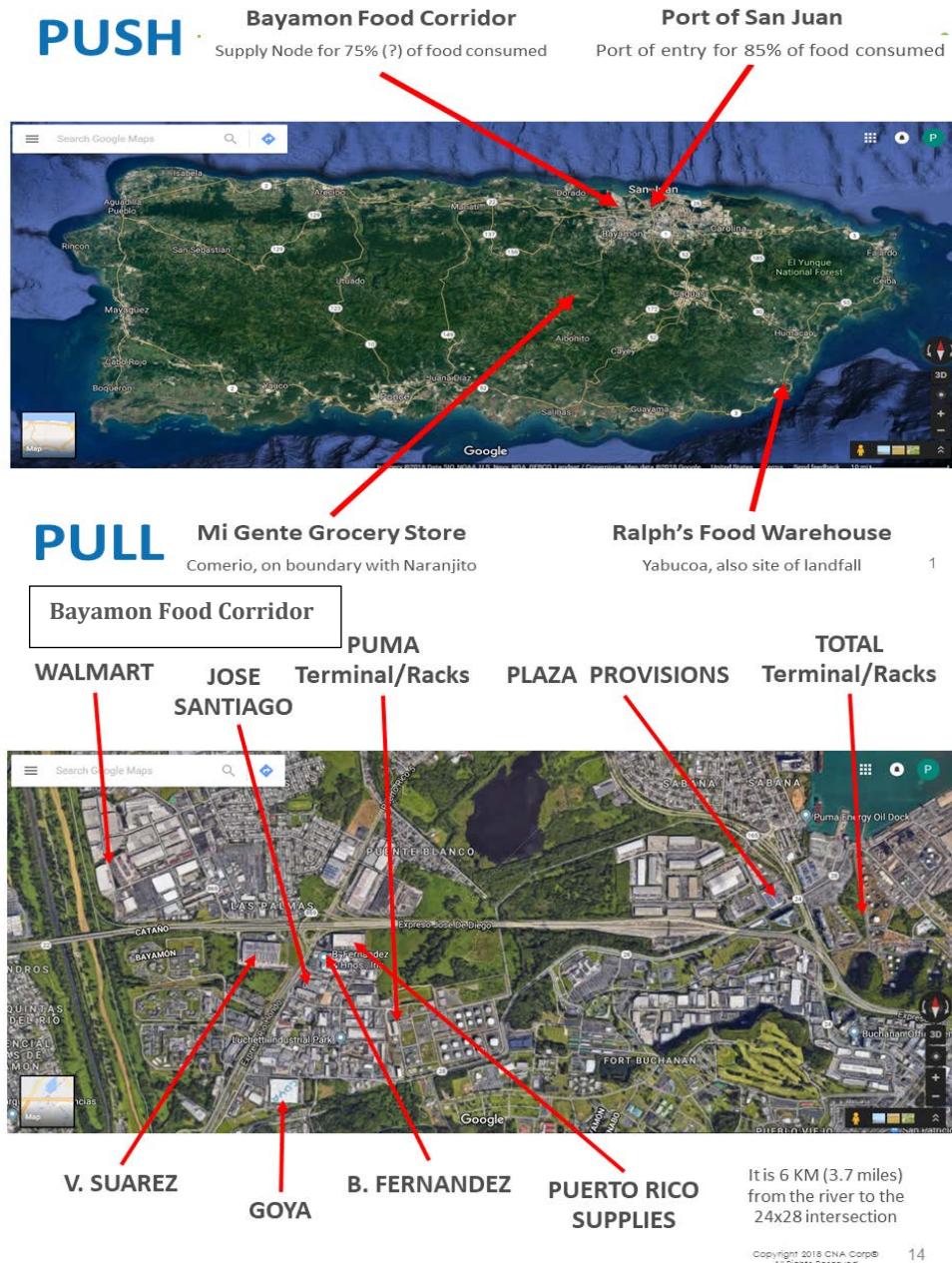


Figure CS1-2. Total retail food sales in Puerto Rico, 2009 – 2017, in million \$.

PUERTO RICO ECONOMIC INDICATORS		GOVERNMENT DEVELOPMENT BANK									
Retail Sales	Food Stores (million \$)	Economic Analysis Division									
FISCAL YEAR *		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
JULY		454.8	488.9	513.5	447.1	453.5	435.0	444.6	446.3	450.5	455.5
AUGUST		437.2	470.0	513.9	440.5	456.5	436.5	456.7	452.9	446.2	444.9
SEPTEMBER		446.4	460.3	489.7	414.8	442.1	426.7	434.4	436.2	436.0	460.2
OCTOBER		468.8	469.5	481.0	427.3	442.6	431.9	464.0	476.4	491.9	496.8
NOVEMBER		485.7	491.8	482.2	437.6	428.0	439.3	450.7	465.2	477.7	512.6
DECEMBER		522.0	536.1	512.9	466.5	462.3	455.6	464.4	474.7	494.2	531.0
JANUARY		466.4	455.7	432.1	444.1	434.9	441.3	455.9	472.9	479.1	
FEBRUARY		458.7	443.7	435.7	431.4	426.8	426.5	437.1	440.4	452.0	
MARCH		472.8	467.5	454.9	451.7	444.7	458.7	453.2	455.1	465.9	
APRIL		460.8	483.0	440.7	452.6	431.6	438.8	442.1	445.0	469.7	
MAY		475.2	493.9	441.0	409.0	439.6	445.4	460.7	461.0	457.9	
JUNE		462.7	483.9	429.9	445.3	429.6	431.1	424.4	430.5	444.1	

Source: Government Development Bank of Puerto Rico [7]

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