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Evaluating the Impacts of Hurricane Maria on the Residential Construction Industry in Puerto Rico and the Effectiveness of Reconstruction Efforts

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ABSTRACT

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In September of 2017, Hurricane Irma and Hurricane Maria, both category 5 hurricanes, swept across the Caribbean, including the U.S. Territory island of Puerto Rico. These two storms, particularly Hurricane Maria, caused catastrophic damages from high winds and flooding to the island paradise. This research investigates the direct effects that Hurricane Maria had on the residential construction industry within Puerto Rico and evaluates how to better prioritize and manage these types of efforts in the future. This research was initiated to identify challenges and opportunities that have been encountered within the Puerto Rican construction industry during the first year of reconstruction, post-Hurricane Maria. Residential structures that were built using current building codes experienced minimal storm damage. Many of the damaged residential structures, on the other hand, were made up of informal construction, predominantly using light wood framing methods. Unfortunately, homes built using informal construction practices were not insured nor eligible for government rebuilding assistance. Therefore, these damaged structures will more than likely be rebuilt using informal building practices again. Other immediate challenges faced by the construction industry included finding skilled labor and creating access to resources. The results of this research can be used to help prioritize reconstruction efforts and provide best practices following other similar disasters that will inevitably occur in the future. This research is unique in that it specifically targets the construction industry's experience and ultimately the ability to increase the effectiveness of the critical role the construction industry plays in rebuilding efforts.

Keywords: disaster reconstruction, Hurricane Maria, Puerto Rico, residential construction

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1 INTRODUCTION

1.1 Overview of Research

In September 2017, Hurricane Maria formed in the Atlantic Ocean and swept across the Caribbean, including the U.S. Territory island of Puerto Rico, as a category 5 hurricane. The hurricane's path passed directly over the island of Puerto Rico causing massive, widespread destruction across the island. The island had already been hit by another devastating storm, Hurricane Irma, just two weeks prior, weakening structures and infrastructure and thus magnifying the damaging effects of Maria. Hurricane Maria is regarded as the worst natural disaster on record to affect Puerto Rico, with total losses from the hurricane estimated at over $90 billion (USD) (NCEI, 2020). Catastrophic damage from high winds and flooding occurred to homes, businesses, and critical infrastructure, including an already weakened electrical grid that had been severely damaged by Hurricane Irma. Much of the informal residential construction (a project built without formal architectural / engineered plans or without permits) was destroyed, leaving thousands of people homeless in the aftermath of the storm. The entire island was without power and cellular phone service. The highway system across the island was impassable due to major flooding that destroyed roadways and overpasses, and from fallen and scattered debris from the hurricane force winds. A major humanitarian crisis ensued due to a lack of emergency resources and a slow relief process.

There were several significant inefficiencies and challenges reported during the initial rebuilding efforts in Puerto Rico following Hurricane Maria. This research investigates the direct effects that Hurricane Maria had on the residential construction industry within Puerto Rico and evaluates how to better prioritize and manage these types of efforts in the future. One major assumption typically made in post-disaster environments is that the construction industry can simply jump in and begin rebuilding homes. However, there are certainly many challenges faced by the construction industry to effectively put the pieces back together in a disaster reconstruction environment.

This research was initiated to identify challenges and opportunities that have been encountered within the Puerto Rican construction industry during the first year of reconstruction, post-Hurricane Maria. It is anticipated that the construction industry encountered challenges with scheduling, labor, material resources, payment structures (including disaster relief and insurance funding), general day-to-day business practices, and other similar challenges. Additionally, there is tremendous potential for low quality reconstruction and lack of building code enforcement, which in turn leads to future negative consequences. The results of this research can be used to help prioritize reconstruction efforts and provide best practices following other similar disasters that will inevitably occur in the future. This research is unique in that it specifically targets the construction industry's experience. This research looks at the critical role the construction industry plays in the effectiveness of rebuilding efforts. This research focuses primarily on residential reconstruction efforts on the Island of Puerto Rico approximately one year after the hurricane hit the island. This research was performed in conjunction with another research thesis targeting Hurricane Maria's effects on the commercial and heavy civil construction industry in Puerto Rico.

1.2 Purpose of the Research

The purpose of this research was to collect data that would help identify challenges and opportunities associated with residential construction/reconstruction efforts approximately 1 year after Hurricane Maria made landfall in Puerto Rico. The data was gathered through a combined two-part approach: first, interviews were conducted with people and/or organizations directly affected by the hurricane; and second, data was gathered through first-hand observation of one-year post disaster reconstruction circumstances, efforts, and outstanding needs.

As a construction professional for over 20 years, I have worked in the South and Intermountain West areas of the United States. During my career, I have built over 640,000 square feet of residential and light commercial structures. After learning of the devastation to homes and buildings in Puerto Rico, my interest was piqued to understand why the destruction was so catastrophic. With the assistance of Doctor Clifton Farnsworth, a construction management professor at Brigham Young University, we implemented a plan to travel to Puerto Rico approximately 1 year after Hurricane Maria made landfall on the island to see firsthand some of the damages and to learn how the construction industry was playing a role in the rebuilding efforts of the island. Our hope was to gather information about construction processes, methods, and deficiencies to gain a better understanding of why there was so much destruction, particularly in residential construction.

1.3 Research Approach

This research was deliberately timed to correspond with exploring how the reconstruction efforts were proceeding approximately one year after the storm devastated the island. The reasoning for that approach was to allow time for critical infrastructure to be back in place and

hope that some sense of normal / routine life was moving forward again. This included talking to different stakeholders (e.g., construction companies, architects / engineers, and homeowners) to determine how the construction industry had been affected by the rebuilding efforts taking place on the island after the devastation.

This research included several objectives. First, we wanted to find out what processes were utilized for rebuilding, i.e., clearing road access, ensuring people had the basics of life including food, water, and secure shelter, and rebuilding their homes, etc. Second, we were interested in current opportunities and challenges that could be identified at the one-year mark. In other words, what was going well, and where could improvements be made. Third, it was important to learn how the residential construction industry had been affected by the hurricane, and just as important to determine the outlook for the industry moving away from more immediate response and transitioning into more long-term reconstruction efforts. Fourth, this research helps bridge the perspectives of different stakeholders and explore the connections with the residential construction industry.

1.4 Limitations

Our visit to Puerto Rico spanned 12 days. While we were able to collect valuable data, we were limited to what we could accomplish in that time frame with no opportunity to return for data relating to progress over the year after that visit. We conducted many interviews with residents and authorities in Puerto Rico through prescheduled appointments and spontaneous interview requests with those we contacted along the way including both business owners and homeowners. Many of the one-on-one impromptu interviews did not allow for follow up interviews. Because of the magnitude of the damage, it was known that this research would not

"solve" any specific problems associated with the rebuilding effort. However, it was anticipated that this research would play an important role in helping define the opportunities and challenges faced by the residential construction industry, and ultimately allow for further research opportunities. Therefore, this research also included the exploration of other areas for future research rather than determining definite conclusions. Still, it was hoped that the results of this research would help bridge the perspectives of different stakeholders and explore the connections with the residential construction industry.

1.5 Definitions of Terms

Informal Construction - Construction method that includes building a structure without architectural / engineered plans or building without a building permit. In Puerto Rico, most informal construction utilizes light wood framed construction.

FEMA Blue Tarps - Temporary (blue colored) plastic tarp distributed by the Federal Emergency Management Association to temporarily cover and protect homes due to damages caused by the hurricane to a structure's roof system.

Residential Construction - Construction method for the common purpose of building a residence / home for people to occupy. In Puerto Rico this means homes that are typically less than 3 stories in height.

Reinforced Concrete Home - A structure made of grout-filled CMU blocks and reinforcing steel. These walls are typically plastered. Although not true reinforced concrete, these structures are typically referred to as such in Puerto Rico.

2 LITERATURE REVIEW

2.1 Overview

An important element within any research project is the literature review. The purpose of the literature review is to define the problem being explored and to demonstrate the boundaries of knowledge regarding the problem. There are three principal objectives in this literature review. First, describe Hurricanes Irma and Maria and the associated damage. Second, explore the federal and local response. Third, identify the impacts to the residential construction sector and their response for disaster reconstruction.

2.2 2017 Hurricanes in Puerto Rico

2.2.1 Hurricane Irma

The best source of information defining Hurricane Irma and associated damage is from the official Hurricane Irma Tropical Cyclone Report (Cangialosi et al., 2018). The following information was taken from this report.

On September 6, 2017, the eye of Hurricane Irma (a category 5 hurricane) tracked about 50 nautical miles north of the northern shore of Puerto Rico. The eye of Hurricane Irma did not make landfall on Puerto Rico, but sustained winds of 48 knots and wind gusts of 64 knots were recorded on the island. Irma caused lowland flooding on the island. Although Puerto Rico did not experience a direct hit from Hurricane Irma, rainfall totals between 10 and 15 inches

occurred over high elevations over the central portion of the island, causing many areas of the island to be saturated. The heavy rains and tropical storm force winds caused widespread power outages and minor damage to homes and businesses. Weak (informal) structures on the island collapsed and many trees were uprooted. A near-total loss of electricity and the water supply for several days also occurred because of Hurricane Irma. Hurricane Irma left Puerto Rico in a weakened state with only two weeks to recover before another massive hurricane made landfall on the island (Cangialosi et al., 2018).

2.2.2 Hurricane Maria

The best source for information defining Hurricane Maria and associated damage is from the official Hurricane Maria Tropical Cyclone Report (Pasch et al., 2019). The following information was taken from this report.

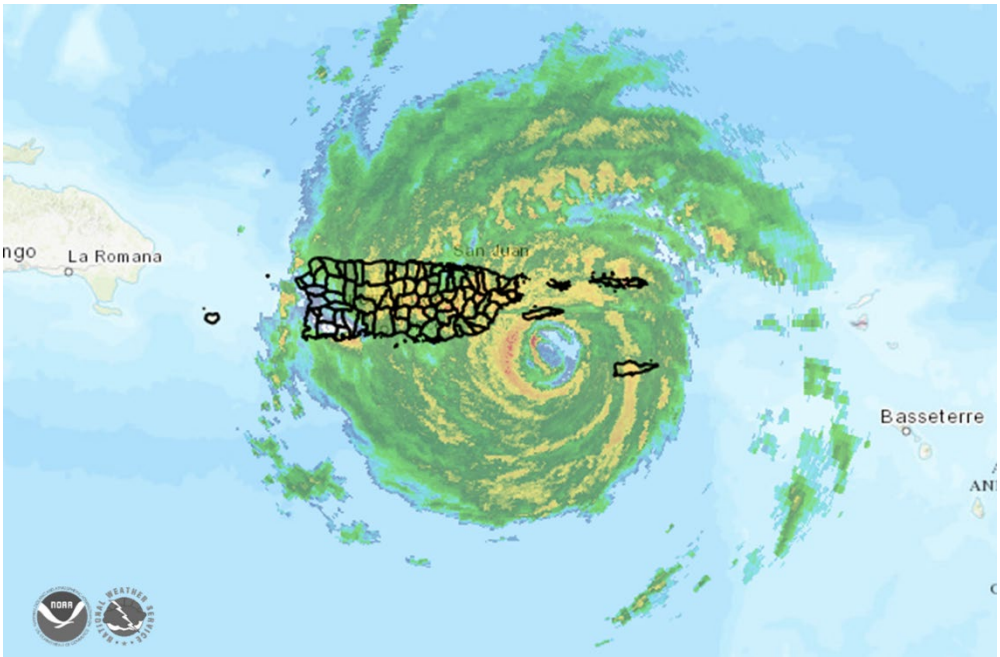

Figure 2-1: Hurricane Maria centered on Puerto Rico (from NWS, 2017).

On September 20, 2017, Hurricane Maria, (a massive category 5 hurricane) which had formed in the Gulf of Mexico made direct landfall in Puerto Rico. Maria originated from a well-defined tropical wave that departed the west coast of Africa on September 12, 2017. The system moved westward over the tropical Atlantic for the next few days. By September 15th, showers and thunderstorms increased and began to show signs of organization, with some curved cloud bands developing. Deep convection then quickly became more consolidated and better organized, and it is estimated that a tropical depression formed about 580 miles east of Barbados. Figure 2-1 shows the path of the hurricane centered over Puerto Rico (NWS, 2017).

Moving westward the cyclone strengthened into a tropical storm on September 16th. Maria turned toward the west-northwest shortly thereafter, and quickly intensified into a hurricane on the 17th of September. While situated in an environment of warm sea surface temperatures and light vertical shear, the hurricane strengthened rapidly. Maria became a major hurricane by September 18, and just 12 hours later it neared Dominica and became a category 5 hurricane with maximum winds of 145 knots (Pasch et al, 2019).

After striking Dominica, Maria continued moving to the northeastern Caribbean Sea. Slight weakening had occurred due to the system's interaction with the mountainous island of Dominica, but the hurricane soon regained intensity and strengthened to its peak on the 20th of September while centered about 25 miles south of St. Croix. Maria moved northwestward toward Puerto Rico and after reaching maximum intensity, underwent an eyewall replacement with an outer eyewall becoming more dominant by the time the center of the system reached Puerto Rico. Maria's center crossed the southeast coast of Puerto Rico near Yabucoa September 20th, and the hurricane's maximum winds at that time were just below the threshold of category

5 intensity. The hurricane's center crossed the island, somewhat diagonally from southeast to northwest, for several hours while slowly emerging into the Atlantic (Pasch et al., 2019).

Figure 2-2: Typical structural damage from Hurricane Maria (from Pasch et al., 2019).

Puerto Rico was devastated by winds and floods. Figure 2-2 and Figure 2-3 show the typical aftermath to residential structures caused by wind damage and flooding, respectively. The government estimate of damage in Puerto Rico and the U.S. Virgin Islands due to Maria is 90 billion dollars, which makes Maria the third costliest hurricane in U.S. history, behind Katrina in 2005 and Harvey in 2017 (NCEI, 2020). The combined effect of the surge and tide produced maximum inundation levels of 6 to 9 ft above ground level to the north of Maria's landfall along the coasts of Humacao, Naguabo, and Ceiba municipalities in Puerto Rico. The destructive power of storm surge and wave action from Maria produced extensive damage to buildings, homes, and roads along the east and southeast coast of Puerto Rico. Along these areas, marinas

and harbors were severely damaged due to the combination of the waves and currents associated with the surge. Across the island, many buildings suffered significant damage or were destroyed. Numerous trees were downed, splintered, and/or defoliated. River flooding was unprecedented in some areas, especially in the northern portion of the island. The La Plata River flooded the entire alluvial valley including the municipality of Toa Baja, where hundreds of families needed to be rescued from their roof tops.

Figure 2-3: Flooding & structural damage from Hurricane Maria (from Pasch et al., 2019).

Maria knocked down 80 percent of Puerto Rico's utility poles and all transmission lines, resulting in the loss of power to essentially all the island's 3.4 million residents. Practically all cell phone service was lost, and municipal water supplies were knocked out. At of the end of 2017, nearly half of Puerto Rico's residents were still without power; however, by the end of January 2018, electricity had been restored to about 65% of the island (Pasch et al., 2019).

It has been determined that Hurricane Maria, a category 4 storm when it made landfall, has been the worst natural disaster on record in Puerto Rico. The storm caused catastrophic damage and a record number of fatalities across the Caribbean. Hurricane Maria came just two weeks after Hurricane Irma, which had already delivered a devastating impact upon St. John and St. Thomas (Prevatt et al., 2018).

Puerto Rico had not experienced a storm of Maria's magnitude or intensity in over 80 years (Masters, 2017). Maria's strong winds were accompanied by heavy rainfall, the second highest on record for a tropical cyclone in Puerto Rico. With over 80% of river gauges reporting flood stage levels, flooding and landslides were prevalent, especially in west-central Puerto Rico. (NWS, 2017). The official death toll was initially set at 64 direct deaths associated with the hurricane (Sanchez, 2018), but with indirect deaths the estimate is as high as 2,975 (Sanchez, 2018; Milken Institute, 2018).

On a trip to the island in December 2017, Randy Noel, who served as that year's chairman of the board for the National Association of Home Builders (NAHB), was particularly struck by what he saw in the community of Toa Baja, which sustained 11 feet of floodwaters during Maria. He noticed every structure built of wood was ruined, while the structures built of concrete were standing, though most had suffered roof and window damage (Croce, 2018). The exact numbers from Maria's damage have varied. Emilio Colón Zavala, president of the Puerto Rico Builders Association, said the devastating storm significantly damaged 250,000 housing units, including 35,000 that were completely destroyed (Croce, 2018). Brown (2018) indicated that the damage may have been even more extensive and widespread than what others had reported, with more than 400,000 houses in need of reconstruction and repairs, representing some level of damage to a third of the 1.2 million houses on the island.

Despite the damage, Puerto Rico has adopted some of the most stringent building codes in the U.S., but its housing stock was still vulnerable when Maria swept ashore. According to Zavala, 55% of the island's housing stock was built "informally," meaning without the proper permits and not to the island's building codes, which stipulate that structures must be able to withstand wind speeds of at least 145 mph. (Croce, 2018). Zavala indicated "homes that were built according to the existing building code were significantly less damaged than the ones that were built noncompliant to code." Zavala further cited a statistic from the Federal Emergency Management Agency that stated 98% of the homes it assessed after Maria which were built to any code sustained little to no structural damage (Croce, 2018). Gary Ehrlich, a senior program manager of structural codes and standards at the NAHB, says that since 2000 when the first editions of the International Building Code and International Residential Code were published, structures built to more modern codes have fared much better than those "built to some legacy codes or not constructed to a building code at all" (Croce 2018). In the United States, roughly 60% of communities have a building code in place, Ehrlich said, and the ones that do not are typically in rural areas that lack the resources to enforce one (Croce, 2018). It is reasonably clear from the literature review that the problem with the massive hurricane damage to residential structures did not stem from inadequate building codes, but rather a lack of regulation and enforcement of those codes.

When Hurricane Maria devastated Puerto Rico, the disaster quickly became a humanitarian crisis causing the official reconstruction process to become difficult to navigate and inaccessible to many property owners (Talbot et al., 2019). Nearly a year after the hurricane hit it was reported that only 40% of Federal Emergency Management Agency (FEMA) financial assistance applications had been approved and 80% of appeal cases were still pending or had

already been denied (Acevedo, 2018). A number of studies have predicted that the residential structural damage will have a significant long-term effect upon the population of the island. The Center for Puerto Rican Studies, based at New York's Hunter College, estimates that Puerto Rico may lose up to 470,000 residents, or 14% of the population, within the first two years after the hurricane. Jennifer Hinojosa, research associate and data center coordinator for the organization, estimates that between 114,000 and 213,000 Puerto Rico residents will leave the island annually for the first two years in Maria's aftermath (Croce, 2018).

2.3 Federal and Local Responses

The 2017 Atlantic Hurricane Season was one of the most active seasons in U.S. History. In the three weeks between August 25th and September 20th, hurricanes Harvey, Irma, and Maria made landfall in quick succession. These hurricanes were followed by devastating wildfires in California. It was a highly active natural disaster year. Collectively, hurricanes Harvey, Irma, and Maria caused $265 billion in damages (NCEI, 2020) and were each individually among the top five costliest hurricanes on record (see Figure 2-4).

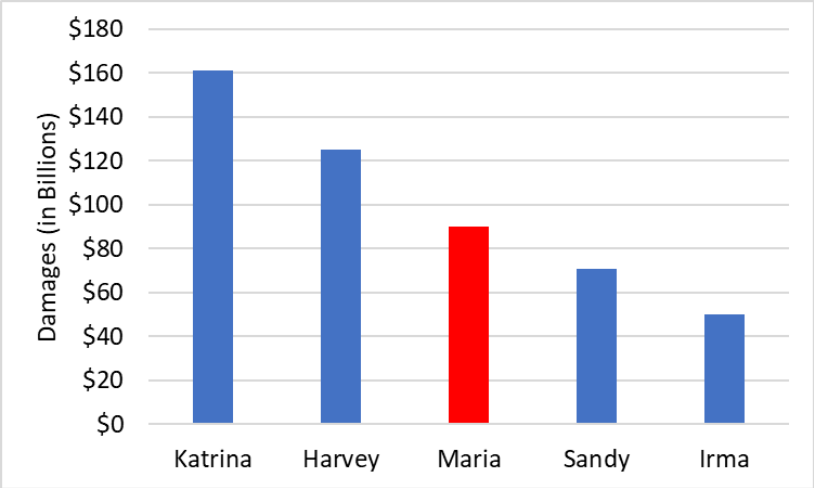

Figure 2-4: Hurricane Maria is among the top costliest US storms (after NCEI, 2020).

On the 25th August, Hurricane Harvey made landfall in Texas as a category 4 storm and stalled over the Houston area for several days and set a record for the most rainfall from a U.S. tropical cyclone. Twelve days later, on September 6th, Hurricane Irma became one of the strongest Atlantic hurricanes on record. The center of the storm passed just north of the U.S. Virgin Islands and Puerto Rico. Hurricane Irma was the first major hurricane to make landfall in Florida since 2005.

On September 20th, just fourteen days later, Hurricane Maria made landfall in Puerto Rico as a category 4 storm. Maria was the first category 4 storm to make landfall on Puerto Rico in 85 years. Following the storm, every airport and seaport in Puerto Rico was closed and even after reopening had limited capacity for approximately seven days post-landfall due to restrictions. Less than 12 percent of the territory's population had access to cell phone service in the aftermath of the storm. Most of the main island's power grid was down until November 17th (nearly two months, with outages continuing through May 2018) which left Puerto Rico's 3.7 million residents without electricity.

FEMA had an overly busy year in 2017. Hurricanes Harvey, Irma, and Maria affected 28 million people in Texas, Florida, US Virgin Islands, and Puerto Rico. In 2017, FEMA supported 59 major disaster declarations and 16 emergency declarations. By April 30th, 2018, FEMA had obligated $21.2 billion towards the impact of these hurricanes, including disaster assistance to survivors and the affected communities. The planning assumptions for a hurricane, earthquake, or tsunami striking Puerto Rico underestimated the actual needs in 2017. This required FEMA to depend on crisis action planning during the incident to address the shortfalls in the planning assumptions. Figure 2-5 shows that for the percent of population impacted, cellular service

impacted, power outages, hospitals impacted, and search and rescue needs where the planned response significantly underestimated the actual effects of the hurricanes.

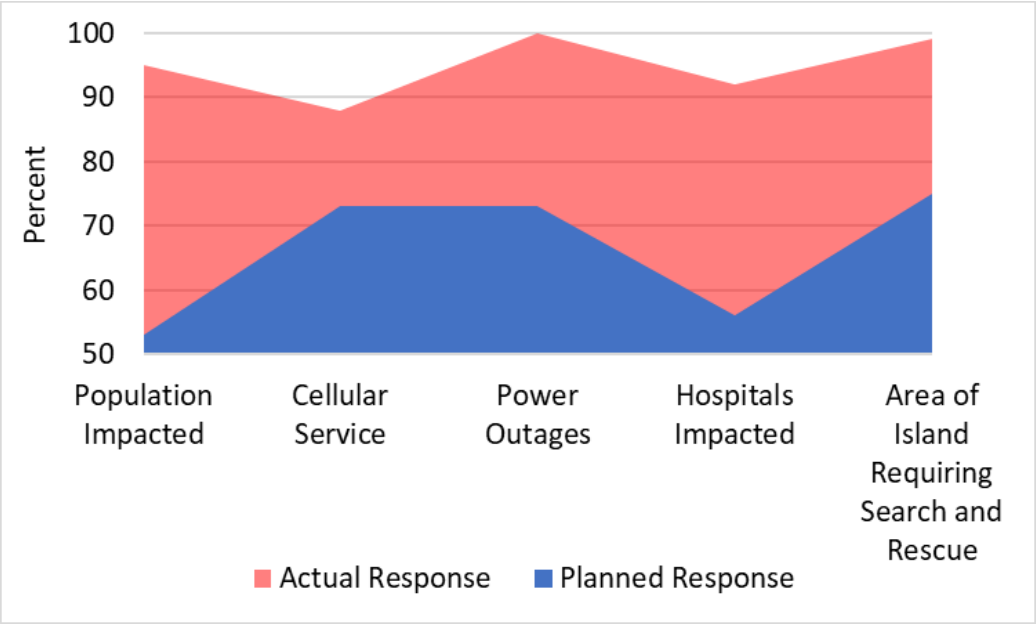

Figure 2-5: Underestimated planning assumptions for FEMA needs for 2017 hurricanes (after FEMA, 2018).

The FEMA disaster planning assumptions did not plan for unmaintained infrastructure (e.g., the electrical grid and transmission power lines) or address the financial liquidity challenges facing the territorial government. The devastating impacts experienced across the infrastructure sectors, compounded by deferred maintenance issues, severely complicated the private sector's ability to return to normal life. FEMA did not anticipate the massive requirements to directly assist electricity, telecommunications, and fuel sector utilities with air and sea movement. Additionally, in Puerto Rico the fiscal pressures limited investments and maintenance in critical infrastructure, including the electrical system, and decreased funding for emergency management. When Hurricane Maria hit Puerto Rico, the territory was $74 billion in

debt and its economy had contracted nearly 15 percent during the previous 10 years. The island was in a recession (FEMA 2018).

The FEMA after action report also concluded that with the severity of three concurrent major hurricanes it required FEMA to deploy a high number of staff to each affected area. FEMA leadership recognized early on with the unprecedented demands for staff to support the widescale response efforts, in addition to other existing response and recovery operations for other disasters, the need would exceed the agency's planned capabilities (FEMA 2018).

Many media outlets and local Puerto Rican government officials were critical of FEMA stating that the organization was not assisting sufficiently and was leaving many people destitute on the island. Even though FEMA had a major catastrophe plan in place, the sheer magnitude of three major hurricanes overwhelmed their capacity. Many resources were already in play when Hurricane Maria struck Puerto Rico. It then took FEMA longer to get supplies and personnel to assist in the aftermath of Maria as compared to Harvey and Irma.

FEMA partners supplied commodities via ground transportation to areas impacted by Hurricanes Harvey and Irma, but the responses to Puerto Rico introduced the complexity of supporting a logistics supply chain that stretched outside the U.S. mainland. Hurricane Maria caused extensive damage to island seaports, airports, and roads. These factors also limited the island's ability to receive commodity shipments immediately after the Hurricane. FEMA maintained a stockpile of commodities at the Caribbean Distribution Center warehouse in Puerto Rico to facilitate a quick response to incidents in both Puerto Rico and the U.S. Virgin Islands, but in response to needs from Hurricane IRMA, FEMA distributed more than 80 percent of its inventory for selected commodities from the Caribbean Distribution Center warehouse. Table 2-

1 shows a summary of the supplies used in response to Hurricane Irma. Unfortunately, Hurricane Maria struck before the supplies were replenished (FEMA 2018).

Table 2-1: Supplies used in Puerto Rico after Hurricane Irma (After FEMA, 2017).

Commodity	On 9/1/17	On 9/15/17	% Change
Water (liters)	718,370	69,300	▼ 90%
Meals	250,572	97,632	▼ 61%
Cots	4,422	0	▼ 100%
Medical Kits	8	6	▼ 25%
Tarps	13,272	0	▼ 100%
Blue Roof Sheeting	15,344	180	▼ 99%

Given the unprecedented resource needs of consecutive response operations, FEMA not only exhausted commodities on hand but also exhausted pre-negotiated contracts to provide meals, tarps, water, and other resources during the responses to hurricanes Harvey and Irma. The ensuing response for Hurricane Maria required FEMA to rapidly solicit vendors outside its pre-negotiated contracts to satisfy resource and program needs (FEMA, 2017). After reviewing the planning and adjustment methods of FEMA during the 2017 Hurricane Season, the critical media response was unjustified and was likely politically motivated.

There are likely many factors as to why the federal response differed. Access was much more limited on the island of Puerto Rico as opposed to the mainland states. Power grid issues were so much greater on the island of Puerto Rico (due to maintenance neglect) and resources were limited due to its remote location (Willison, et al., 2019). It seems evident that the response times were different at critical times and the delays experienced in Puerto Rico only added to the devastating effects of the hurricane. One of the first appropriations of federal money in the history of the USA was for disaster aid relief, emphasizing the critical importance of the federal

government's responsibility to aid its citizens in the case of natural disasters (Willison et al., 2019). The research results show that the federal response was quicker and more generous with money and staffing to Hurricanes Harvey and Irma in Texas and Florida, likely because those storms landed first, compared with Hurricane Maria in Puerto Rico. Hurricanes Harvey and Irma made landfall as category 4 hurricanes, and Maria hit Puerto Rico as a 'high-end' category 4, or just below the threshold of a category 5 hurricane (Willison et al., 2019). Because of this, Maria caused more damage in Puerto Rico than Irma in Florida or Harvey in Texas in terms of loss of electricity and housing destruction, with overall damage estimates comparable to Harvey, and greater than estimates for Irma. Assuming that infrastructure costs are higher in Texas and Florida compared with Puerto Rico, the high damage estimates in Puerto Rico emphasize the severity of storm damage. We also assume that disaster responses should reflect the needs due to the degree of damages and need of the population. (Willison et al., 2019).

2.4 Residential Disaster Reconstruction

Maria caused extensive damages in almost every aspect of the infrastructure and the natural and human-built environments. Cruzado (2018) presented an overview of the damages to the energy infrastructure, highway signs, traffic signals, luminaires, steel roofs, wood and concrete homes, multistory buildings, and bridges. Two case studies were presented: a highway sign, for which estimates of wind speed based on backward calculations were presented, and a reinforced concrete roof that was damaged by wind loads. The authors of this study recommended increasing the design wind speed for the Puerto Rico Building Code (Cruzado et al., 2018). They based this conclusion on poorly built structures made mostly of wood and corrugated metal that could not withstand the gale winds of Hurricane Maria. Roofs were simply ripped from structures. Most of the wood structured homes that had been built were not

designed by engineers, therefore not designed to withstand the hurricane force winds. On the other hand, reinforced concrete homes generally withstood the storm well. Cruzado et al. (2018) further concluded that implementing minimum requirements for building as well as inspections would be beneficial in creating structures that will better withstand climate events.

Although the government estimate for Hurricane Maria damage is $90 Billion (NCEI, 2020), others have estimated the damage higher ranging from between $94 Billion (Llorens-Velez, 2017) to $102 Billion (Masters, 2017). The storm knocked out power to all of Puerto Rico and destroyed communication services and weather monitoring systems (Cruzado et al., 2018). Cost estimates for the actual damage associated with only residential structures is more difficult to ascertain. However, the literature is relatively clear on where the damage occurred within the residential sector. For the most part, reinforced concrete homes withstood hurricane winds quite well. Damages that occurred to reinforced concrete homes did not tend to affect the structural integrity of the home. Rather, minor damage was common with non-structural elements such as windows and doors, or from water damage where leaking occurred. Although most of the reinforced concrete structures resisted the hurricane wind loads, several reinforced concrete houses and buildings suffered extensive damage from landslides and developed scouring of soil in the foundation area (Cruzado et al., 2018). Further, most multistory buildings on the island are predominantly made of reinforced concrete. There were not any multistory structures that collapsed due to hurricane winds, although they were noted to sustain other non-structural related damages (e.g., doors, windows, parapets, etc.) (Cruzado and Pacheco-Crosetti, 2018).

The most widespread damage to residential structures occurred to informally built wood framed structures that were not designed or built to withstand the hurricane force winds. For generations in Puerto Rico, informal home construction has been more the rule than the

exception, especially in towns and rural areas outside of San Juan. This is one reason why Hurricane Maria caused such widespread and calamitous destruction as it tore across the entire island (Viglucci, 2018). The island's building codes are equal to Florida's windstorm rules, at least on paper. But enforcement is wildly uneven, say industry insiders. It is estimated that as much as half of the housing on the island was built without permits, according to Puerto Rico government officials. No one knows precisely how much of that there is, but the government's housing secretary Fernando Gil stated there could be as many illegally built structures as the roughly one million legal dwellings on the island (Viglucci, 2018). Other estimates of informally built houses present on the island before Hurricane Maria range from 260,000 to 700,000 homes – which constitutes 60% of total homes on the island (Brown, 2018; Florido, 2018; Suarez, 2018). After the hurricanes, 1.1 million Puerto Rican households requested help from FEMA, and approximately 58% were denied. Among those who appealed, 75% were rejected again. The median grant given to repair homes in Puerto Rico was $1,800 (Robles and Patel, 2018).

Housing units considered 'informal' (or 'illegal construction') are a more common method of construction in rural communities; where residents often sell or inherit properties through informal agreements, subdivide land without completing the title process, occupy government owned land to build homes, or build a house without completing the construction permitting process. Informal housing reconstruction is defined in this research as design and construction by community members to establish permanent features of housing without following formal construction procedures or codes (Talbot et al., 2019). The informal construction often comes in the form of family providing sweat equity, building without inspections, or reusing scrap material. Repairing or rebuilding illegally erected dwellings to meet building codes is difficult,

if not nearly impossible. Many such homes are located in flood zones or unstable hillsides where rules may not allow rebuilding (Viglucci, 2018).

Many informally built communities originated in invasions of public or private land by squatters — often abetted by local politicians and grandfathered in after the fact — residents often had no title to their lots, which meant FEMA could not pay for repairs, though it could help them relocate (Viglucci, 2018). Because of the extremely large number of informally built homes, many Puerto Rican residents were unable to receive the necessary resources for repairs and reconstruction due to the stringent, but necessary, regulations on housing aid eligibility and formal disaster recovery programs. Therefore, many residents resorted back to some sort of informal construction methods to reconstruct their houses, relying on their own efforts and resources for reconstruction, often through the help of local community and family relationships. This process of rebuilding through self and community supported efforts is known is social capital (Talbot et al., 2019). Social capital represents the features of social organizations such as relationships, networks and trust which bring a wide range of benefits including coordination and cooperation (Portes, 2000). These resources are essential in the immediate aftermath of a disaster as it allows communities to mobilize which ultimately facilitates survival, improves access, and creates empowerment in a community (Aldrich, 2015; Nakagawa and Shaw, 2004).

Most residents whose homes were damaged are not willing to wait, perhaps for years, for government help. Many began rebuilding soon after the storm, salvaging materials or buying inexpensive plywood and zinc at the hardware store to "slap" homes back together, relying strictly on social capital. Most poor Puerto Ricans are unlikely to pay architects or engineers to draw up plans or absorb the costs of permits or better building materials required to meet code (Viglucci, 2018). Previous research suggests that social capital increased access to resources and

the reconstruction process (Aldrich, 2015). However, because this form of social capital appeared to also continue to perpetuate the cycle of informal construction, there is still more to learn from an area like Puerto Rico which experienced extensive devastation and has a historical lack of residential construction code enforcement (Talbot et al., 2019).

A critical challenge in disaster recovery is to address short term needs quickly, with the foresight of avoiding the creation of new or worsening existing long-term social needs that can contribute to a community's future disaster vulnerability (Finucane et al., 2020). In studies of disasters and disaster risk reduction, vulnerability is commonly defined as "a measure of the propensity of an object, area, individual, group, community, country, or other entity to incur the consequences of a hazard" (Coppola, 2015). Often, the urgent, short-term pressures during the aftermath of disaster recovery result in the longer-term vulnerability reduction being overlooked as a fundamental block of the recovery process (Finucane et al., 2020). Principles of disaster risk reduction and management emphasize that post-disaster recovery and development need to be informed by effective resilience building and community engagement and empowerment strategies (Finucane, 2020). In other words, there should be more emphasis placed on rebuilding with resiliency in mind.

A group of journalists from the New York Times visited Puerto Rico around the same timeframe as the research team from Brigham Young University visited the island. The Times journalists visited 163 homes in two neighborhoods in Punta Santiago to document the progress that had been made after 12 months since Hurricane Maria made landfall. They observed a community with signs of fresh paint and, in some of the middle-class parts of town, rebuilt rooms and new furniture. But in neighborhoods where the residents live on small pensions and disability benefits, there were still gutted kitchens and electrical wiring running randomly along

unfinished walls. Roofs were covered still with plywood or plastic, appearing to perhaps collapse at any moment. Some homes still had no running water. Several families lived in single rooms in unfurnished houses, sleeping on the floor (Robles and Patel, 2018). Figure 2-6 shows the widespread number of homes in a poor neighborhood still covered with "temporary" blue tarps multiple years after the hurricanes hit Puerto Rico. This suggests that many of the issues discussed in this literature review continue to hamper reconstruction efforts within the residential sector.

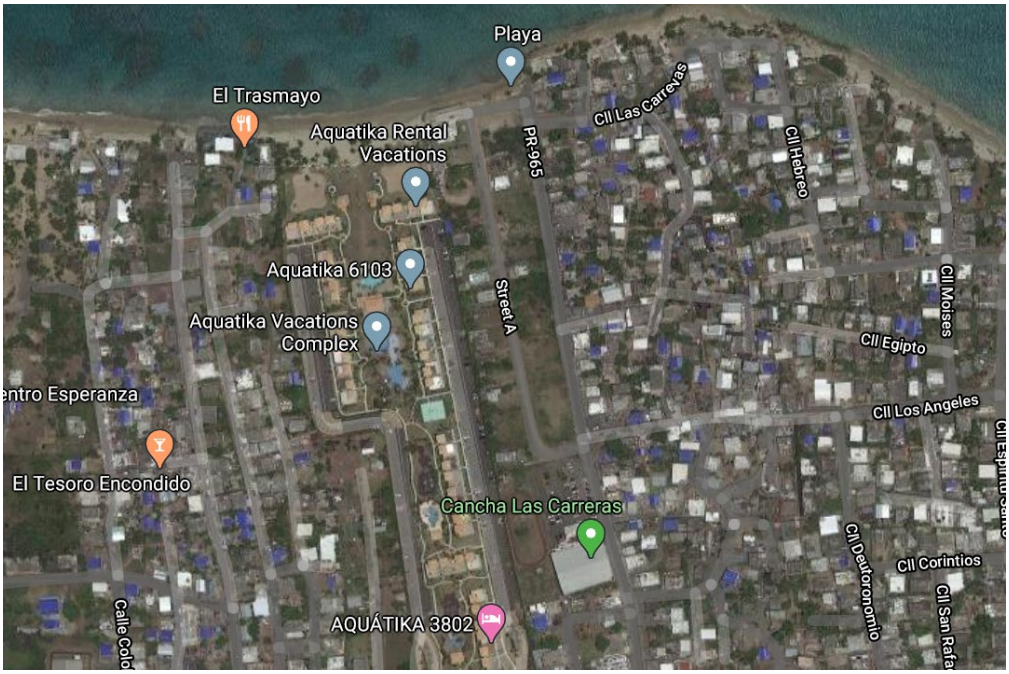

Figure 2-6: Aerial view of Loiza, Puerto Rico, 2020 (from Google, 2020).

2.5 Summary

In summary, this literature review has shown that the larger gap is not in understanding that damage occurred to residential structures. The damaging effects of Hurricane Irma and Maria on homes in Puerto Rico and the challenges associated with rebuilding are well

established. Rather, the larger gap appears to be a disconnect between residential homeowner's reconstruction needs and their expectation of government assistance, local government decision makers and pre-storm readiness efforts, and the reconstruction demands placed on the residential construction industry. The intention of this thesis is to explore the challenges and opportunities that have been encountered within the Puerto Rican residential construction industry, especially at the interface with the various stakeholders (i.e., homeowners, government officials, and the residential construction industry itself). There is little direct information in the literature on how the residential construction industry has been affected by the hurricanes, and this research was established to explore the construction industry's role in the reconstruction efforts.

3 METHODOLOGY

3.1 Introduction

The purpose of this research was to collect data that would help us identify residential construction/reconstruction approximately 1 year after Hurricane Maria made landfall in Puerto Rico. The data was gathered through a combined two part-approach. The principal form of data gathering was performed by conducting interviews with people and/or organizations directly affected by the hurricane. The secondary form of data gathering was through first-hand observation of one-year post disaster reconstruction circumstances, efforts, and needs.

In this research we wanted to find out what processes were utilized for rebuilding efforts associated with residential construction (e.g., clearing road access, ensuring people had food and water - basics of life, secure shelter - safe places for people to live, and rebuilding roads, infrastructure, homes, etc.). We were also interested in learning about current deficiencies at the one-year mark. Finally, we were also curious to observe the outlook of the residential construction industry following Hurricane Maria.

Our plan was to review how the reconstruction process was proceeding approximately a year after the storm devastated the island. The reasoning for that approach was to allow time for critical infrastructure to be back in place and hope that some sense of normal / routine life was moving forward again. Our plans were to talk to construction companies and individual

homeowners to see how the construction industry had been affected by the rebuilding efforts taking place on the island after the devastation.

3.2 Qualitative Research Approach

This research followed a qualitative approach, meaning the data gathered stemmed from personal perspective, experiences, and observations of those living in Puerto Rico during and after Hurricane Maria. Qualitative research takes into account case studies, personal experiences, cultural matters, interviews, and artifacts. It may also include historical text. As a field of study, qualitative approaches include research concepts and methods from multiple established academic fields (Drisko, 2016).

Qualitative methods are best for researching many of the why and how questions of human experience, in making a decision for example (not just what, where, when, or "who"), and tend to have a strong basis in the field of sociology to understand government and social programs (Given, 2008). Qualitative research is widely used by political science, social work, and education researchers (Alasuutari, 2010).

The data gathered for this research was predominantly qualitative because it included open-ended questions, allowing for free response during the interviews. This project was based on two different qualitative research approaches: case study and phenomenology research. A case study involves an in-depth exploration of an event, a process, or an individual (Creswell, 2009). Cases are bound by activity or a timeline. Case research includes detailed information gathered using varied procedures during a given period of time (Creswell, 2009). This research fits the case study criteria due to the event of the hurricane and the timeline of the one-year mark.

The research included several interviews which spoke to the human experience both during and following the event.

Phenomenology research approach involves gathering information via verbal descriptions based on the individual's perception of an event (Marques and McCall, 2005). It may include elements and underlying factors that make up their experiences. This research is gained through in-depth interviews, which we conducted with local construction professionals, local government authorities, and local residents.

3.3 Survey Instrument

This research was done utilizing a cross-sectional survey. A cross-sectional survey collects data to make inferences about a population of interest at one point in time. Cross-sectional surveys have been described as snapshots of the populations about which they gather data (Given, 20008). Using this method of research allowed us to include a snapshot of personal experiences and current conditions a year after Hurricane Maria. The surveys were conducted using a semi-structured format (Bricki and Green, 2007). This semi-structured format allowed for a set of questions with the option to expound based on information given during the interview. Questions were open ended to chase important developments that occurred during the interview process.

It was anticipated that the research would yield better results if interviews were conducted face-to-face. This also gave the flexibility of conducting interviews in either Spanish or English. There were two principles that helped guide whether we conducted the interview in Spanish or English. First, is the interviewee comfortable speaking English? Second, if conducted in English, we considered whether interviewee could effectively communicate in

English with fluency. If not, we converted the interview over to Spanish. The research team was comprised of two bilingual individuals: one graduate student comfortable with everyday Puerto Rican Spanish; the other was also fluent in Spanish, but more comfortable with technical construction and engineering Spanish terminology because of job experience.

The following baseline questions were developed for this research. These questions were developed specifically for the construction industry. The approach for interviewing local government officials and homeowners while on the island was to ask them to share "their story" of the rebuilding process with the research team. These latter interviews began with the research team explaining the purpose of the research and then guiding the interview with directed questions as the interview developed. The contractor questions were also pre-translated into Spanish to ensure that both options were prepared as needed. The general idea of the questioning was targeted toward learning how construction practices and processes had changed due to Hurricane Maria. The baseline contractor questions are shown below.

3.3.1 Baseline Interview Questions - English

1. What types of reconstruction work has your company been involved with since Hurricane Maria?

2. How does this type of construction work compare to projects you were performing before Hurricane Maria?

3. What are the biggest opportunities that your company has had since Hurricane Maria?

4. What are the biggest challenges that your company has faced since Hurricane Maria?

5. What factors have hindered the progress of your reconstruction efforts? What are the bottlenecks in the reconstruction process?

6. How has your company's bidding practices changed over the past year? How has competition been affected?

7. What adaptations to your general business practices has your company made following Hurricane Maria?

8. How has your ability to procure labor and materials for your projects been affected by Hurricane Maria? How have you dealt with these challenges?

9. How has your scheduling process been affected over the past year?

10. How has your estimating process been affected over the past year?

11. What type of project delivery has been used for reconstruction projects? Has this process changed over the past year? If so, how?

12. How have the permitting, plan approval, and inspection processes been affected by Hurricane Maria?

13. If you could go back, what would you do differently regarding your company's efforts following Hurricane Maria?

14. What are some of the biggest lessons your company has learned about performing disaster reconstruction?

15. What recommendations do you have regarding making disaster reconstruction more effective for the construction industry?

3.3.2 Baseline Interview Questions - Spanish

1. ¿En qué clase de trabajos de reconstrucción ha participado su empresa desde el huracán María?

2. ¿Cómo se compara este tipo de trabajo con los proyectos que realizaba antes del huracán María?

3. ¿Cuáles son algunas de las mayores oportunidades que su compañía ha tenido desde el huracán María?

4. ¿Cuáles son algunas de los mayores desafíos que su empresa ha enfrentado desde el huracán María?

5. ¿Qué factores han obstaculizado el progreso de sus esfuerzos de reconstrucción? ¿Cuáles han sido los desafíos en el proceso de reconstrucción?

6. ¿Cómo han cambiado las prácticas de licitación de su compañía durante el año pasado? ¿Cómo se ha visto afectada la competencia?

7. ¿Qué adaptaciones a sus prácticas comerciales generales ha hecho su compañía después del huracán María?

8. ¿De qué manera el huracán María ha afectado su capacidad para obtener mano de obra y materiales para sus proyectos? ¿Cómo has lidiado con estos desafíos?

9. ¿Cómo se ha afectado su proceso de programación de horarios durante el año pasado?

10. ¿Cómo se ha visto afectado su proceso de estimación durante el año pasado?

11. ¿Qué tipo de entrega del proyecto se ha utilizado para proyectos de reconstrucción? ¿Este proceso ha cambiado durante el año pasado? ¿Si es así, cómo?

12. ¿Cómo se han visto afectados los procesos de permisos, aprobación de planos e inspección por el huracán María?

13. ¿Si pudiera hacerlo de nuevo, qué haría diferente en relación con los esfuerzos de su compañía después del huracán María?

14. ¿Cuáles son las lecciones más importantes que su empresa ha aprendido sobre la reconstrucción de desastres?

15. ¿Qué recomendaciones tiene con respecto a la reconstrucción de desastres para que sea más efectiva en la industria de la construcción?

3.4 IRB Approval

As part of the approval process to perform this research, the research questions were submitted to the BYU IRB (Brigham Young University, Institutional Review Board). Our research team had to ensure that we were compliant with established guidelines for conducting human subjects research. As part of that process we also had to ensure baseline questions were compliant with the necessary approval process. An application was submitted to the IRB in conjunction with the permission process to travel to Puerto Rico. The necessary IRB approvals were given, generally indicating that this research was IRB-exempt, since our research team was predominantly learning about the effects to companies, business practices, and construction rebuilding processes.

Our plan for gaining informed consent was through asking each individual for permission to record and refer to the interview for the purpose of this research. Oral consent was the only requirement and each interviewee was informed of the purpose of our studies and given the opportunity to participate or to decline.

We maintained respect for persons by ensuring the autonomy of participants. Our research team considered any risks an individual might experience by giving an interview. We maintained confidentiality in our qualitative research by avoiding discussion of other interviews previously conducted with future interviewees. Those who gave consent to the interview also agreed to have their name published as needed.

3.5 Sampling

With a limited amount of time allocated to performing interviews while visiting the island, the interview process needed to be as efficient as possible to maximize our time there. Therefore, we created a four-part sampling strategy to maximize our efforts in finding qualified individuals and to create a rich and robust dataset. First, our research included stratified purposeful sampling, which illustrated the characteristics of subgroups and helped create comparison of attitudes regarding their experience (Bricki and Green, 2007). This was a useful approach due to the interviewees having different educational, social, and economic backgrounds, which framed their perspective during this experience regarding residential construction. Second, we took a random sampling approach (Bricki and Green, 2007) to making our initial contacts. We selected construction companies off the AGC roster that were associated with residential construction. We began with companies located in the most populous areas and worked outward from there. Third, during our interviews, we employed the snowball or chain sampling technique (Bricki and Green, 2007). This consisted of asking interviewees for referrals to other likely participants that may add to our research. This was an effective approach as it led to additional contacts not listed on the professional directories. Finally, with limited time, one of our goals was to gather the broad experiences. We followed the general concept of maximum variation sampling. Maximum variation sampling is purposely selecting a wide range of variation on dimensions of interest (Bricki and Green, 2007). By incorporating this practice, we could identify common patterns that cut across the variables.

In general, we interviewed more than just general contractors and those within residential construction such as construction trade partners. Interview participants included homeowners who were rebuilding due to the storm. Lastly, our research covered some of the local

government officials. In a way, this was also a form of a cross-sectional survey. Previously we defined that type of survey as being at a single point in time. It can also be used to describe cutting across a broad group of individuals to get as much diversity in response in order maximize the response across the cross-section of individuals.

Reliability in our research relied on the fact that quantitative research is supported by the positivist or scientific paradigm that regards the world as made up of observable, measurable facts (Cypress, 2017). The more times the findings of a study can be replicated, the more stable or reliable the phenomenon is thought to be (Merriam, 1995). Our interviews with multiple participants in each subset listed above provided reliability in their observations and experiences, and each of those responses showed repetition that helped stabilize the data. Validity is broadly defined as the state of being well grounded or justifiable, relevant, meaningful, logical, conforming to accepted principles or the quality of being sound, just, and well founded. (Merriam-Webster, 2020). Thus, validity in qualitative research means "appropriateness" of the tools, processes, and data (Leung, 2015). All interviews were conducted with individuals with first-hand experience in their assigned category.

As part of our approach of using maximum variations sampling, we conducted interviews with the following three different groups on the island to get a wider perspective:

1. We spoke with individuals not associated with the construction industry, but who had sustained damage or lost their homes due to the hurricane and were working to rebuild their homes.
2. We spoke with companies / persons working / involved in the construction industry to find out how reconstruction efforts were going according to their businesses and how they were affected either positively or negatively regarding Hurricane Maria.

3. We also spoke with leaders of different municipalities to see how the reconstruction efforts were going in their provinces and how they prepared for the storm and the aftermath that followed.

3.6 Data Analysis

Automated data analysis was not an option due to the nature of the open-ended questions in the interview process. Therefore, we relied on manual coding of the data. The general process we used to analyze the data included inductive coding, which meant we sorted all the raw data to develop trends and themes in the construction industry, in the local government, and with the local homeowners. We labeled and organized the data based on the interviewee's category (construction, government, homeowner). Within those subsets, we grouped like-responses together to construct validity and reliability in our research. Once we could identify themes, we compiled that data into research, which we could then present.

4 LESSONS LEARNED – OPPORTUNITIES FOR CHANGE

4.1 Data Collection

In July 2018, a small research team from the BYU construction management program traveled to the Island of Puerto Rico. The research team consisted of Dr. Clifton Farnsworth, construction management professor at BYU, Brad Wells, BYU construction management graduate student and residential construction company owner, and fellow construction management graduate student Timothy Barrett. The purpose of the trip was to identify the progress of the reconstruction efforts on the island following Hurricane Maria. The plan was to review how reconstruction was progressing approximately one year after the storm devastated the island. The reasoning for that approach was to allow time for critical infrastructure to be back in place and hope that some sense of normal / routine life was moving forward again. The team planned to talk to construction companies and individual homeowners to see how the construction industry had been affected by the rebuilding efforts that were taking place on the island after the hurricane devastated the island.

Each day, the research team scheduled interviews with persons and companies that had been contacted via phone call or email correspondence to schedule a time to meet, or spontaneous construction site visits were made and asked for permission to talk to the general contractor and some qualified trade partners. This method was somewhat successful, as many

people wanted to tell their story regarding the struggles of the past year regarding to the hurricane rebuilding efforts.

In the afternoons after scheduled appointments were finished, the research team would travel the island and stop at obvious hurricane-affected areas (quite noticeable by the blue FEMA tarped roofs). The team knocked on doors to ask if the resident would discuss their situation and rebuilding efforts. During the visit to Puerto Rico, the research team did not encounter anyone who did not seem eager to share the experience of their struggles to rebuild including their efforts and the challenges that accompanied them.

Individual interviews were conducted during the time that the research team was in Puerto Rico. Table 4-1 shows a summary of the total number of interviews that were conducted for this research project.

Table 4-1: Interviews conducted in conjunction with this research project.

Category	Type	Number of Interviews
Government	Municipality	3
	FEMA	3
	Government Housing	1
	US Forest Service	1
	GSA	1
Construction Industry	Architects	5
	Residential/Commercial	8
	Civil/Infrastructure	4
	AGC	1
Residential Site Visits	Homeowner	12

Interviews were conducted in the following municipalities (see Figure 4-1): Aguadilla, Arecibo, Barceloneta, Carolina, Fajardo, Guaynabo, Hatillo, Loiza, Mabi, San Juan, San Sebastian, Toa Baja, and Yabucoa. These generally represent where the largest concentrations of

people are as well as the locations that were most impacted by the storm. For the research in this thesis, the key interviews consisted of 3 township mayors and their staff, 5 different architects, 6 engineers, and each of the individual residential site visits that sustained some sort of loss / damage to their home during the storm.

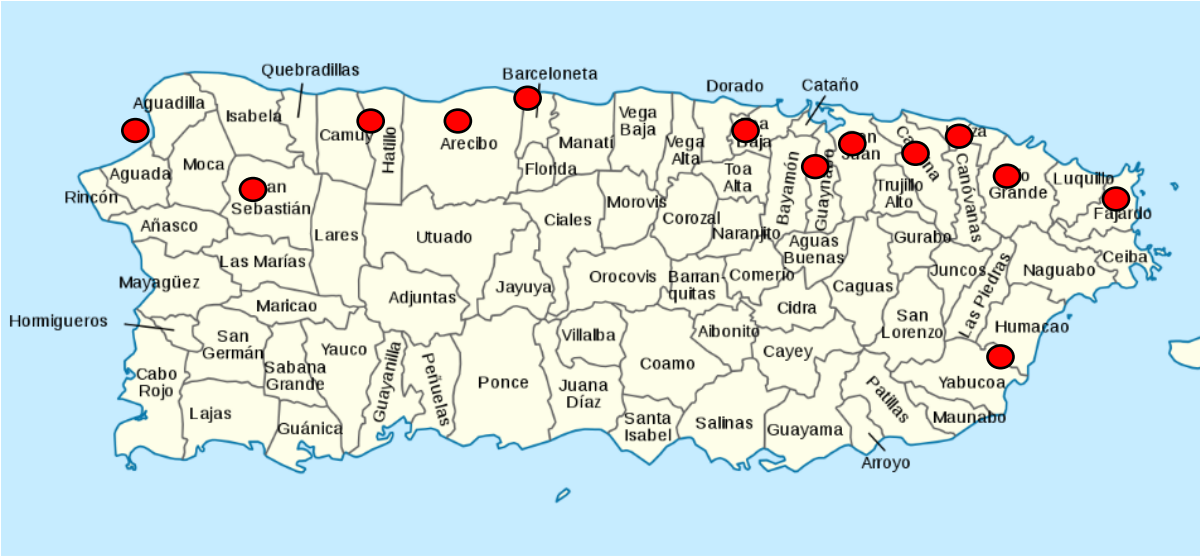

Figure 4-1: Locations where interviews were conducted for this research project (map image from Wikimedia Commons, 2020).

4.2 Meeting with Local Officials

Interviewing independent township leaders about how Hurricane Maria recovery efforts went in their respective communities would give the research team an idea of what construction needs those areas needed. The eastern corner was where the hurricane made landfall and the research team understood there was quite a bit of residential damage there. The other was a mountainous region and the research team had heard that they were one of the first areas to restore power and begin rebuilding and wanted to find out why.

Figure 4-2: Municipalities where government leaders were interviewed (map image from Wikimedia Commons, 2020).

4.2.1 San Sebastian

An interview was set up with the mayor of San Sebastian – a township that was lauded as one of the first to restore power and order to their area. San Sebastian is located in the northwest part of the island.

The leadership of this township felt that if they displayed a positive attitude of being able to rebuild, it would help the public have a sense of hope that everything would be all right in the end. The strong moral and positive attitude of the leadership helped to restore hope in the people of San Sebastian after the devastation of Hurricane Maria. There are over 16,000 homes in the township of San Sebastian. There were 427 houses lost due to the storm and over 2,000 more that needed repairs and restoration due to damages suffered by the storm. The San Sebastian leadership team calculated that because they were in a more remote mountainous area, that more populated areas of the island would likely receive outside assistance before they did. Therefore,

they knew whatever plan they made, it needed to include the possibility that help would not come soon and they needed to prepare to help themselves.

The San Sebastian hurricane task force met in the mayor's office soon after the storm to plan. Their top priority was safety. There was no electricity and the roads were impassible. The following are actions they implemented to assist immediately after the storm:

1st –Local contractors with heavy equipment were hired to remove debris to open the roads so residents would have access to the center of town, which would serve as the main point of assistance.

2nd – A distribution center of food was opened for residents to obtain food for their families.

3rd – Food was taken and distributed to many incapacitated residents of the township who could not travel to distribution centers.

4th – Township workers fixed collapsed roads to obtain access to other stranded areas of the island.

5th – Residents became involved in helping with the rebuilding and recovery efforts.

6th – The township used large generators to get the water system working again even though there still was not electricity. Tanker trucks were also used in areas near the dam to deliver water to residents.

7th – In the central part of the town, twenty washing machines were set up for public use for local residents.

Approximately two weeks after the hurricane destroyed much of the island, the mayor and his team realized that federal help to restore electricity to their township would not happen anytime soon because their township was in a rural, mountainous region of the island. The mayor and his task force found 3 local retired electrical linemen from the AEE (Autoridad de Energía Eléctrica), along with a voluntary team of city employees (many who were electricians) to assist. The city purchased a used power line truck and mobilized the makeshift electrical team to restore electricity to the township of 40,000 people. The new electrical team focused on safety and connecting power one home at a time. The mayor called his electrical team the PPA (Pepino Power Authority) after the nearby Pepino Mountains and started repairing the destroyed and dilapidated electrical lines within the township. Restoring power throughout the township allowed property owners to begin rebuilding.

4.2.2 Fajardo

While in Puerto Rico, an interview was also conducted with the Mayor of Fajardo. The township of Fajardo is located on the eastern side of the island, near the area that the hurricane made landfall.

The mayor of Fajardo had been in office since 1988. He was a very talkative 72-year-old and was eager to discuss his township. The mayor mentioned he was in Puerto Rico when Hurricane Hugo hit in 1989. The biggest difference he saw between Hugo and Maria was the fact that Hugo was not a big enough storm to go over the mountains of the island, but Maria traveled much further. He mentioned that they were blessed to have the US military come in after Hurricane Maria and help deliver fuel. The fuel was needed for the equipment and vehicles used to clear debris after Hurricane Maria. His township is located on the east coast, close to

where Maria made landfall. The mayor of Fajardo set up a task force team to help distribute food after the hurricane had passed.

Part of the mayor of Fajardo's recovery plan to assist residents in the Fajardo township was a method of going house to house to check on the citizens' well-being. Citizens would meet at local churches and baseball fields in the township to get food. They designated a church in each of their areas where food could be distributed. They followed this process with the help of the food bank and FEMA for 6 months.

In order to open up the roads after the storm, the mayor's plan included sending employees home before the storm with township equipment such as dozers and frontend loaders to their respective barrios. After the storm, employees could use the heavy equipment to clear paths and make their way back to the township center. This action opened their local roads to create access to the main parts of the township and island. The mayor's wife was also instrumental in helping with the social aspects of ensuring the citizens of Fajardo felt hope, were cared for, and fed.

According to the mayor of Fajardo, working with FEMA was not a pleasant experience. As of July 2018, the township of Fajardo was still owed 6 million dollars, according to the mayor's office. After a year of working with them, he explained that the estimators and insurance companies were not willing to pay enough to cover individual damages. The Army Core of Engineers was able to do major clean up in general and quickly. The people in the Fajardo township all pitched in during the cleaning up process.

4.2.3 Loiza

The third mayor that the research interviewed was the mayor of Loiza, one of the poorer townships on the island. Loiza has a population of roughly 26,000 people and is considered a low-income area (average annual income is $17,402) (US Census Bureau, 2020). The township had a significant amount of informal/illegal construction that was destroyed by Hurricane Maria and most residents were not eligible for official assistance due to the informal/illegal construction nature of their residences. The research team learned that 85% of the Loiza township is in a major flood zone. In 1988 when Hurricane Hugo hit Puerto Rico, flooding destroyed much of Loiza, and the residents at that time moved away. The poorer social class slowly moved into the deserted township after Hurricane Hugo and began to populate the area once again. A general observation by the research team of the area in July 2018 found that Loiza was still quite despondent. According to the Mayor's office, as of July 2018, over 437 homes still had temporary roofs and the roof of the Loiza city offices was damaged by the storm and still leaked.

During our interview with the mayor of Loiza, she implied that the federal government had not done enough for their township and they were still waiting for someone else to help them. Her attitude was that she was waiting for the federal government to do more for their rebuilding efforts. The mayor estimated it would take more than 5 years to recuperate / rebuild. Her attitude was remarkably different than the other two mayors that the research team interviewed. She had determined that unless the federal government did more for her township, things would most likely not improve. Perhaps if she had a similar attitude and post hurricane plan as the other mayors the research team interviewed, her township would be farther along in

the recovery process than they were at the time of the interview. She might have motivated/inspired the people in Loiza to be more self-reliant.

4.3 Meeting with Local Contractors – Reconstruction Progress

Interviewing local contractors was important to the research team to get a firsthand account of how construction companies reacted and were involved in the rebuilding efforts in Puerto Rico after Hurricane Maria. The goal was to also understand the construction industry both before and after the hurricane. The research team had pre-established a set of baseline questions to ask these research participants, but their experiences were so unique and their responses so broad that a formal summary of the survey results was not applicable. The following summaries are for those interviews that specifically were connected to residential reconstruction efforts.

4.3.1 GW Construction

The research team met with GW Construction, a firm that builds factories, large custom homes, and hotels. During their interview, they explained that from a construction standpoint, they have increased prices due to subcontractor labor price increases and material shortages. They mentioned both were a result of Hurricane Maria. For example, getting windows for their custom home projects required about 12 months lead time as of July 2018, which was more than 3 times as long as the normal lead time before the hurricane. The research team wanted to know how their business was doing one year after the hurricane. GW Construction stated they were seeing more work, had hired more employees, and were experiencing material shortages, but no labor shortage. As of July 2018, their firm had 11 employees, but they constantly had others who would step in if work were offered. Additionally, they stated it took much longer to get

estimates from trade partners and suppliers. GW Construction stated they had a backlog plenty of work and were being paid well because their projects were from private clients and not government bids.

4.3.2 Integra Design Group

Integra Design Group gave the research team the opportunity for an interview. The director of the architecture department was the prime individual present during the interview. Integra is a large design, engineering, and construction firm. They were asked if their business strategy had changed after Hurricane Maria. They explained that immediately following the hurricane their firm changed the focus of how they worked on their projects. One week after the disaster, they were able to return to work. For their clients, Integra immediately implemented a structural assessment, job visits, and a photo documentation program, so they could document the damages caused by the hurricane. Integra's plan to keep their clients' interests as priority number one after Hurricane Maria had paid dividends for future work for Integra. At the approximate year mark after Hurricane Maria, Integra had a good backlog of clients / projects due to their commitment to the customer.

Integra's director of architecture informed the research team that before Hurricane Maria, smaller contractors were not busy, and that the construction industry in Puerto Rico, had been declining for at least 10 years. In July 2018, approximately one year after Hurricane Maria, any contractor who wanted work was busy, especially roofing contractors. The director of architecture mentioned that a major challenge all construction companies were facing after Hurricane Maria was price controls. Costs had dramatically increased after the hurricane. For example, the cost of a CMU (concrete masonry unit) went from $0.60 per block to $1.00 per

block. The director also estimated at least 60% of construction on the island was illegal, or informal construction. He explained that in most urban areas, the second-floor construction of many homes was made of wood, not built to any type of code minimums, and without permits. This type of second story structure received a lot of damage from the Hurricane Maria.

Another construction material / pricing challenge that construction companies faced was the material inventory added tax that companies had to pay per Puerto Rican government regulations if they stock piled inventory / construction materials on the island. Therefore, many construction companies on the island of Puerto Rico, would wait and bring materials from the U.S. mainland via shipping vessels to the island only when needed for a specific project. This tax regulation created a material shortage because most private companies try to avoid extra taxation. Waiting to ship materials from the U.S. mainland until it is needed, only increased the lead time of construction materials. The director of architecture at Integra stated that most Puerto Ricans are more reactive than proactive. He stated, "They would rather wait until it's necessary to solve a large problem, rather than intervene sooner with a plan to prevent further damages or problems." According to the director of architecture, there are no formal functioning government building inspectors on the island; therefore, there is no enforcement of government code. Projects being monitored or inspected regularly are large scale projects that are managed by licensed architects and engineers whose firms are accountable for the inspections and proper construction of each project. This process is usually applicable for government and commercial projects. Residential construction projects are often left unregulated and uninspected.

At the conclusion of the interview with Integra Design Group, the director of architecture made the comment "poor people have poor ways." He went on to explain that there was a street named "Via Hugo" in the township of Loiza, which is an area that was destroyed by Hurricane

Hugo in 1988 where the poorer class have flocked to and taken over in the years since. They built in that area even though it was in a high danger area for flooding, but because no one else rebuilt there, the poorer class felt it was their best solution. This helps explain why Loiza is overrun with informal construction.

4.3.3 Desarrolladora J.A. Inc.

The research team was able to secure an interview with the vice president of Desarrolladora J.A. Inc., which is primarily a heavy-civil contractor. The vice president was also the president of the Association of General Contractors, Puerto Rico chapter at the time of the interview. The research team learned from Desarrolladora J.A. Inc. that from 2005 up until September 2017, the construction industry in Puerto Rico was shrinking and depressed. New construction had been declining in Puerto Rico. After the devastation of Hurricane Maria, and due to the rebuilding / reconstruction needs in all sectors of construction, one year after Hurricane Maria, the construction industry was booming in Puerto Rico. Desarrolladora J.A. Inc. informed the research team that construction projections showed 5 to 10 years of positive work growth in just the rebuilding efforts of damages caused by Hurricane Maria. When asked what immediate lessons learned and challenges faced after the hurricane, Desarrolladora J.A. indicated all current projects were stalled for at least 3 months. Due to FEMA paying truck drivers 3 times more per load to haul off hurricane debris than they would receive for hauling a load of material to a construction site, work on existing large projects came to a standstill.

Another challenge that construction companies faced after Hurricane Maria was price controls. Rebar, which is used in all facets of construction in Puerto Rico, went from $0.39 per lb. to $0.70 per lb. 3000 PSI concrete, which is also used in many facets of construction on the

island, increased from $80 per cubic yard to $90 per cubic yard. A big lesson many larger construction companies who were members of the AGC (Association of General Contractors) stated they learned was the importance of cash flow. Directly after Hurricane Maria, many trade contractors would only accept payment in cash. If a company did not have a good cash flow and reserves in the bank, they could not guarantee prompt payment, and therefore, many trade contractors would not work for them. Cash was king immediately after the hurricane.

4.3.4 Donato Design and Development Group

In an interview with one of the architects at DDD Group, a design, construction management, and consultation firm, the architect expressed that most engineers and architects in Puerto Rico would like to see required construction design minimums to withstand hurricane force winds up to 200 mph. She lived in Puerto Rico through Hurricane Hugo as well, and the architect explained that Hugo seemed like a baby storm in comparison to Hurricane Maria. She explained that the township of Yabucoa, where the hurricane made landfall is the area that received the most severe devastation.

When asked about illegal / informal construction in Puerto Rico, the DDD Group architect stated she believed at least half of all construction on the island was illegal, or informal construction. Building inspections in Puerto Rico are the responsibility of county officials but are not efficient. She stated that many homeowners do not want to spend money or take time to get permits for proper building compliance to take place, so they hire chiveros, who are inexpensive, unskilled laborers, often from the Dominican Republic. Those workers begin to build without any type of plans or knowledge. This construction method lends itself to a more cost-efficient approach initially, but more expensive in the long term.

After the research team saw the damages to a home on the coast of Puerto Rico due to deteriorating/delaminating rebar, the research team asked if epoxy-coated rebar was required for construction in Puerto Rico. The architect stated epoxy coated rebar is not required, and it is typical for older rebar to become de-laminated in coastal areas due to humidity and exposure to the elements. Many poor homeowners build homes/additions a little at a time causing exposure to elements. Most homeowners build as time and money / materials allow. It is common to see rebar sticking vertically out of the corners of unfinished concrete block structures for months, if not years before the wall is completed. The humidity and salty coastal air create a natural consequence of deteriorating the reinforcing steel that is left exposed to the elements. Further testing would need to be done to determine the loss of strength of the reinforcing steel that is left exposed to the elements for an extended period.

4.3.5 Casas Borincanas

In an interview with the owner of Casas Borincanas, a contractor / developer with over 30 years of experience building on the island of Puerto Rico, he stated that the homes he had built did not receive major damage from Hurricane Maria. Casas Borincanas builds as well as sells engineered home kits that are approved (engineered) to be built in all areas of the island and are designed to withstand hurricane forces. The Casas Borincanas owner explained that concrete homes that were built to current code standards did not sustain much damage from Hurricane Maria. Since Hurricane Maria, Casas Borincanas has seen an increased demand of people wanting to buy their homes or the engineered home kits they sell.

Casas Borincanas has seen issues involving the selling of pre-engineered home kits to potential clients who hope to rebuild with one of their home plans. Many families who lost

entire homes and want to rebuild did not carry insurance on their existing home, therefore, the burden of their catastrophic loss falls completely on themselves. Additionally, even though FEMA came to Puerto Rico with intentions to help the people financially in their time of need, the maximum allowable payout for 2017 disasters was $33,300. This money was not intended to "fill the hole" but rather "cover a gap." Many Puerto Ricans submitted claims to FEMA hoping to "fill the hole", but 73% of those claims were denied. One of the main reasons so many claims were denied was because many homeowners do not have titles or legal deeds to their property. Without legal proof of ownership, FEMA cannot pay out on a claim.

The Small Business Administration had also been active in Puerto Rico, providing loan assistance to residents whose homes were lost or damaged due to Hurricane Maria. Casas Borincanas stated that it was difficult for people to qualify for the loans. The approval process was difficult because it required documentation that many potential clients did not have (such as title / property deeds to the land where they would like to build).

According to the owner of Casas Borincanas, he said that approximately 35 to 40 thousand people (in more remote areas of the island) were still without power 10 months later. With the knowledge that other contractors on the island were experiencing material shortages, the research team asked Casas Borincanas if their company was experiencing material shortages due to the high demand for the home kits they were selling. Casas Borincanas stated they were not experiencing a shortage. They explained the reason they were not affected by material shortages was because his business owned warehouses where they stored between 70 to 100 of their home kits.

The research team also asked how Casas Borincanas ensured that their home kits were built to proper specifications. He indicated that each home kit sold includes a $650 engineering inspection fee that is used to pay a licensed engineer to inspect the project during construction.

4.3.6 Tu Hogar Renace Trade Contractor

The research team met at a reconstruction site with a trade contractor who was repairing a roof damaged by the effects of Hurricane Maria. This trade contractor worked for the Tu Hogar Renace program, a HUD sponsored government program for helping non-catastrophic hurricane repair needs. Tu Hogar Renace translates to Your Home Reborn. In this program, homeowners would apply for repairs and government approved adjusters were sent out to verify legitimate damages. Approvals were based on adjuster recommendations and once approved; the trade contractors were allowed to make the necessary repairs. Contractors were paid directly through the program and not by the homeowners. Figure 4-3 is a picture of the home that the research team visited. At this site, the roofing contractor showed typical roofing repairs for damages from Hurricane Maria for flat concrete roofed homes. Structurally, the home that was being repaired was fine, but the concrete roof had begun leaking after all the rainfall from the hurricane.

Figure 4-3: Site visit to concrete flat roofed home damaged by Hurricane Maria.

The research team wanted to talk with someone firsthand who was involved in the reconstruction efforts of helping put people's lives back to some sense of normalcy. During the interview, the roofing trade contractor mentioned that with his current workload of roofing repairs, he and his crew of 6 employees had at least two years of work ahead of them fixing claims that were caused by Hurricane Maria. He and his team usually began work at 7 am and would work until 8 or 9 pm each evening, for 6 days a week. When asked how he scheduled the work ahead of him, he explained that adjustors that would process the claims before he ever got to a job, and he would receive a form with the location of the job to repair and what repairs were approved for him to do. He explained that the storm was a terrible thing for Puerto Rico to go through, but because of the rebuilding needs after the storm, his company had benefited with a full workload for years to come.

4.4 Visiting Residential Properties

Interviews with homeowners who experienced the storm and the destruction of their homes was important to see how the rebuilding process was proceeding. The research team visited with owners from several parts of the island to find out how the storm had affected them and how the rebuilding process was proceeding for them. The summary contained in this thesis includes the most important elements from those interviews related to the residential construction process. In speaking with individuals, four common responses were discovered. Some persons had received financial assistance and had completed the repairs to their homes. Others had received approval for assistance and were waiting for repair work to be completed on their homes. A third group did not receive substantial damage from the storm and did not request government assistance. And the last group received substantial damage, including some who

experienced a complete loss of their home, but did not qualify for government assistance to repair / rebuild their homes.

Although there were minimal site visits made, the research team was able to make extensive observations regarding the types of damage that occurred to residential structures. All the homes on the island were subjected to extreme wind loads. Reinforced concrete homes fared well in the high winds. The team noted that some reinforced concrete structures still had blue tarps but did not appear to have structural damage. It was also observed that some wood framed structures survived the high winds. This is likely due to better construction methods being used. On the other hand, wood framed homes that were destroyed from the winds appeared to be informal/illegal construction. Homes that were built along the ocean front were also exposed to storm surge and wave damage. The structures built in these areas all appeared to have structural damage. Reinforced concrete homes faced partial structural damage, including lateral displacements, foundation undermining, and significant flooding. Wood frame homes typically experienced complete failure, in many cases simply leaving behind a bare foundation.

After the research team visited with the owner of Casas Borincanas, they had the opportunity to visit a home reconstruction site using a purchased home kit from Casas Borincanas. The homeowner explained the destroyed home had been a wood structure. The roof blew off during the hurricane, allowing rain to come in and flood the home, ruining everything inside. Figure 4-4 shows the construction of new block walls on an existing foundation after they finished tearing everything else down due to the mold and water damage. The homeowner said family and friends helped them clean up the debris of the ruined home. They did not have any government agency help in cleaning up their property. Figure 4-5 shows new bathroom plumbing roughed in the existing foundation. Figure 4-6 shows a code compliant residential

reconstruction site and permit information was displayed onsite. When asked how they were paying for the reconstruction, the owner stated that they were using a combination of insurance money, a Small Business Association loan, and private loans to pay for their new home.

Figure 4-4: New wall construction on an existing foundation.

Figure 4-5: New plumbing cut into existing foundation.

Figure 4-6: Typical code compliant reconstruction for destroyed home.

During a visit to the township of Yabucoa, a community along the eastern side of Puerto Rico where Hurricane Maria made landfall, the research team met a homeowner whose home was built right along the coastline overlook with the ocean in their backyard some 20 feet below. She explained that she had lived in that home with her husband for over forty years. Her husband, who was blind, and in his sixties, was born in that home. As the team looked around, it did not appear that there was much of any home left to inhabit (see Figure 4-7). The homeowner then led the group down the hill toward the ocean and into a lower level of what was left of their home. Figure 4-8 shows the damaged concrete ceiling due to the crashing storm surge that had inundated the home. It was apparent that the structural integrity of the home had been significantly impacted by the storm. The home was still without power, but the owners had a small generator that they used a few hours each day to provide nighttime light and it charged a small freezer someone had donated to them after the hurricane. The owners described how

devastating the storm was and that they did not qualify for FEMA help. 10 months after the storm they were still living in what was left of their home with no plan or finances to rebuild.

Figure 4-7: Remains of a beachfront home in Yabucoa.

Figure 4-8: Concrete spalling and deteriorating reinforcing steel in damaged ceiling.

A few hundred feet farther down the shoreline, the research team met another homeowner whose home had also been destroyed by the hurricane. This woman was living with her two daughters in what was left of her home: four concrete walls with a blue tarp for a roof (see Figure 4-9). During the storm, she found refuge in a restaurant that had an elevation higher up on the hillside. The roof of her home had been washed away by the storm surge and the reinforced concrete exterior walls of her home had been severely damaged (see Figure 4-10). She was also still without electricity and her original septic system and drain field had been washed away into the sea.

Figure 4-9: FEMA blue tarp roof on existing home in Yabucoa.

Figure 4-10: Damaged exterior concrete walls of home.

She was one of the few (percentage wise) that had all required documentation necessary to be approved for financial help by FEMA. In taking a closer look at the exterior concrete walls still standing on her home (Figure 4-10), the concrete had flaked away in many spots, exposing the reinforcing steel (rebar). Figure 4-11 shows that the reinforcing steel was delaminating and flaking apart. It was obvious that the strength of the reinforcing steel embedded in the concrete walls of her home was compromised; however, to what extent is unknown without further investigation and strength testing. This homeowner informed the research team that she had been paid approximately $8,000 dollars by FEMA for help with repairs to her home. When

asked what repairs she had been able to complete with the funds, she told the research team, "none." She had used the money to buy concrete block, reinforcing steel, cement, and windows to build an addition to her home. When the research team was on site, she showed us the new half constructed walls with reinforcing steel projecting out the top of them. She stated that she had run out of money and was applying for more assistance. When asked about the plan to replace her roof, she mentioned that she was waiting for a church organization that had told her they would help her replace her roof. This specific case represents an occurrence that was quite common. Homeowners typically felt that the FEMA assistance was not sufficient to replace the damaged roof. However, it was common for homeowners who received financial assistance to use the money for other repairs, or in this case a home addition.

Figure 4-11: Delaminating reinforcing steel in reinforced concrete wall.

During another exploration day on the island, the research team visited an area of beachfront properties along the north central part of the island. This area was known for its black sand beaches. While observing and documenting the damages to the homes along the beachfront area, it was apparent that the storm surge waves had washed away the beach and undermined the foundations of the homes along the beach, causing the homes to break up and fall into the sea. While taking photos of the area, an owner of one of the residences drove up and put a for sale sign on the door of what was left of his home. He shared his story of the devastation with the research team. His home had been there for at least 40 years and his wife grew up in that home. When they were first married and living there, the shoreline of the ocean was approximately 200 yards away from his home. Over the years there was a demand for the black sand that made up the shoreline where they lived, and people started loading up the black sand in trucks and hauling it off. The removal of the black sand over the years had left the homes in that area within 50 yards of the sea. When the storm surge from Hurricane Maria battered the north side of the island, there was no beach of any substantial distance left between the homes and the water's edge. During the storm, the large waves battered the compromised shoreline and undermined the home foundations and the houses fell into the sea (see Figures 4-12 and 4-13). When asked about his plan for recovery or FEMA assistance, he explained that they did not qualify for FEMA assistance because they did not have a title for their property and home. He had attempted to get a loan from a bank to rebuild, but the restaurant he owned was also flooded and damaged, so he was unable to work and did not have a job and therefore did not qualify for a loan. He explained that he and his wife had determined to leave the island and go live with their daughter who was living in Florida.

Figure 4-12: Homes destroyed at water's edge by storm surge.

Figure 4-13: Owner explaining how the storm had undermined the foundation.

4.5 Current Challenges and Deficiencies

The people of Puerto Rico still face many challenges caused by the effects of the storm. Some must travel extended distances to arrive at familiar places because the shortest / most common route is still not passable. Others must decide whether it is worth starting over and rebuilding on Puerto Rican soil, or abandoning their roots and leave the island for a fresh start. Either way the decision is not easy, and many hard days are still ahead.

The research team noted that close to a year after the storm made landfall on the island, there were still many deficiencies in Puerto Rico resulting from damages caused by Hurricane Maria. Many reinforced concrete homes did not sustain structural damage but the sustained winds and rainfall from the storm caused the roofs to leak. Many of those leaky roofs still await repairs. City street lighting was collapsed and intersection semi-fores were still not working or repaired in several locations throughout the island. Several Roads and bridges were also still in need of repair in many areas of the island. Many locations throughout the island still had debris and trash still lying where it fell during the storm or was heaped up in piles from partial cleanup of the hurricane damages (see Figure 4-14). There were still many roofs needing to be fixed (as seen in Figure 4-15 with the recognizable "Blue Tarp Roof"). The home shown in Figure 4-15 appears to be structurally sound but was still awaiting roof repairs ten months after the hurricane passed. The research team noted many homes, as seen in Figure 4-16, that had an uninhabitable wood frame second stories that had been destroyed by the hurricane. It was clear that these structures represented the far too common informal construction practices and were not eligible for federal assistance. But the construction industry was doing their part by making strides each day and week to rebuild what was lost to mother nature.

Figure 4-14: Hurricane Damage left in place.

Figure 4-15: Blue tarped roof.

Figure 4-16: Home with uninhabitable second story wood framed construction.

4.6 Discussion and Summary of Lessons Learned

4.6.1 Cultural Challenges

There are cultural challenges that Puerto Ricans face as they move forward with life after Hurricane Maria. Puerto Rico does not have a thriving business economy. Many of the younger generation who desire a higher education come to the United States mainland to attend school. Often those students end up staying in the United States because they see more and better economic opportunities on the mainland than on the island of Puerto Rico. As the younger generation continues to leave the island, the older generation is left behind with their traditional ways of living, causing customs and culture to stay the same. During several interviews with younger adults on the island, the research team was told that many had already left the island with no plans to return and others were in the process of finalizing plans to leave because the hurricane had destroyed everything they had, and they had decided if they were going to start over, they would do it on the mainland of the United States. Puerto Rico is a culture of multi-generational family living. It is not uncommon for newlyweds to live with their parents. Often, the younger generation family ends up building or adding on to the existing home to create a little more space or privacy for their family. It is common that those construction additions are built with less expensive materials that are purchased from the local home improvement "box store" with no intent to build to hurricane codes standards. These types of structures are often built by unskilled workers, using informal construction methods = sometimes even the families themselves construct something together the best they can. This generational pattern creates

many problems with ownership of property as well as the structures being unsafe for dwelling and most certainly not safe in the face of a hurricane.

4.6.2 Different Municipalities – Different Priorities – Proactive vs. Reactive

By interviewing different municipality leaders, the research team found differences in the ideas and approaches to handling the aftermath of the hurricane. When interviewing Fajardo's municipality leader, he explained his actions and hurricane plans to the research team. Not only did the township governing team handle the aftermath, they had prepared before the hurricane hit. Fajardo's township employees were sent home with heavy equipment needed before the storm made landfall so they could dig out debris to access roads back to the city center after the storm was over. After the hurricane, those employees worked together as they dug out the debris to open the rest of the streets in the municipality.

Without power and stores closed, Fajardo city employees went from house to house to assess needs and encouraged residents to meet in nearby churches and ball fields to collect supplies and food. There was a central church in each barrio that distributed food to residents for approximately 6 months. Other township leaders did not have the same type of proactive pre-hurricane plan; rather, they opted to sit out the storm and wait for help.

4.6.3 Government Regulations and FEMA

In multiple interviews while on the island, the research team was told that approximately 60 percent of the construction built on the island of Puerto Rico was illegal construction, or what some term informal construction. That means approximately 60 percent of all construction taking place on the island was/is built without a permit, without engineered plans, or without proper inspections to ensure that life-safety standards are being met. The research team did find

owners who had deeds to the land they were building on and had permits and had hired an engineer to inspect the work of the new construction; however, a majority, when asked, did not have permits or even plans.

FEMA reported that 73% of all claims from Hurricane Maria were initially denied. Many of the claims were denied due to lack of proof of ownership or property title or the illegal / informal construction also did not qualify for FEMA relief. In discussions with multiple individuals who had a FEMA claim denied, the individuals felt that FEMA just did not care about "their" situation.

The Federal Government (FEMA) was not sufficient and was a challenge for many hurricane victims who thought they could rely on this agency to "save" them. Like any government institution there are rules and regulations. FEMA offers relief to those who qualify, but they were limited to $33,300 per claim. The first thing FEMA offered were blue tarps to provide some shelter from rain and to help prevent mold. Tarps were distributed to anyone that requested without submitting a claim. 18 months of rent was also available to those who lost their home if the applicant qualified.

One big misunderstanding with the Puerto Rican people was they assumed FEMA would step in and provide an entirely new rebuilt home. Their perception of FEMA was misinformed. FEMA's role was to help residents with initial recovery, but not to cover every expense of rebuilding. FEMA also had the role of educating people on the rebuilding process. This was a great frustration point for many residents. A major issue FEMA addressed after the hurricane subsided was to quickly cover roofs of homes that had been destroyed or blown away during the storm with the recognizable "blue tarp roof" to prevent further damage to the homes from rain.

In addition to financial help, a major focus for FEMA was recovery education. FEMA assisted after the hurricane with teaching residents how to clean up their homes from the water damage. FEMA also instructed citizens how to thoroughly disinfect their homes with bleach to avoid unsanitary conditions such as mold or infections. During a visit with FEMA employees, the research team learned that FEMA also assisted in teaching the residents how to rebuild their homes properly. One FEMA employee stated that many roofs leaked after the storm, so the tarps were used to "replace" the missing roofs. FEMA had many tutorials / how-to step by step instructions on how to fix up / rebuild damaged structures on their website. FEMA provided many illustrated handouts of proper construction methods that were available for people to use and follow when rebuilding damaged parts of their homes. FEMA representatives in Puerto Rico also explained that one of the largest obstacles was teaching people how to properly build a roof that didn't leak.

Some individuals qualified for SBA (small business administration) loans for rebuilding. These loans required the homeowner to keep receipts of all rebuilding costs in case they were audited. After 1 year the borrowers were required to start paying back the loans. Many of the SBA loan applications were rejected for the same reason that FEMA applications were rejected, because homeowners did not have property deed or title to the property where they lived. Without proper property deeds, the Small Business Administration could not process and approve a reconstruction loan.

4.6.4 Cultural Poverty

The Latin culture of Puerto Rico is very laid back and Puerto Rico has extreme poverty throughout many areas of the island. The research team noticed the worst damages to residences

appeared to be in areas of greater poverty. This fact is outside the bounds of this thesis, but it is worth noting that the poorer areas of the island appeared to sustain more substantial damage. It is likely that this substantial damage is caused in part because there is not a functioning building inspection enforcement department on the island ensuring that construction is built to proper Hurricane minimum standards. The township of Loiza is evidence of this, in that much of the township lies below the storm surge flood plain and was wiped out after Hurricane Hugo in 1988. However, many impoverished people inhabited the area after that hurricane and now, some 30 years later, were found in the same situation with destroyed and flooded residences in the aftermath of Hurricane Maria.

4.6.5 Process of Rebuilding Needs to Change

The research team noted that many materials sold / used in Puerto Rico were used/installed in ways that would not be able to survive a hurricane storm. Wood frame structures typically do not withstand a category 5 storm, but anyone can go to the local home improvement store in Puerto Rico and find dimensional lumber is plentiful and available for purchase (see Figure 4-17). Reinforced CMU walls built properly are sufficient to withstand category 5 winds due to the addition of reinforcing steel. However, when built periodically over a number of years and the reinforcing steel is left exposed to the elements for years before a wall is built, the exposure to the humid, salty sea air elements can cause failure in the reinforcing steel and weaken it (see Figure 4-18). Structural steel is also a viable option. Both options (reinforced CMU walls and structural steel) are more expensive than dimensional lumber construction. Wood structures can be made to withstand hurricane force winds, but only through careful design, proper execution, and additional material/fastener devises.

Figure 4-17: Inexpensive dimension lumber at home improvement store.

Figure 4-18: Second story masonry addition in progress.

It is reasonably apparent that the poorer social class defaults to wood construction due to its low cost and easy access on the island. To lessen the damages of the next hurricane, the Puerto Rican government needs an agency (inspection services) that actively monitors new construction. Most private and government buildings and structures on the island are built to hurricane standards. The problem lies with individual, private residences. A permit process would help alleviate the burden of illegal construction. When legally permitted to build, the inspections would then become necessary. Inspections would ensure greater quality structures.

One of the greatest challenges to overcome is the lack of proof of ownership to land. Younger generations stay close to family, which means they tend to build on, or build a second level not according to any building code. It is not uncommon for multigenerational families to live in one residence. When the younger generation comes of age, they want to stay close by. To save money, they add on to the parent's structures and build with lower quality materials and

without proper knowledge they are building structures that are unsafe. As they are adding on without any proper documentation, there is no way to insure the properties. They are also exempt from FEMA claims since they are not owners of that portion of property.

4.6.6 How Can the Island Improve Residential Building Practices?

On the small island of Puerto Rico, the population is 3.4 million people. Many of the poorer class are not formally educated. After the hurricane, many relied on the government for food to survive. The Puerto Rican government itself has had and continues to have serious financial problems. Many of the larger general contractors on the island will not do work for the Puerto Rican government because they do not want to be paid in "I.O. U.'s." Unless the contract is with the federal government, those companies will not do business with the state government. It will take years to improve building practices. If the federal government were to fund the creation of an island wide building department, perhaps the local building practices would improve more quickly.

4.6.7 How Can the State Monitor Building Quality?

The creation of a working state entity, primarily needed for residential single family, DIY type construction would help ensure that building quality improves. The commercial, government and privately funded construction projects do not have an issue with quality because they are monitored and controlled by architects and engineers that ensure that quality and code minimums are followed. The real quality problems lie in the lower income residential areas.

A large obstacle was a lack of inspections for residential properties. One company (Casas Borincanas) that sells and builds housing kits that do-it-yourself residents can purchase, has found a way to ensure their home kits are built properly. Each item needed for the new

home, from the windows to the faucets to the electrical wire, is included in the sale of the DIY kit. As part of the package purchase, the cost of an engineer is included to monitor the building process. Through this method, quality construction is ensured.

4.6.8 Construction Labor Needs are High – Plenty of Work Right Now

The rebuilding needs due to the destruction of Hurricane Maria have caused the construction industry to rebound from its anemic past decade. There is plenty of construction work available. Thru interviews with construction companies on the island the research team learned that there is a shortage of skilled and knowledgeable construction laborers. There are plenty of people willing to work and fill labor positions but lack the education for proper skilled construction needs. Without enough skilled laborers to manage and oversee the unskilled laborers, proper construction practices will not happen.

Before the storm hit Puerto Rico, the island was experiencing a construction recession. It began around 2006. For example, in 2005 Las Piedras Construction employed approximately 800 people and completed $60-$80 million annually. After 2006 as the building industry declined, Las Piedras only employed 150 employees and did $30 million annually. Prior to Hurricane Maria, construction was still on that downward trend.

Since Hurricane Maria, many residents of Puerto Rico have turned to unskilled laborers or informal construction to save money on rebuilding, which means the construction is likely not built to code. Because many of the FEMA claims were declined, along with a lack of property deeds, residents are sticking with their old ways of construction. They feel that continuing to build in the tradition of adding on with inexpensive materials is their only option. The

frustration is understandable and there are many changes at the government local levels that need to be implemented to see the overall changes in residential construction in Puerto Rico.

4.6.9 How Can They Fill the Labor Need for Smaller Jobs?

It is unclear how the labor needs can be filled on the island when there is a shortage of skilled construction labor not only in Puerto Rico, but across the mainland of the United States. In talking to one homeowner, he saw that many Puerto Ricans who do become educated leave the island and move to the mainland of the United States for better paying jobs and easier lifestyle. There are companies who actively recruit young graduates from Puerto Rico to come to the United States mainland to work in the construction industry. Educated Puerto Rican engineers and construction managers are greatly needed on the island, as well as an increase in programs and opportunities for preparing a much-needed workforce of skilled laborers.

4.6.10 How Can Citizens Acquire the Proper Insurance?

The research team found that most lower income residences did not carry insurance. This was typically because either the property owners could not afford to pay insurance or the property that they built / lived in was not insurable according to insurance standards. Another reason why lower income residences do not have insurance is because many of the residences were "illegal or squatter residences." These residences were not built on deeded land, or they were built on top of existing structures. When food and shelter are the primary basics of life for the impoverished population in Puerto Rico, the thought of homeowner's insurance does not even register as something necessary to persons in that situation. When future storms strike, the perpetuating cycle of informal construction practices will be enhanced and simply continue for those without proper insurance.

5 CONCLUSIONS

5.1 Project Summary

2017 was an unprecedented year of hurricane destruction in the Caribbean and gulf region. Three category 4 hurricanes made landfall in a 30-day period on U.S. soil. Based on historical models that FEMA used to predict future preparedness, the amount of Federal aid needed was not adequately anticipated. For future reference, 2017 will stand out as a severe year for natural disasters. Unfortunately, by the time Hurricane Maria made landfall as the third category 4 hurricane to make landfall on U.S. soil in 30 days, many federal resources had already been exhausted before others became available. Because Hurricane Maria caused an unprecedented disaster scenario, it was not known how the construction industry would respond to the rebuilding efforts, especially regarding the residential construction industry in Puerto Rico and the rebuilding efforts. Therefore, this was a unique opportunity to perform this research. A goal of the research was to target one-year post hurricane construction efforts, so as to get a good feel for the lessons learned during the first year of rebuilding and to find out the effects for long-term reconstruction efforts.

In late July 2018, a small research group from the Brigham Young University Construction Management program visited Puerto Rico to get a firsthand look into the reconstruction efforts approximately a year after Hurricane Maria devastated the island. The research was performed through personal interviews with local government leaders, contractors

working in the reconstruction process, and homeowners who had experienced damaged or destroyed homes due to the hurricane. A unique perspective was learned regarding the residential construction efforts on the island Puerto Rico.

5.2 Summary of Research Objectives

The first objective was to find out what processes were utilized for rebuilding, i.e., clearing road access, ensuring people had food and water - basics of life, secure shelter - safe places to live, and rebuilding their homes, etc. The research team wanted to know these basic processes because they were viewed as necessary items that needed to be in place before effective rebuilding could begin. FEMA learned from the hurricane events of 2017 that the emergency plans in place for that year's hurricane season were insufficient and has since procured a larger reserve to be in place for future disaster events. Many individuals the research team spoke with indicated that the state government of Puerto Rico was in financial disarray before Hurricane Maria and therefore not prepared with sufficient emergency plans, equipment resources, or finances to facilitate reconstruction efforts. The state appeared to be completely dependent upon federal assistance and programs for rebuilding help. This dependent situation is unique because many Puerto Ricans whose homes fell victim to storm damage felt that the federal government (FEMA) would completely rebuild their damaged homes. When homeowners realized that was not the case, many were at a loss as to how to rebuild, especially those that were built illegally / informally to begin with. We discovered that major problems with informal construction techniques, lack of building code enforcement and uninsurable structures inhibited the effectiveness of the residential rebuilding process.

Objectives two and three were to find current opportunities / challenges and to learn about the residential construction outlook moving forward. Residential construction in Puerto Rico as an industry was anemic at best before Hurricane Maria, but thanks to all the rebuilding/reconstruction project opportunities (mostly funded by the Federal Government) caused by the hurricane, the construction industry should see a boom for the next 10 years. Most large local construction companies on the island are heavy civil/highway contractors and they will be busy rebuilding the island for several years. That trend will in turn likely trickle down to other disciplines of construction throughout the island. Smaller trade contractors, specifically roofers, have plenty of opportunities for work. As reconstruction continues, it provides jobs for many who were unemployed before the hurricane. However, the current labor challenge is to find skilled labor that understands proper construction techniques and procedures.

Objective four was to target the perspectives of the different stakeholders to explore the connections in the residential construction industry. Although we were specifically targeting the residential construction industry, we felt that our research needed to understand the local governments' and homeowners' points of view regarding proper residential rebuilding processes. The local governments primary focus immediately after the hurricane was to ensure that basic travel, infrastructure, and the ability to mobilize around the island were restored before effective home reconstruction could begin. Through our research, we discovered that the residential construction in Puerto Rico is a dichotomy of sorts. On the one side, there were homes that were built to hurricane storm standards, which consequently as a whole, received minor damages from the storm and were eligible for financial assistance from insurance and federal agencies. On the other hand, there were homes that were built using illegal / informal construction techniques which did not qualify for federal or private insurance financial assistance. Homeowners from

this second group expressed a great deal of frustration with the rebuilding process because there was no formal help available to them.

5.3 Lessons Learned

Self-reliance and initiative go a long way when it is time to dig in and get life back on track. All residents in Puerto Rico found themselves without power and dealing with some level of destruction after Hurricane Maria. The length of that power outage had much to do with how rural the area was and how quickly debris could be cleared to allow equipment access to the area. Dealing with the personal property destruction was more complicated. There were three key issues that seemed to affect the repair or reconstruction of damaged homes: Was the home insured, did the property owners have clear title / deeds for their property, and was the home built to minimum hurricane construction standards or built illegally / informally?

Illegal / informal construction on the island of Puerto Rico has been a problem for many years and continues to be such at the current time. As long as the human desires to create and self-preserve exist, and the local "home improvement" store is not too far away, people of every social class will strive to have a "shelter" of some sort over their head. Illegal / informal construction is mostly evident in residential construction because "poor people have poor ways," as one resident stated. The desire to provide shelter for one's family is greater than the desire to pay the government for the right to construct a home on one's property. Unfortunately, the poorer class in many natural disasters are the ones who suffer and lose the most.

As long as illegal / informal construction continues to be allowed in Puerto Rico, those who build to those informal construction sub-standards will be asking for federal assistance again when the next "Hurricane Maria" hits the island. Informal construction is an issue for

residential construction because of the lack of building code enforcement among single family dwellings. There needs to be a social shift away from construction methods that do not meet hurricane resistant minimums and a move toward implementing and teaching the long-term benefits of construction code minimums. The territory of Puerto Rico needs to have a governing entity that will enforce building codes and construction standards at all levels. Most homes that experienced catastrophic loss, were homes that were built in either flood zone areas or built with informal / illegal construction methods.

Proper construction education is key to helping the people of Puerto Rico understand the necessity for code compliant residential minimums. A residential construction culture paradigm shift needs to happen. The reference to residential construction culture is because most commercial / civil construction is supervised and managed by licensed engineers who ensure proper construction methods. Residential construction should not be allowed in known flood zones to prevent catastrophic loss in those areas next time a hurricane makes landfall. One thing is certain, Hurricane Maria was not the last major Hurricane to hit Puerto Rico. Therefore, if residential construction methods are not changed / improved / enforced before the next big storm event, Puerto Rico will be in the same situation it was in after Hurricane Maria.

5.4 Research Contribution

This research contributes to the knowledge that ultimately, the allowances of informal construction in Puerto Rico cause human life to be more difficult. It is clear that Hurricane Maria caused much destruction, but allowing informal / illegal construction practices to continue, only sets the island up for failure when the next major hurricane makes landfall. Agencies must change or become accountable, attitudes must shift, and public education about the "why" must

be implemented. Estimates indicate that about half of the island's residential construction is of the informal/illegal variety. The island certainly needs a greater level of accountability and education regarding residential construction practices.

5.5 Limitations of Research

The research followed a sound methodology for collecting a broad range of perspectives with a limited number of interviews. This allowed the researchers to take a broad look at how the various stakeholders were impacted collectively. However, this also limited the ability of the researchers to provide definite solutions to the problems. In many ways, this research has been more about simply defining different opportunities and challenges that existed between the different stakeholders during the rebuilding effort. Additional lessons can be learned by studying this in significantly greater depth.

5.6 Opportunities for Future Research

The valuable research accomplished by the team exploring the impacts of Hurricane Maria and Irma on the residential construction industry of Puerto Rico could be further explored through additional research. With the lessons learned in this thesis, opportunities for further exploration include the following:

- A study of why many young educated persons are leaving Puerto Rico and moving to the U.S. mainland instead of staying and building homes and families in Puerto Rico.
- A five-year follow-up study to see what construction standards have been implemented, especially among the poorer class, to ensure a limited or reduced number of informal / illegal construction residences.

- A long term (five or ten year) follow up study on the rebuilding efforts. Was the debris taken care of? Are there still homes not rebuilt?
- A more specific research approach about residential building codes and code enforcement in Puerto Rico including plan review, standardized building inspections, and code enforcement.
- A study of the local political preparedness for future natural disasters.

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