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Assessing the Effects of Reconstruction on the Commercial and Civil Construction Industry Following Hurricane Maria in Puerto Rico

Timothy Jafek Barrett-Rodriguez
Brigham Young University

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Timothy Jafek Barrett-Rodriguez

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Clifton B. Farnsworth, Chair
James P. Smith
Evan D. Bingham

School of Technology

Brigham Young University

ABSTRACT

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Timothy Jafek Barrett-Rodriguez
School of Technology, BYU
Master of Science

In September 2017 Hurricane Maria made landfall on the U.S territory island of Puerto Rico, causing substantial damage to the already weakened infrastructure and other aspects of the built environment. This research attempted to identify the challenges and opportunities that have been encountered within the Puerto Rican commercial and civil construction industry during the first year of reconstruction, post-Hurricane Maria. This was done by identifying the effects of the storm as well as the strategies of construction companies involved in the reconstruction process. The study used the events occurring after the passing of the hurricane as a case study to conduct interviews with those involved in the reconstruction efforts. The interviews followed a semi-structured interview approach to gather the data. The research found how the reconstruction efforts in Puerto Rico affected the commercial and civil construction industries, exploring the challenges, opportunities, and changes to typical business practices with regard to finances, labor, equipment, and material changes after Hurricane Maria. This was accomplished by highlighting the methods and processes used by the construction industry professionals and identifying the ones that were effective and/or ineffective in rebuilding the island. This research provided a number of key findings regarding reconstruction efforts. first, the large amounts of reconstruction related work following the storm boosted the economy of the industry and companies began growing in size and employing more personnel to fit their business needs. Second, unfortunately the vast amounts of reconstructive work created by Hurricane Maria also created a deficit in skilled labor in Puerto Rico. Third, initial reconstruction efforts were heavily focused on clearing debris, greatly benefitting companies that owned their own equipment. Finally, material availability proved to be a limiting factor in reconstruction, and lead times were directly increased because of Hurricane Maria.

Keywords: disaster reconstruction, Hurricane Maria, Puerto Rico, commercial construction, civil construction

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1 INTRODUCTION

1.1 Nature of the Problem

Worldwide natural disasters affect multiple stakeholders, including the lives of victims directly involved and the construction industry tasked with the reconstruction efforts. As a U.S. Territory island in the Caribbean, Puerto Rico faces a yearly hurricane season. Unfortunately, Puerto Rico already has significant infrastructure challenges, partially caused by lack of enforcement of adequate standard design and construction practices. Damaging hurricanes that hit the island cause substantial damage to the island's already weakened infrastructure and other aspects of the built environment. Disaster funds are often provided to aid disaster victims and hire contractors to bring forth the reconstruction efforts. However, pre-disaster construction design, means, and methods provide obstacles that ultimately cause reconstruction efforts to be more challenging. Little is known about effective long-term reconstruction efforts and the interaction between those involved in the reconstruction processes. This is problematic because it is not well understood how disaster reconstruction efforts affect the construction industry, and construction professionals may not know how to adjust business practices to effectively account for rebuilding efforts. Additionally, industry professionals, together with political and humanitarian aid leaders, are faced with the challenge of deciding whether the reconstruction

efforts should rebuild to the original substandard construction quality, designing and reconstructing to appropriate standards, or simply not rebuilding at all.

In September 2017, Puerto Rico was hit by two category five hurricanes, Irma and Maria. Puerto Rico sustained significant damage from Hurricane Irma. However, the disaster was magnified when Hurricane Maria immediately followed two weeks later with additional winds and water across the island of Puerto Rico (Kishore et al., 2018). Considered the worst natural disaster on record to affect Puerto Rico (and one of the most damaging ever within the US or its territories), the storm caused an estimated excess of $90 billion (USD) in total damages, with the majority of these being in the already hurricane riddled Puerto Rico (NOAA, 2018). High winds and flooding caused significant damage to the infrastructure, homes, commercial, and industrial properties. A major humanitarian movement was set in motion because of the intense damage and slow relief process. By the one-year anniversary of this occurrence, the day-to-day life in Puerto Rico had become fairly stabilized; however, the island continues to rebuild, and the rippling effects of Maria will continually be felt for years to come.

1.2 Purpose of the Research

Following Hurricane Maria, several significant inefficiencies and challenges were reported during the initial response and rebuilding efforts in Puerto Rico (Meyer, 2017). This research investigated the direct effects of Hurricane Maria on the construction industry in Puerto Rico, with an emphasis on exploring these inefficiencies and challenges. The purpose of this research was to specifically identify challenges and opportunities that have been encountered within the Puerto Rican commercial and civil construction industry during the first year of reconstruction, post-Hurricane Maria.

This research addressed the following three basic questions for the commercial and civil construction sectors in Puerto Rico:

1. How have the commercial and civil construction industries been affected by the reconstruction efforts in Puerto Rico following Hurricane Maria?
2. What were the strategies and processes used by the construction industry in rebuilding Puerto Rico following Hurricane Maria?
3. What strategies and processes have been effective and/or ineffective in rebuilding Puerto Rico following Hurricane Maria?

It is anticipated that this research can be used to better prioritize and manage the reconstruction efforts in the inevitable events that will occur in the future. The research will potentially help decrease the extensive time delays in the reconstruction process and minimize the reoccurring and extensive damages caused by a disaster event.

1.3 Layout of the Research

This research begins by addressing the available literature related to disaster reconstruction in Puerto Rico. It addresses the need for post-disaster research as well as post-disaster planning. It briefly touches on Puerto Rico's economic history before diving into the effects Hurricane Irma and Hurricane Maria had on the island. The research then discusses the methodology followed to accomplish the research purpose. The research essentially followed a case study approach to investigating the reconstruction efforts after Hurricane Maria. It is principally based on qualitative data gathered through a semi-structured interview approach.

The findings from the semi-structured interviews were examined, and the takeaways from eight entities involved in the reconstruction process as well as elected officials from three

municipalities are discussed. The challenges, opportunities, and changes to typical business practices are compared in the following five aspects: financial, labor, equipment, material, and other. Recommendations from industry professionals that participated in the research are then given. Second to lastly, a summary of the research with lessons learned and an implementation of the research is provided. Research contributions are identified, and recommendations are given for future research opportunities.

1.4 Research Limitations

There are several potential limitations that have been identified for this research project. These include the following:

- The research data was gathered from companies randomly selected from the Association of General Contractors roster and web searches. Companies not included in these pools were not considered.

- This research was limited to the individuals who were available and willing to participate in the interview process.

- This research addressed only commercial and civil construction companies that were contributing to the reconstruction efforts in Puerto Rico. There were not any companies that may have closed their doors as a result of Hurricane Maria that were found for this research.

- The research only involved companies that were successfully participating in reconstruction efforts following Hurricane Maria. There were not any participants with a failed experience that were interviewed.

2 REVIEW OF THE LITERATURE

2.1 Introduction

Hurricane disaster reconstruction is a continuing challenge for the island of Puerto Rico. This review of literature sought to begin to understand what Puerto Rico is doing well in its reconstruction efforts, and what areas need improvement in comparison to other countries with similar disaster occurrences. The review also looked at what other countries, groups, and leaders have learned from their disasters, and what has been applied to improve their overall disaster reconstruction process. Ultimately, the review sought to understand what gaps exist in the current understanding regarding disaster reconstruction.

The review demonstrated there is little information available regarding long term solutions to disaster reconstruction specific to the Caribbean. This is especially true in understanding the direct effects that reconstruction efforts have on the construction industry. Additionally, there is a substantial amount of information with respect to the effects of Hurricane Maria that is not published in academic peer reviewed sources.

2.2 Need for Post-Disaster Research

Weather-related disasters that have an adverse effect on human life occur frequently around the world. According to the United Nations International Strategy for Disaster Reduction (UNISDR), there was an annual average of 335 weather-related disasters between the years 2005

and 2015. This is an increase of 14 percent from 1995-2004 and almost 100 percent from 1985 to 1994 (Wahlstrom, 2015).

Disasters occur worldwide and affect each country and its people differently. The complex variety of the disasters has created different approaches for handling the different disasters, depending on its type and geographic location (Audefroy, 2011; Shaw, 2006). Flooding events across the world are a major contributing factor for the near daily weather-related occurrence; however, these floods are not just caused by heavy rain but also by poorly constructed and designed construction (Miles, 2015). This illustrates the need for post disaster reconstruction research and planning as a means to raise awareness and improve the combating of future weather-related disaster events, specifically the need for post disaster reconstruction focusing in construction perspective research (Berke et al., 1993; Yi and Yang, 2014).

2.3 Post-Disaster Planning

One of the first steps to approach weather-related disaster reconstruction is planning. Post-disaster planning has three main aims: the timely restoration of normal activities and living conditions, protecting the community against the future impact of hazards, and the achievement of common objectives between the parties involved (Berke et al., 1993). The disaster planning must begin at the community level and include assessing the strengths and weaknesses of the country's current post-disaster reconstruction, the role of reconstruction planning in urban and regional planning, and the possibility of reconstruction planning being carried out before the disaster strikes in order to anticipate future needs and reduce the time required to set reconstruction in motion after disaster strikes (Berke et al., 1993; Audefroy, 2011).

Earthquakes are another major natural disaster event that affect the lives of many people in just one occurrence. Haiti, another Caribbean country in the island of Hispaniola, suffered a devastating earthquake in 2010, which measured 7.0 on the Richter scale (Audefroy, 2011 and Bornstein, 2013). During this event, one of the best protectors of human life were properly constructed structures. Typically, the buildings that follow a specific building code during their design and construction process are the ones that can withstand the earthquake's effects; however, in some areas of Haiti, the traditional mode of construction, that did not follow a typical building code, were capable of sustaining the effects of the 2010 earthquake (Audefroy, 2011). This opened the door to combining the low-cost traditional build with modern building codes to provide a solution to the lengthy, expensive, and reoccurring earthquake reconstruction in Haiti. The disaster reconstruction process should be considered as a development opportunity, and should be linked to vulnerability reduction measures of the community, which in the long-term will lead to enhancement of human security by opening the door of different types of innovative solutions (Shaw, 2006).

2.4 Hurricane Reconstruction

In the United States, on average 1.75 hurricanes strike the mainland coastline every year (NOAA, 2018). One of the costliest and deadliest hurricanes in U.S. history was Hurricane Katrina, which hit the Louisiana coast in 2005. Katrina caused an estimated 1,570 deaths of Louisiana residents and $40–50 billion in monetary losses (Kates et al., 2006). The damage cost has since been updated to $125 billion. In 2017, the total amount of damage caused by natural disasters was a record $306 billion in the U.S. alone, according to the National Oceanic and Atmospheric Administration (NOAA, 2018). Harvey was the most expensive storm, causing

$125 billion in property damage, aid, and relief spending matching the cost of Katrina 12 years earlier (NOAA, 2018).

All of the destruction caused by past hurricanes have created reconstruction projects where several construction companies attempted to take advantage and seize the opportunity. Many of these companies, however, lacked planning and failed to recognize how hurricane reconstruction affected their companies, profitability, scheduling, estimating accuracy, and business volume, while dealing with insurance company problems, labor shortages, and material shortages (Tatum and Terrell, 2012). Good disaster reconstruction plans and execution are the best way to fully capitalize on the opportunity. Subsequently, any reconstruction that occurs very rapidly should be treated with suspicion, for it implies that there has been a failure to consult adequately with the interested parties (Berke et al., 1993).

2.5 Island in Financial Crisis

It is important to establish that the economy of Puerto Rico had been in a recession for nearly a decade prior to any hurricanes making their landfall in 2017 (Schwartz, 2018). However, an economy in recession was not uncommon for the island. Events over the past century contributed to Puerto Rico's fiscal crisis. First, in 1917 the Jones-Shafroth Act established triple tax-exempt bonds. This act made all bonds issued by the Government of Puerto Rico exempt from taxation by the Government of the United States (Hunter, 2017). The triple tax-free bonds became very appealing to American investors to the point of owning Puerto Rico's seventy-three million dollars in bond debt. This bond debt it is owned primarily by individuals, mutual funds and hedge funds. Next, in 1961, an amendment to Puerto Rico's Constitution allowed the island's debt limit to be measured differently. This allowed for

additional debt to be issued that didn't count toward the limit, virtually making the debt limit obsolete (Dolan, 2019).

The situation seemed to improve from the mid 1970's to the mid 2000's when manufacturers with businesses located in Puerto Rico benefited from corporate tax benefits under Internal Revenue Code (IRC) Section 926. This section provided a tax credit to certain kinds of businesses in US Territories, so corporate income taxes on profits made in the island could be avoided. The need to house these corporations created a rise in the construction industry economy until the Section 936 stopped and another recession followed (Schoen, 2017). Later in 2012, the economy took another boost with an initiative from the Puerto Rican government named "Schools for the 21st Century" that redesigned, remodeled and reconstructed eighty-one schools around the island with the aims of modernizing and making them fit for the twenty-first century (Infra PPP, 2014). However, these efforts were not sufficient as Puerto Rico filed for municipal bankruptcy in May 2017, four months before hurricanes Irma and Maria, after owing its creditors more than $70 Billion.

2.6 Hurricane Irma

To better understand the extensive damage caused by Hurricane Maria, it is important to establish that Hurricane Irma was also problematic. Making its landfall in Puerto Rico on September 6, 2017, just two weeks prior to Maria, Hurricane Irma was a category five hurricane with winds of up to 185 miles per hour (CDP, 2018). At the time, it was the strongest hurricane to hit the island since 1928 (Guzman, 2017). The hardest-hit strong winds and heavy rainfall areas were located in the north, northeast and mountain regions of the island. These areas received a peak total of just over thirteen inches of rain that created widespread flash flooding,

causing seven of rivers on the island to run at flood levels and waves reaching up to 30 feet around the coast (Alvarado, 2017).

Hurricane Irma passed through the Caribbean and Florida, leaving behind a path of destruction totaling upward of $65 Billion in damage (CDP, 2018). Of that $65 Billion, approximately $759.4 Million was attributed to damage in Puerto Rico alone (NOAA, 2017). Included in these figures were damages to residential structures, where a total of 1,530 homes experienced some kind of damage. Of those homes, 1,448 were moderately damaged, thirty-two suffered major damage, and fifty were completely destroyed (HUD, 2018). The 460 shelters around the island were used to house around 6,200 people and 500 pets during the storm; however, two days later only 173 refugees remained in these shelters (Alvarado, 2017).

The strong winds created by Irma also caused damages to the electrical grid in Puerto Rico. Electric Power Authority (PREPA) had 1.1 million customers, out of 1.5 million total customers in the island, that lost electric power at the time of its landfall. Figure 2-1 illustrates the damage suffered to the electrical grid. Two days later 865,000 remained without power, and five days following the storm 371,000 customers were still without power (Alvarado, 2017 and Johnson et al., 2017). Hospitals were also affected, as the Puerto Rico Health Department reported about forty-two percent of local hospitals were using generators due to a lack of electricity during this time (Alvarado, 2017). Because of the lack of power at filtration plants, around 362,000 Puerto Rico Aqueduct & Sewer Authority clients were left without water immediately following the storm. Five days after the passage of Irma, that number decreased to 62,000 customers with9out water, most of them located in the San Juan area (Alvarado, 2017). The lack of electric power also caused 781 of the 1,600 telecommunications towers around the island to cease operating (Alvarado, 2017).

Figure 2-1: Example of Downed Power Lines in Puerto Rico (Image Courtesy GAO, 2019)

The strong winds also rendered the roads inoperable with 72 roads being blocked with debris at least 616 car incidents reported on the roads and highways, most involving fallen trees. Six landslides were also reported (Alvarado, 2017). The economy also suffered as upwards of thirty percent of plantain, banana, papaya and coffee crops in Puerto Rico were damaged by Hurricane Irma's winds, which represents $30.6 million in losses for farmers (Alvarado, 2017).

Following Hurricane Irma, the immediate response from the government included financial relief packages. The Federal Emergency Management Agency (FEMA) aided in the relief to the homes by approving $12.9 Million total individual and households program dollars as well as $11.1 Million in total public assistance grants dollars were obligated within the two weeks span between hurricanes Irma and Maria (FEMA, 2017a). Efforts to restore the electrical grid were also underway. The PREPA estimated that the storm was strong enough to leave parts of the island without power for four to six months (Guzman, 2017). These efforts stalled when news of a second category five hurricane was about to hit the island two weeks later.

2.7 Hurricane Maria

Maria originated from a well-defined tropical wave that departed the west coast of Africa on September 12, 2017. According to a report by the National Oceanic and Atmospheric Administration (NOAA) the wave made its way west over the Atlantic where it grew in size and strength. By September15, showers and thunderstorms amplified, and curved cloud organization began developing. The tropical wave continued to grow and organize until a tropical depression formed about 580 miles east of Barbados on September 16. Maria shifted directions northwest and quickly intensified into a hurricane on September 17. While situated in an environment of warm sea surface temperatures and light vertical shear, the hurricane strengthened extremely rapidly. Maria became a 100 knot (115 MPH) major hurricane on September18, and in just 12 hours it became a category five hurricane with maximum winds of 145 knots (167 mph). Maria's first landfall was as it hit the island of Dominica in the Caribbean Sea where a slight weakening had occurred due to the storm's interaction with the topography of the island. However, shortly after Dominica the hurricane regained momentum and strengthened to its peak intensity of 150 knots (173 mph) on September 20 before passing by St. Croix and hitting directly into Puerto Rico. This was just two weeks after Hurricane Irma ravished through the US territory. The hurricane entered through the municipality of Yabucoa, on the southeast, and exited into the Atlantic Ocean from the northwest corner of the island (NOAA, 2017).

When Maria first made landfall near the southeastern town of Yabucoa the storm plowed across the island with sustained winds that, uprooted trees, downed weather stations and cell towers, and ripped roofs off homes (Mercy Corps, 2020). The coast was hit hard as structures there were also pounded by the nine feet high tidal surge (NOAA, 2017). The damaged to ports, roads, and airports slowed down the arrival and transport of aid. Whatever electrical power was

spared by Irma was eliminated by Maria, leaving Puerto Rico one hundred percent without electricity, while access to clean water and food became limited for most. The heavy rains and flash floods brought on by the storm worsened situation in Puerto Rico. Streets turned into rivers full of debris as floodwaters, as shown in Figure 2-2, raised greater than 30 inches tall and often sewage ridden (Mercy Corps, 2020). The central mountains of Puerto Rico were the areas that received the most rain on the island during Maria, with just under forty inches being reported (Rodriguez, 2017). About eighty percent of the island's crops were wiped out by Maria, representing a $780 Million loss in agricultural harvests (Mercy Corps, 2020).

Figure 2-2: Damage Caused by Maria (Image Courtesy Pagan-Trinidad, 2019)

There were many commercial structures that were affected by the storm. As an example, some fundamental buildings such as hospitals and schools were still standing and had good structural performance after Maria but were rendered inoperable because water had penetrated and flooded the interiors. The buildings suffered extensive nonstructural damage and loss of

function because the rain overwhelmed the roofs to the point of damage and destruction, as well as penetrating through doors and windows (Frank, 2019) All major hotels and resorts faced business interruption and extra expense losses after the storm. Sixteen major hotels completely closed for repairs and the ones that remain open ran at seventy percent room availability while repairs were underway (Gregory, 2018).

With regard to residential structures, Maria caused damage to a total of 306,138 homes, with 292,838 homes receiving moderate damage, 8,688 homes sustaining major damage, and 4,612 homes completely destroyed (HUD, 2018). During this time, the official death count stood at sixty-four deaths until a year after the storm where the Puerto Rican government raised the official death toll to 2,975 people (Schwartz, 2018). However, a study published in the New England Journal of medicine argues the total death toll to be 4,645 people with a ninety-five percent confidence interval (Kishore et al., 2018).

The hurricane completely destroyed the island's power grid and infrastructure. It left power lines lying on the ground and rivers flowing over bridges. Following the storm, none of the island's 3.4 million residents had electricity as the island's power infrastructure had essentially been destroyed, leaving the island in darkness as shown in Figure 2-3. Originally the governor had estimated that the repairs to the grid would take a month to get electricity back for the whole island (Rodriguez, 2017). This, however, was not the case as it actually took nearly a year, 328 days, for the entire island to get its electricity restored (CDP, 2018). After spending $3.2 billion erecting 52,000 new electrical poles and stringing 6,000 miles of wire to restore power to the island (Robles, 2018), chief executives of Puerto Rico Power Authority (PREPA) argued that the Puerto Rico's electricity system is not in much better condition post Maria than how it was before the storm initially destroyed the power infrastructure on the island. They

estimate that up to one-quarter of the rush work done to restore power Puerto Rico after the storm will have to be redone. Many billions of dollars more must still be spent to reconstruct the system and fortify the transmission lines that have been so tattered and poorly maintained (Robles, 2018).

Figure 2-3: Puerto Rico at Night Following Maria (Image Courtesy Ramos, 2017)

In addition of the damage to electrical infrastructure, the telecommunications infrastructure was also affected by the high winds of Hurricane Maria. After the storm, more than ninety-five percent of all cell sites and towers were knocked out of service across the island,

with nearly two-thirds of the island's municipalities having their sites completely destroyed (Hernandez, 2017). It was estimated that on average, households went eighty-four days without power, sixty-eight days without running water, and forty-one days without cellphone service. Unable to have their basic needs met, hundreds of thousands of Puerto Ricans left altogether for the mainland United States in the immediate aftermath, with an additional 179,000 estimated to leave by 2024 as the lasting effects of the storm continue to be felt (Mercy Corps, 2020).

Following Hurricane Maria, the immediate response from the government included financial relief packages. The Federal Emergency Management Agency (FEMA) aided in the relief to the homes by approving $1.3 Billion in individual and households program dollars as well as $7.1 Billion in total public assistance grants dollars obligated since the time of the storm (FEMA, 2017b). At the time this research is being performed, Maria is considered to be the costliest hurricane to hit Puerto Rico, third in the United States after Katrina and Harvey, with an estimated excess of $90 Billion in damages and $3.2 billion alone to fix the electrical power grid (NOAA, 2018).

2.8 Literature Review Summary

This literature review supports this research by validating the need for Post-Disaster research and post disaster planning. It demonstrated the reconstruction efforts of past hurricanes that affected different areas of the United States. Also, the background for hurricane Irma was laid to better understand why Hurricane Maria's destruction was so catastrophic. In all of this the literature review established that there was a need for civil and commercial reconstruction efforts. However, the literature review indicated that it is not known how these efforts affect the civil and commercial construction industry.

This research was initiated to assess the effect that Hurricane Maria had on the construction industry of Puerto Rico and to identify the challenges and opportunities that these industries faced in their reconstruction efforts. This study aims to fill the gap in the literature by illustrating how the construction industry is impacted by disasters and better defining their specific contributions in the rebuilding efforts. Understanding the successful strategies and processes used by the industry professionals in rebuilding the island during the reconstruction period would greatly benefit the construction industry for future disaster related events.

3 METHODOLOGY

3.1 Introduction

This research used the events occurring after the passing of Hurricane Maria in September 2017 as a case study to conduct interviews with those involved in the reconstruction efforts. This was done in order to accomplish the research purpose of identifying the effects of Hurricane Maria on the construction industry of Puerto Rico, as well as defining the successful strategies used during the reconstruction process. The interviewees were composed of industry professionals, government officials, political leaders, and the general population affected by the hurricane and involved in the reconstruction process. This research used qualitative questions to gain the most information about the parties involved. Researchers followed a semi-structured interviewing process, using a baseline of fifteen proposed questions for all interviews. However, the semi-structured format had the flexibility to adjust the interview questions depending on the responses obtained and the involvement of the interviewees.

3.2 Case Study on Hurricane Maria

A case study was conducted following the reconstruction events after Hurricane Maria's landfall in Puerto Rico. Case studies are a design of inquiry found in many fields, especially evaluation, in which the researcher develops an in-depth analysis of a case, event, activity, process, or one or more individuals. These cases are normally bound by time and activity, and

researchers collect detailed information using a variety of data collection procedures over a sustained period of time (Creswell, 2014). For this research, an in-depth analysis of Hurricane Maria's effect on the construction industry of Puerto Rico was made a focusing on the reconstruction efforts of one year after the storm. The data related to the commercial and civil construction industries gathered from the case study was used for this research. This research project generally explored the effects of Hurricane Maria reconstruction on the construction industry. However, the focus of this thesis was on the commercial and civil construction sectors, while another thesis focused on lessons learned pertaining to the residential construction sector.

3.3 Quantitative vs. Qualitative

Research approaches generally fall into one of three main categories: quantitative, qualitative, or a combination of the two. Quantitative research involves problems that have been previously studied by other researchers to the point that clearly defined variables and theories already exist and can be tested. Concepts, variables, and hypotheses are chosen before the study begins and remain fixed throughout the study… One does not venture beyond these predetermined hypotheses (Creswell, 2014).

Qualitative research is generally exploratory, with unknown variables and lack of theory base. For qualitative studies, the research problem needs to be explored because little information exists on the topic. The variables are largely unknown, and the researcher wants to focus on the context that may shape the understanding of the phenomenon being studied. In many qualitative studies a theory base does not guide the study because those available are inadequate, incomplete, or simply missing. Qualitative methods demonstrate a different approach to scholarly inquiry than methods of quantitative research. Although the processes are similar,

qualitative methods rely on text and image data, have unique steps in data analysis, and draw on diverse designs. (Creswell, 2014).

Although each method has distinct benefits and limitations, qualitative research methodology was used to collect the majority of the data due to the exploratory nature of the task the research was investigating. Even though the research participants may have used quantitative information to carry out their strategies in an attempt to gauge their effectiveness, the interpretation of this information was subject to the biases of the decision makers. Also, the conditions under which these decisions were made differed between the research participants. These multiple variables supported the use of qualitative research methodology.

3.4 IRB Approval

Prior to interviewing human participants for this research, training and approval was required from Brigham Young University's Institutional Review Board for Human Subjects (IRB). The IRB is responsible for the protection of the rights and welfare of human subjects participating in all research administered on campus, or conducted elsewhere by University faculty, staff, or students. Human subjects are defined as "living individual(s) about whom an investigator conducting research obtains data through intervention or interaction with the individual; or identifiable private information" (Belmont, 1979). It is important to recognize the dual burden of ethical research to advance relevant knowledge while maintaining the integrity and respect of human participants.

Due to the research participants being human subjects, an IRB proposal was submitted as part of the preparations for the interviews. This research project was deemed exempt because, although the interviewers were speaking to individuals, the responses were discussing processes

and procedures associated with their company or entities and not identifiable private information about themselves. The interviewers practiced informed consent during this research, letting participants choose whether or not to participate in the research and informing them of the research's purpose. Verbal consent was used. The interviewers also sought to maintain the anonymity of the individuals that participated in this research.

3.5 Interview Methodology

Due to the learning nature of this study, rather than evaluating statistical performance, qualitative interviews, following a semi-structured interview approach, were conducted. Subsequently, the research relied on the views and opinions as expressed by the interview participants. Semi-structured interviews are conducted on the basis of a loose structure and are composed of open-ended questions that define the area to be explored. This process gives the researcher flexibility to chase important developments that may occur during the interview process (Creswell, 2014). In this research, a semi-structured interview approach, combined with a set of baseline questions, allowed the interviews to be guided depending on the responses from the participants. This made for a wider range of responses depending on the experience the participants had with each question.

The interviewees were selected at random from the Associated General Contractors (AGC) contractor list, internet web searches, industry professional referrals, and street contacting. The research participants consisted of contractors, subcontractors, local government officials, federal government employees, architects, and engineers that were all involved in the reconstruction process following Hurricane Maria in Puerto Rico. In total, twenty-six people participated in this research.

3.6 Interviews

The following are the Baseline Interview Questions used to guide each interview for this research. Due to the semi-structured nature of the interviews, additional follow-up and clarification questions were asked based on an individual interview basis.

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?

The baseline questions were also pre-translated into Spanish, to account for individuals who would be more comfortable performing the interview in Spanish. The two graduate students selected for this research both had Spanish speaking capabilities; one of the students was born and raised in Puerto Rico, and the other was fluent in construction terminology through his work experience. The process used to select whether the interviews were in English or Spanish depended on the preference of the research participants. Interviews were conducted in English if the participant was comfortable with answering fluently in English. However, if the person elected to use Spanish or it became apparent that the person was struggling for the English translation, the interviews were conducted in Spanish. The Spanish translation of the baseline questions included:

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?

The researchers took detailed notes during each interview and used an audio recorder when possible. When necessary, the interviews were translated to English and then transcribed. After all transcripts were made, every unique point made during each interview was identified. With the points were identified, they were then sorted based on similar themes. These themes were used to develop the categories that are contained in the research study.

4 FINDINGS

4.1 Research Overview

The principal component of this research was conducting interviews with individuals that had firsthand experience dealing with the reconstruction efforts following Hurricane Irma and Maria. It was therefore necessary to seek out individuals that could identify the direct effects of Hurricane Maria on the construction industry and the reconstruction efforts in Puerto Rico. For this research it was desired to seek out a broad range of experiences across a wide variety of stakeholders to better understand the impacts of the reconstruction efforts. This would further provide an idea of how these various challenges and opportunities being faced by the construction industry would have upon the overall effectiveness of the reconstruction efforts. A total of 26 semi-structured interviews were conducted consisting of individuals involved in the reconstruction efforts; these included commercial contractors, civil contractors, subcontractors, elected government officials, government agencies, architects, and homeowners. The interviewees were selected at random throughout the island and each was asked a series of baseline questions based on their involvement with the reconstruction efforts post Hurricane Maria. The full set of baseline questions can be found in Chapter 3. Interviews were conducted in the following municipalities: Aguadilla, Arecibo, Barceloneta, Carolina, Fajardo, Guaynabo, Hatillo, Loiza, Rio Grande, San Juan, San Sebastian, Toa Baja, and Yabucoa. These locations are shown in Figure 4-1.

Figure 4-1: Interview Locations

A total of 26 research participants took part in the interviews for this research project. Of those, 24 participants had a direct relation to the commercial and civil construction industry. It should be noted that the research contained in this thesis was conducted in conjunction with a parallel thesis exploring the effects of the disaster on the residential construction industry. Therefore, any information provided during the interviews regarding the effects on the residential construction industry and the rebuilding efforts associated with homes is reported in the other thesis. It should further be noted, that an additional dozen interviews and site visits were conducted regarding the residential reconstruction efforts. Those additional interviews are not reflected in the 26 interviews identified herein. As shown in Table 4-1, the key interviews for this research consisted of eight government officials (three municipality mayors, three FEMA representatives, one US Forest Service employee, and one GSA representative) and seventeen from the construction industry (five architects/engineers, seven from the commercial construction industry, four from the civil/infrastructure industry, and one AGC representative).

Figure 4-2 shows the distribution of the interviews pertaining to this thesis. The findings of the commercial and civil aspect of the interviews are presented here in Chapter 4.

Table 4-1: Interviews Participant Breakdown by Category and Type

Interview Participant Breakdown		
Category	Type	**Number of Interviews**
Government	Municipality	3
	FEMA	3
	Government Housing	1
	US Forest Service	1
	GSA	1
Construction Industry	Architects	4
	Residential/Commercial	8
	Civil/Infrastructure	4
	AGC	1

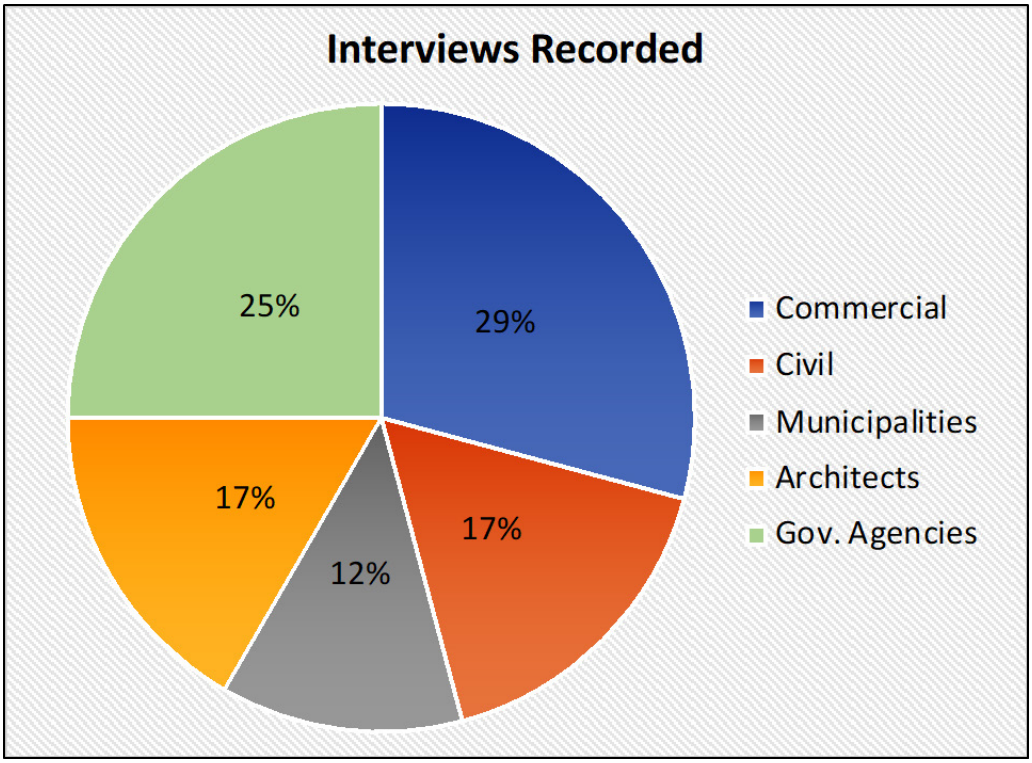

Figure 4-2: Interview Participants Percentages

4.2 Interview Takeaways

This section provides a brief summary of the general findings from the interviews with the key construction companies.

4.2.1 Desarrolladora JA

Prior to Hurricane Maria, the construction industry of Puerto Rico was in a recession where the projects stalled due to a lack of resources and power. After Hurricane Maria, the construction industry was in an economic upswing. For example, Desarrolladora JA was doing $30 Million worth of work in 2014. Over the next two to three years it decreased to around $10-12 Million worth of work while breaking even on profits. In the six months after Maria, the company had done $20 Million worth of work with a ten to twelve percent profit. However, this company also suffered challenges with communication, labor, material availability, and price increase as discussed in Section 4.5 Challenges Created by Reconstruction. In particular, every project the company was working on prior to the storm received an automatic three-month extension on their contractual turnover date because all construction was focused towards the reconstruction efforts. It is important to note that the pre and post-construction projects the company worked on were predominately road and bridges repairs for the same owners.

Immediately following the storm, the only construction available were road repairs funded by the state authority. Because these were 100% federally funded, many contractors made the leap and became heavy civil contractors. The government still gave opportunity to new road contractors but through a tedious process. This policy was a trial for Desarrolladora JA as new competitors were entering the market; however, only about one-fifth of the contractors

stayed doing heavy civil work after. With the economic boost, the company strategy was to gradually grow in size to avoid the risks associated with growing too quickly.

4.2.2 Del Valle Group

Del Valle Group is one of the four largest civil contractors in Puerto Rico. Their main focus are heavy civil construction projects as ninety-five percent of their work include roads, bridges, and water dams. Before the economic downturn in 2008 Del Valle Group consisted of around 1,800 employees and was doing around $120 Million of work a year. This revenue had decreased to $45 Million pre-Maria, and then increased to $65 Million of work after Maria, with around 400 employees on payroll.

The first stage of reconstructive work Del Valle Group was involved was with the debris removal and opening of the roads. Once the roads were clear, they shifted to road, bridges, and dam reconstruction. In Puerto Rico bridge construction design build project delivery is not standard; however, it was approved to speed up the bridge reconstruction process. In one project a bridge was finished more efficiently and faster because of design build. A bridge collapsed because of flood related slope failure and Del Valle Group was able to fix it relatively quick because their inhouse engineer was able to provide the design. The interviewee indicated that "the state drags their feet, they do their own design, or subcontract it out, and it takes significantly longer. Something that would takes normally one hundred days took only ten days." Repairing dams works a little differently. The federal government organizes and manages the project while the contractor executes the work. The design was done by the Army Corps of Engineers, then they worked with Puerto Rico Power Authority (PREPA) for the interpretation. Del Valle Group then did the constructability review before the project was ready to start.

Del Valle Group also dealt with the lack of skilled labor as discussed in Section 4.5 Challenges Created by Reconstruction. Many trained personnel have left Puerto Rico for the United States in search for work and better opportunities. Del Valle Group indicated that they see two options; either training new personnel or bringing some trained ones back from the United States. Even though it can be a challenge to train skilled labor, training is what will more than likely happen. Del Valle Group was not too worried about companies from other countries coming to Puerto Rico and creating competition during the reconstruction; rather, what worried them is that these other companies might poach their employees, the place that their company success is built on.

When asked about the future, Del Valle Group wanted "to grow as a company and get more work. [They] want to do more work because [they] know [they] have the ability and capacity to do more work." At around $100 Million, they have a larger bonding capacity than most of the local contractors and if the $500 Million bids are broken down (as discussed in Section 4.5 Challenges Created by Reconstruction), Del Valle group will be in a better position to achieve their growth goals.

4.2.3 Las Piedras

Las Piedras Construction was also suffering from the economic recession in Puerto Rico since 2008. In 2005, The company had 800 employees and did $60-80 Million worth of work. Right before Maria they employed 150 employees and their amount of work had decreased to $30 Million. After Maria they employed 300 employees and were significantly exceeding the amount of work they did the previous year. Maria made it difficult to find skilled labor, equipment, and materials, as further discussed in Section 4.5 Challenges Created by

Reconstruction. When Las Piedras Construction needed to increase their workforce to handle to new emergency related projects, they overcame the lack of skilled labor challenge by hiring relatives of their current employees. They found that when doing that, the training was better received, and the length of training shortened. Equipment shortage was not an issue for this company because they own their own heavy equipment. However, the materials for their projects were affected because of the congestion at the ports. After Maria, Las Piedras Construction found a new opportunity to work in the reconstruction of the National Rain Forest El Yunque with over fifteen reconstruction projects being done there. One of these projects is illustrated in Figure 4-3, as well as another landslide in the background.

Figure 4-3: Las Piedras Landslide Repair in El Yunque

4.2.4 Commercial Construction

Representatives from commercial construction companies based predominately out of San Juan provided feedback during the interview process. These companies concentrated solely on private and insurance work during the reconstruction process, with insurance work taking longer, up to a year, to receive payment. As shown of Figure 4-4, the insurance payouts would take so long that damage to some commercial structures throughout the island had still not been yet been repaired a year later. Multiple interviewees indicated that state government work was avoided due to the non-paying nature of the work.

Figure 4-4: Damage to Commercial Structure Visible One Year After Hurricane Maria

One of the companies interviewed shifted from doing high-end residential construction before the storm to focusing on the reconstruction of factories. It was a general knowledge that material lead times increased significantly so some material substitution was allowed by the owners. There were no labor shortages and the companies grew in size during this time. A typical risk management practice was the use of subcontractors to contractually shift the risk, so the amount of subcontracted work increased during this time. Regarding work backlog, one company said, "after a winning a job, the construction will not start for 6 months because of the large amount of work we currently have; whereas, before the hurricane, construction would start shortly after job was awarded." This company experienced difficulties with heavy equipment availability in the year following the storm. Any available equipment would be leased for a year at a time.

4.2.5 Design Firms

Architect and engineering firms were involved in the reconstruction process post Hurricane Maria. All the architecture and engineering firms that participated in the research experienced changes in design standards with the most common change being the shift from a 144 mph design wind standard to a new standard design wind standard of 200 mph. One architecture firm was able to resume business after five days of the storm because they had a generator that could power their main office; however, work was limited due to no internet access being available.

Architects discussed that inspections on commercial and civil projects are performed in Puerto Rico and are typically through the county's jurisdiction; however, the commercial inspections are not thorough or very efficient. This is typically due to the owners wanting to save

money upfront and cutting corners with permitting. As described by an architect, “people do not want to spend money or time regarding permits in order to build right. So, they hire Chiveros for their cheap labor. Chiveros are usually from the surrounding islands and build without plans,” (A chivero is an individual that offers cheap unskilled labor.) This may lead to cost savings up front, but not in the life of the product. Another common problem that the architects discussed was with the rebar utilized in structural projects. The architects indicated that it is typical for rebar in Puerto Rico to delaminate because epoxy coating rebar is not a standard. The delamination is caused by the sea water and saltpeter leaking through cracks in the concrete and making contact with the rebar. At this point, the rebar begins deteriorating at a faster rate due to the exposure to the weather elements and the lack of epoxy protection. An example of this delamination is shown in Figure 4-5.

Figure 4-5: Results of Delaminated Rebar Exposed to Elements

Rather than epoxy coating the rebar, instead a common practice for protecting the life and integrity of structures is the use of Sika FerroGard on the exterior of the concrete. The exterior layer of existing paint is removed, then the Sika FerroGard is applied directly on the concrete to strengthen the rebar inside. Sika FerroGard is a "corrosion inhibiting impregnation coating for hardened concrete surfaces. It is designed to penetrate the surface and then to diffuse in vapor or liquid form to the steel reinforcing bars embedded in the concrete. Sika FerroGard protects the embedded steel by depositing a physical barrier in the form of a protective layer on the surface of the steel reinforcement. This barrier inhibits corrosion of the steel." (Sika, 2020). This product seems to work. However, it is a reactive solution to treat the delamination problem after the delaminating begins. It is not a preventive solution so there are still many structures that experience delaminating issues. Sika FerroGard is mainly used in in the preservation and restoration of historic and existing buildings.

4.2.6 Subcontractors

The subcontractors that participated in this research were also impacted by Hurricane Maria; however, the trend was more aligned with a positive impact than a negative one. When asked if their business was impacted by the storm, one subcontractor claimed their "company went from seventeen employees to forty-one and had six months' work of back log work. Hurricane Maria did not [negatively] affect the construction industry in Puerto Rico, it actually improved it."

Interviewees indicated that the subcontractors that did not own equipment could also benefit from the available debris clearing work through the rental, leasing, or purchasing of heavy equipment. However, the debris removal from roads and bridges also created a hindered

market for subcontractors when companies from the United States came to participate in the opportunity. The challenge to the local companies was when the US companies would poach their employees by offering higher wages, something that the local companies could not always compete with. However, the interviewees indicated that the majority of employees that left for the higher pay would ultimately later attempt to return to their former employers once the other work had ended.

Following the storm, companies still had clients and jobs that needed attention. Although it was difficult for some, because the cleanup and reconstruction related work as a result of Maria was more lucrative, one tenured subcontractor had a long-term mindset to ensure that they would keep business in the future. This company has kept their business afloat during the fluctuations of the economy. As an asphalt contractor they had built a reputable name and used the low number of competitors in their trade to their advantage. This company's bread and butter was parking lots, utilities and anything that involves site work. The interviewee indicated that "asphalt is good business to be in because it needs to be maintained every ten to fifteen years and often times we get hired to fix the other guy's mistakes." This company further indicated that they had also avoided work that involved political corruption that had led other companies to fraud and imprisonment.

It should be noted that although many contractors expressed a positive outlook for future work, some subcontractors were concerned about the future. There was specific concern expressed that with the completion of the clearing and grubbing jobs some companies were fearing what would happen to the construction industry in Puerto Rico once the funds allocated for the reconstruction effort were used.

4.2.7 AGC

A member of the presidency of the Associated General Contractors of America (AGC) chapter in Puerto Rico discussed how the AGC was involved in the reconstruction efforts. The research found that the contractors in the AGC chapter immediately had difficulties with communication after the storm. This lack of communication and misinformation affected all contractor's capacity to perform work. For example, most contractors had to drive everywhere to be able to communicate in person, sometimes even "knock[ing] on doors to find the person [they] were looking for."

The Associated General Contractors of America shifted their role after Hurricane Maria to protect local contractors. The national AGC chapter helped pay employees who were directly affected by Maria. The national chapter leadership also sought to make sure that the Stafford Act was enforced, and that the local contractors were used for reconstruction work whenever possible. The Stafford Act is a law that declares that the emergency assistance provided by the federal government be used for the rebuilding of communities so individuals, businesses, and governments can function on their own, return to normal life, and protect against future hazards. (PRR, 2017) This enforcement was accomplished by breaking down bigger bids into several smaller ones so that the local contractors could bid on them. The AGC and three other groups met monthly with the governor to make sure codes were being enforced in Puerto Rico. The AGC and highway system had a separate monthly meeting to discuss discrepancies in material prices caused by Maria. The AGC also aided in the housing reconstruction by investing their skills to help rebuild La Perla, a historic neighborhood in San Juan that was severely affected by Hurricane Maria.

4.2.8 Federal Government Agencies

Representatives of Federal government agencies, such as the General Services Administration (GSA), US National Forest Service, and FEMA were interviewed for this research. This research focused on how the government agencies were involved with the reconstruction to the property under their jurisdiction.

The GSA is an "independent agency of the United States government established in 1949 to help manage and support the basic functioning of federal agencies. GSA supplies products and communications for U.S. government offices, provides transportation and office space to federal employees, and develops government-wide cost-minimizing policies and other management tasks." (GSA, 2018) In Puerto Rico, the GSA handled the reconstruction of the federal facilities under their supervision.

After Hurricane Maria made its landfall, the challenges with communication, labor, material availability, and price increase (further discussed in Section 4.5 Challenges Created by Reconstruction) also affected the GSA's reconstruction process. After an initial assessment of the damage, it was determined that the repairs would be too extensive for the inhouse maintenance technicians to handle, so the work was subcontracted. It took around thirty days to find a contractor capable of performing the work, an additional forty-five days for the work to begin due to material congestion at the ports, and forty-five days to get all facilities back up and ready for habitability at full capacity. The immediate action plan was to perform temporary repairs to allow the functionality of the building. Once that was complete, another project was subcontracted to handle the permanent repairs.

The GSA in Puerto Rico not only handled the reconstruction of the federal government property in the island, but also the federal property in some of the surrounding US Virgin

Islands, such as the island of Saint Croix. This posed a bigger challenge with the reconstruction in materials, labor, and transportation due to the priority being given to the first responders. Initially, flights to St. Croix were unavailable for around a week after Maria. Luckily, the preparation of storing away and fastening anything that could be picked up by the wind in the storm as well as using storm gutters served useful because the only damage suffered at this property was two broken windows after the storm shutters were taken away by the wind during the storm.

This research also explored reconstruction effects on El Yunque, the only tropical rainforest in the U.S. National Forest Service. El Yunque includes some a number of roadways and trails in some of the highest mountainous region on the island. It was discovered that landslides affected the reconstruction efforts in its rainforest, and closed roads and trails along its path. There were around 240 landslides that impacted the roads and trails in El Yunque. Due to the FAA aviation tower being located in El Yunque, several volunteers and first responders aided in the road clearing; however, some clearing had to be contracted out for the larger landslides, as shown on Figure 4-6. The contractors also aided in the preservation of the forest by engineering "step pattern" retaining structures to increase their stability and avoid future relapses.

With regard to infrastructure related damage, FEMA tends to act is an emergency manager, not a response manager. They normally provide the funds to hire the personnel needed for a response, but do not have a plan for managing the response itself. In other disaster reconstruction cases occurring within the United States, FEMA would reimburse the states after the reconstruction took place; however, Puerto Rico had no cashflow. This significantly slowed things down since FEMA needed to audit the companies they released the funds to, to know that the work was complete.

Figure 4-6: Landslide Reconstruction in El Yunque National Rainforest

4.3 Local Elected Officials Interviews

The research participants included three local elected officials from different towns of Puerto Rico; San Sebastian, Fajardo, and Loiza, as shown on Figure 4-7. These towns differ in size, socioeconomic status, official's tenured length of time in office, and are located on different regions of the island. San Sebastian is in the Western Region, Fajardo in the Eastern Region, and Loiza is in the Northern Region. These elected official participants were targeted for this research because of their location and their involvement with the reconstruction efforts post Hurricane Maria. A summary of their interview responses is discussed in the following sections.

Figure 4-7: Municipalities Interviewed

4.3.1 San Sebastian

By area, San Sebastian is the seventh largest town of Puerto Rico with seventy-one square miles. It is composed of over 40,000 constituents with thirty percent being over the age of sixty. San Sebastian is sub-divided into twenty-four Barrios, or neighborhoods, that are further subdivided into smaller sectors composed of subdivisions, (Blank, 2012). Its economy is made up by coffee and fruit agriculture as well as cattle and dairy industry (EPRL, 2017). The mayor had been in office since 2005 and up until the time of the interview a year after Maria, was involved with the reconstruction of San Sebastian.

4.3.2 San Sebastian and Hurricane Maria

Hurricane Maria left debris behind that made all the roads in San Sebastian un-transitable and affected over 16,000 homes located in the town's jurisdiction. Within seven days, the debris was removed; however, the elderly population began to experience health complications due to

the hurricane's effects, particularly the lack of electrical power. As discussed in Section 2.5 Hurricane Maria, the storm severely affected the electrical infrastructure of the island with some areas not having power a year after its landfall. Puerto Rico's electrical power provider the Autoridad de Energía Eléctrica, AEE, had the strenuous task of repairing a grid that was faulty before the storm to restore power to the whole island (Mufson, 2017). In San Sebastian, however, after two months of being in the dark, Mayor of the town and his office took it upon themselves to restore the electrical power. With the life of its elderly citizens in mind, the Mayor said he "couldn't take it anymore, because there were lives at stake and we had to take action." And thus, the first city led emergency response initiative to restore electrical power was formed in Puerto Rico.

4.3.3 The Pepino Power Authority

The Mayor worked with professionals in his community to get the lights and the electricity needed for the life-saving equipment turned back on. Knowing it would take time before the community would have its power restored by the AEE, the town bought two emeritus AEE trucks and established the Pepino Power Authority, or PPA, after the city's official name, San Sebastián de las Vegas del Pepino. The PPA then took it upon themselves to restore the electrical power to the community (Florido, 2018). The biggest priority for the mayor was to restore power to its community safely so the PPA was an OSHA approved initiative and followed a safety protocol made by a former electric safety employee of the AEE. This protocol helped maintain the number of accidents, work related injuries, and deaths at zero during the time of the power restoration.

The PPA was composed of 32 licensed electricians and retired AEE employees from the town's community members. Within six weeks, the PPA had restored power to the main parts of town and by January 15, 2018, three months after the storm, ninety-two percent of power had been restored, and the majority of more secluded areas had power. San Sebastian became one of the first towns on the island to reclaim full power for its residents and The Pepino Power Authority's achievement led to new legislation in Puerto Rico; Law 107 that empowers local governments to create their own power authorities at times of emergency allowing critical services to be restored (FEMA, 2018).

4.3.4 Fajardo

The municipality of Fajardo is located on the eastern most coastal tip of the island. It measures just over thirty-one square miles and has a population of nearly 37,000 people that live in one of its nine Barrios, or neighborhoods, that are further subdivided into smaller sectors composed of subdivisions, (Blank, 2012). The municipality of Fajardo's economy is based on manufacturing of medical equipment and instruments, as well as the various offerings of the tourist industry (EPRL, 2017). The mayor of Fajardo had been in office since 1989 and at the time of the interview a year after Maria, was still involved with the hurricane reconstruction efforts of the municipality.

4.3.5 Fajardo and Hurricane Maria

The first order of business for the mayor's office was to take care of their constituents. This initially could not be done because they too experienced the road inaccessibility due to the large amounts of debris left behind by Hurricane Maria. The Mayor of the town rented equipment to clear the roads and help distribute aid. Luckily, Fajardo has one of the best landfills

in Puerto Rico so with the Help of FEMA and the National Guard, the debris was cleared faster than other municipalities with Barrio Fajardo Centro (downtown Fajardo) cleared in one day.

The Municipality of Fajardo Town also served as the “Centro de Acopio” or gathering center for military throughout Puerto Rico. The military landed in Roosevelt Roads Naval Station, a former United States Navy base in the neighboring Municipality of Ceiba and used the large athletic complexes found in the municipality as their gathering centers. The locals of Fajardo love sports and athletics, which is why the Mayor made it a priority to repair the athletic complexes that were damaged in the storm to give the residents hope after the storm.

While this interview focused more on the residential aspects of reconstruction, the mayor was interested in the infrastructure, economics, and travel aspects that were broken in their municipalities. The Mayor coordinated the response of the people while FEMA led the efforts on the commercial and civil aspects of reconstruction.

4.3.6 Loiza

Located on the northern coast of Puerto Rico, Loiza measures just under twenty square miles. Loiza 30,000 residents live in one of its six Barrios, or neighborhoods, that are further subdivided into smaller sectors composed of subdivisions, (Blank, 2012). It is a low-level economic sector with an economy composed of fishing, tourism, coconut farming, manufacturing, retail sales, and the hotel industry (EPRL, 2017). The mayor of Loiza, had been in office since January of 2017, nine months before Maria, and up until the time of the interview a year after the storm, was involved with the reconstruction of the town.

4.3.7 Loiza and Hurricane Maria

The Mayor of Loiza had the main goal of providing aid to the people of the municipality. This was complicated; however, as eighty-five percent of the municipality lives in a flood zone, so the roads were inaccessible due to the debris and flooding. Within three days following Hurricane Maria, the sewer and drainage were cleaned, and the road debris removed to allow access through the municipality.

While this interview focused more on the residential aspects of reconstruction following Hurricane Maria, the mayor was interested in the infrastructure, economics, and travel aspects that were broken in the municipality. The Mayor coordinated the response and aid of the people, while FEMA led the efforts on the commercial and civil aspects of reconstruction. Looking towards the future, the Mayor had prepared for a potential disaster event with a storage of cots, generators, and nonperishable food supplies for its constituents. The mayor also was negotiating with the state government to build a four mile stretch of road that unites the northern part of Loiza to its southernmost tip and connects to Puerto Rico Highway Three (PR-)3 with the goal of being better prepared in a future emergency. This potential project construction costs are estimated to be around $32 Million because of the need to be elevate the surrounding land above the flooding levels prior to building the road. A project located in Manatí, shown in Figure 4-8, had to undergo a similar elevation process to that needed in Loiza. This project was managed by the Corps of Engineers, following Hurricane Maria, and had two purposes; to serve as an elevated road to connect two flood zones, and act as a dam to keep potential floods from extending deeper into the municipality.

Figure 4-8: Road Elevated Above Flood Line in a Flood Zone

4.4 General Reconstruction Findings

This section of the thesis discusses some of the general reconstruction findings. This information helps define the remainder of the research findings.

4.4.1 Types of Reconstructive Work

The research uncovered two main types of reconstructive work, privately funded and government funded. Similar responses were grouped together to create four subcategories; insurance work, private sector work, federal work, and state work. The subcategories were then organized into six main groups; Roads, Road Clearing, Land Slides, Bridges, Dams, and Commercial reconstruction.

Immediately following the storm, the primary focus of the reconstruction process was the debris removal from the roads. This priority came about due to the communication systems being down and as one participant put it, “contractors hav[ing] to drive everywhere and knock on doors

to be able to have in person communication," (as further discussed in Section 4.3 Challenges Created in Reconstruction). Fortunately, most of the debris clearing contracts were set up before the storm and helped speed this process along. The funds for the Debris Removal were provided by the government, with both the state (local) and federal (FEMA) governments providing funding. The biggest difference between these two was that the federal funds were guaranteed while the states were not. This is further discussed in Section 4.5 Challenges Created by Reconstruction. After the roads were cleared and the damage was assessed, the infrastructure focus shifted to repairing and rebuilding the roads and repairing the electrical grid.

Both storms caused significant amounts of damage to Puerto Rico's roadway infrastructure, rendering them unfit for normal, use as shown in Figure 4-9. Bridges were also affected and destroyed by Hurricane Maria, as the floods caused the collapse of sixteen bridges throughout the island. One of these bridges, shown on Figure 4-10, had repairs underway a year after the storm. In some areas, bridges are the only way to connect towns so any damage to them would cause the local residents to be cut off from civilization (Russell and Blair, 2018). Funds for the roads and bridges repairs followed the format of the road clearing, with both federal and state funds being used. According to the civil contractors, the process for evaluating which roads received what funding was determined by their respective jurisdiction. The jurisdiction was determined by the number of numerical digits the road named had. Repairs on roads with one, two, or three numerical digits, the major roads, would fall under the National Highway System jurisdiction while four-digit roads would fall under FEMA jurisdiction as these were smaller roads belonging to the municipalities. This was key for contractors to know which projects to resort their manpower and efforts to, because of the guaranteed federal grants available for payment once the job was completed.

Figure 4-9: Rural Road Damage

Figure 4-10: Piles Driven into the Ground for Bridge Reconstruction

Dams were also affected during Hurricane Maria. The heavy rainfall increased the water and pressure levels causing the dams to reach their failure point. Some dams were opened to relieve the pressure and others had damage that needed to be repaired prior to operating again. This created opportunities to the contractors, especially one that built a relationship of trust

through previous projects and was involved in the preconstruction process using the Design-Build delivery system. Being included this early in the preconstruction process, contractors were able to perform "constructability reviews" that analyzed the scope, cost, and schedule and led to higher quality, within budget and on time project deliveries.

Buildings owned by private entities also suffered damages because of Hurricane Maria. This created a large opportunity for commercial reconstruction work in the island. The commercial reconstruction work proved to be stable because it was funded predominately through insurance payouts.

4.5 Challenges Created by Reconstruction

Hurricane Maria created several challenges for the reconstruction efforts in Puerto Rico. The research participants responses were analyzed and categorized into five categories; Financial Challenges, Challenges with Labor, Challenges with Equipment, Challenges with Materials, and Other Challenges.

4.5.1 Financial Challenges

As discussed in Section 4.4 General Reconstruction Findings, there were two main types of reconstructive work, privately funded and government funded. Within the government funded reconstructive work there were federal, state, and municipal funds. The biggest challenge faced during the reconstruction process was receiving payments for the work of state and municipal funded work. These funds were received by FEMA; however, as one research participant noted, "[they] are not a bank. Money from FEMA was not given directly to the local government but was more of a reimbursement. Puerto Rico has no cashflow, so loans were needed to initially

fund the projects." This created hurdles for many companies to receive their moneys on time for reconstructive work. All contractors that worked on state funded jobs were still awaiting payment a year after the work was completed.

Another financial challenge that every contractor dealt with was a low bonding capacity. The size of some of the federally funded reconstruction projects were significantly larger than what the local companies were used to performing and therefore beyond their normal bonding capacity. This didn't allow for many local contractors to bid these larger infrastructure related reconstruction projects.

4.5.2 Challenges with Labor

Labor availability in Puerto Rico had been declining in the years prior to Maria. This posed a greater challenge when the demand for labor increase after Maria. As discussed in section 4.6 Opportunities Created by Reconstruction, there was an increase in available labor post Hurricane Maria. Contractors saw an overall increase of available labor and manpower; however, this was unskilled labor. Every company was faced with the task of investing in their employees by training them, something that takes time. This caused a delay in projects where the labor was extensive and as a result some of these projects had increases in the cost of labor that were up to thirty percent larger.

4.5.3 Challenges with Equipment

Immediately following the storm, the heavy equipment available in Puerto Rico was used exclusively to clear the roads. This created a challenge for companies to keep their jobs on track and on schedule as little equipment was available for rent to use in non-debris clearing projects.

For example, one contractor experienced “equipment rental price increases by 20-25% right after the storm if the equipment was available at all.” A way to overcome the material availability was by owning or leasing equipment, or by subcontracting any scopes that required the heavy equipment to companies that owned their own heavy equipment. Subcontracting also proved successful in mitigating the risks associated with owning or leasing equipment. This challenge was no longer an issue a year after the storm. Additionally, electrical generators increased in price as their demand went up due to the extensive time it took to repair the damage suffered to the electrical grid. This is reflected by the prices of generators twelve and thirty months after the storm as shown in Figures 4-11 and 4-12 respectively.

Figure 4-11: Electrical Generator Price at Local Home Depot Twelve Months After Maria

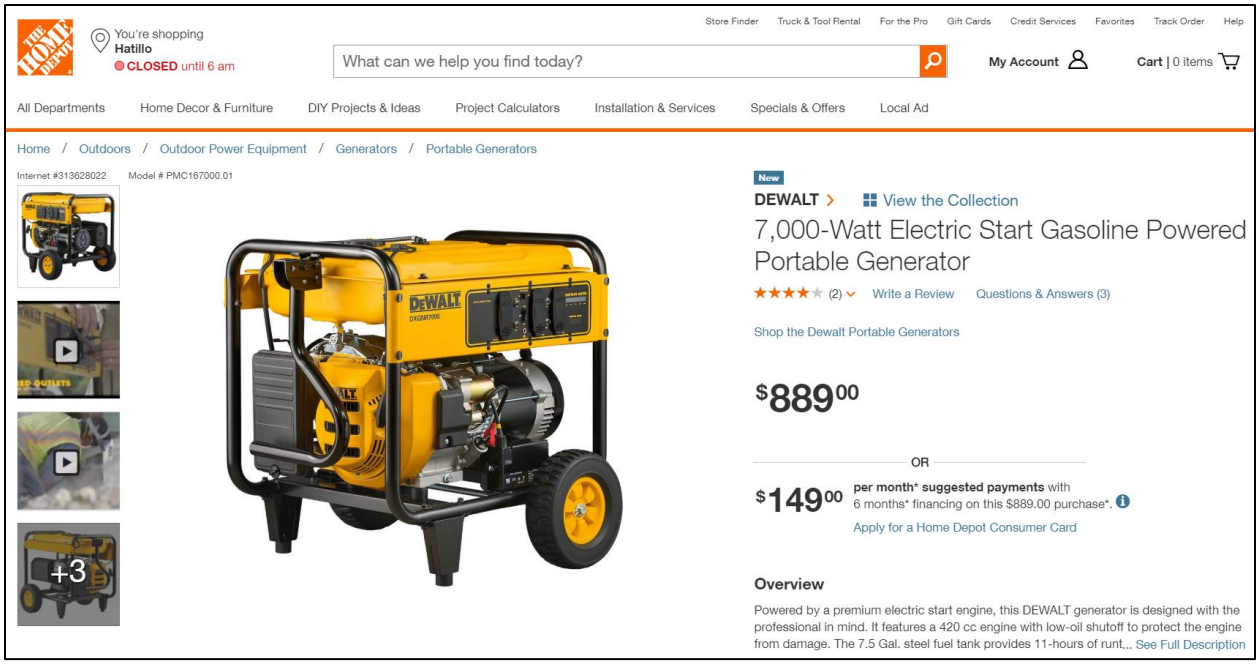

Figure 4-12: Electrical Generator Price at Local Home Depot Thirty Months After Maria (Image Courtesy of Home Depot 2020)

4.5.4 Challenges with Materials

Materials availability, deliveries and prices were affected throughout the reconstruction process with steel, cement, asphalt, and rebar being the four most affected. This was endured by every contractor, subcontractor, owner, and everyone needing materials for up to six months after Hurricane Maria.

The biggest limiting factor were the congestions at the ports. First the materials had to go through a mainland US port due to the Merchant Marine Act of 1920, also known as the Jones Act. This act mandates that U.S.-flagged ships be used between U.S. ports, be built in the United States, and staffed by U.S. legal residents. While it benefits U.S.-owned shipping companies, the regulation drives up the cost and schedule of imports to Puerto Rico (Long-Garcia, 2018). Second, the priority in the ports was given to the Federal Emergency Management Agency,

(FEMA) whose priority was for the food and water for the victims as well as restoring the electricity back. Previously importing things from the US took eight to ten weeks. The congestion on the ports increased the average it took the material to arrive by three to four weeks meaning the imports into Puerto Rico post Hurricane Maria would often remain at the ports for an extended amount of time.

The research discovered that materials in Puerto Rico are predominately bought from companies in the United States. These companies normally as for full payment before shipping the materials. By doing this, the Puerto Rican companies decrease their cashflow because they cannot bill for the materials after they have been installed or constructed. Because of this, some companies are forced to take out loans from a bank or a private lender to be able to purchase the materials needed for construction.

Another challenge that hindered the availability of material in the island was the inventory tax Puerto Rico places on their unsold goods including raw materials. The law states that businesses must pay their respective municipal tax on merchandise that they didn't sell within a calendar year (Garofalo, 2019). Originally this tax was used as an additional source of revenue for the municipalities; however, after Hurricane Maria, this tax "led to empty warehouses without extra material and limited inventory," as one participant put it. The twenty-five percent tariff on steel and ten percent tariff on aluminum imports imposed by the federal government only worsened the situation. Some companies were able to work around the time requirements and were exempt from paying taxes, but a surplus in storage was still unobtainable.

Material prices also escalated during the initial reconstruction efforts. The price of steel went from $620 per ton to $830 per ton after Maria. Concrete increased from $80 to $90 per cubic yard of 3,000 psi concrete. Rebar went from $0.39 per pound to $0.70 per pound. Asphalt

went from $100 per ton to $120 per ton. These numbers and their corresponding percent increases are shown below in Table 4-2.

Table 4-2: Material Price Increase Pre and Post Maria

MATERIAL PRICE COMPARISON			
Material	**Avg. Price Pre-Storm**	**Avg. Price Post-Storm**	**Avg. Increase**
Concrete	$80 / yd³	$90 / yd³	12.5%
Rebar	$0.39 / lb	$0.70 / lb	81.65%
Asphalt	$100 / Ton	$120 / Ton	20%
Steel	$620 / Ton	$830 / Ton	33.9%

Fuel availability was also affected during the reconstruction process due to the rations that were put in place due to the increase of generators after the storm. Fuel was needed to not only to run the machinery and equipment, but to also power the electrical generators owned by business and individuals throughout. This created a surge in the demand and caused a fuel ration for the entire island.

4.5.5 Other Challenges

As discussed in Section 4.4 General Reconstruction Findings, the first reconstruction priority post Hurricane Maria was to clear the roads from the debris. This created an influx of civil companies in Puerto Rico, including local companies that had construction industry experience but not civil construction experience, and foreign companies trying to take advantage of the construction opportunities. Although shortly lived, these new companies increased the

competition in the island but had lower quality compared to their competitors with more experience because of their lack of expertise prior to the storm.

One of the biggest immediate challenges throughout reconstruction was fixing and dealing with the damage to the electrical power grid. Bigger power plants that generate electricity did not suffer much damage, but the power grid that distributes the electricity did, as shown on Figure-13. Puerto Rico's outdated and unmaintained electrical power grid suffered heavy damage by the strong winds and debris during Hurricane Maria's landfall. This coupled with the fact that their concrete poles failed made it difficult to begin the reconstruction process. The poles failed because they were only engineered to support the electrical cables and not the additional communication cables that were renting space on the poles. The repairs to these poles were still underway a year after the storm as shown on Figure-14.

Figure 4-13: Damage to Electrical Grid

Figure 4-14: Electrical Grid Repairs

The biggest problem with not having power was for the hospital and dialysis centers. Most hospitals had generators, but they need to be refueled. This was complicated without roads and communication, as there was a fleet of people ready to help but no communication. The Army and National Guard controlled and organized the logistic of supplying the fuel to hospitals; however, the fuel supply was not designed with the personal generators of 3 million people in mind. One interview participant believed the "rationing of fuel in fear of a shortage created the problem. People could only get around $20 worth of gas at each visit, so there were long lines at the gas stations as people tried to buy enough fuel for their needs." However, because of the rationings, there never was a shortage of fuel." Water filtration was also negatively affected by the lack of electricity.

The lack of communication was a challenge suffered by every company on the island. Immediately following the storm, the only means of communication was a single radio station.

Cellphone towers were not operational and communication landlines were destroyed. After power was restored, all the communication companies shared their towers so everyone could have communications. In the meantime, the communication companies brought their own generators to support their reconstruction.

Hurricane Irma posed another challenge with the reconstruction following Hurricane Maria. Specifically, there seemed to be more debris from Hurricane Maria than their might have otherwise been if Maria had been a lone storm. When describing this effect, one participant said "Irma loosened up and created a lot of debris. Maria picked it all up and flew it everywhere creating the damage." In other words, there seemed to be more damage to deal with from Hurricane Maria, simply due to the debris that was already scattered about from Hurricane Irma.

4.6 Opportunities Created by Reconstruction

Hurricane Maria also provided opportunities for the reconstruction efforts in Puerto Rico. The research participants responses were analyzed and categorized into five categories; Financial Opportunities, Opportunities with Labor, Opportunities with Equipment, Opportunities with Materials, and Other Opportunities.

4.6.1 Financial Opportunities

Although the devasting effects of Hurricane Maria were felt a year after its landfall, there were some financial opportunities for the construction industry in Puerto Rico. One opportunity that came about was the increase in the volume and price of bids. One contractor said that "before the economic downturn ten years ago, the output of construction in Puerto Rico was $5 Billion. Before the hurricane it was under $1 Billion and right after the hurricane it was around 2

billion." This meant that the reconstruction efforts were helping the construction industry strengthen as more work became available and the construction industry was no longer in a recession. Additionally, being the lowest bid was no longer the deciding factor as companies were able to raise their fees in comparison to pre-Hurricane Maria. Companies now counted with the financial resources and power needed to keep projects from stalling.

As discussed in Section 4.5 Challenges Created by Reconstruction, the construction companies had a low bonding capacity and were not able to participate in the bids for the larger projects. Fortunately, the AGC chapter in Puerto Rico came in and made sure that the Stafford Act was enforced by advocating for the use of local contractors to the best of their abilities. This meant that the only way that local companies could propose on a project was if the large bid was broken down to smaller bids. This strategy proved successful as it boosted the local economy, allowed local companies to take an active part in the rebuilding effort, and avoided larger foreign competitors from taking over the industry.

4.6.2 Opportunities with Labor

Labor opportunities were created during the reconstruction efforts post Hurricane Maria. New construction jobs were created as well as positions with some big enough to last two years. Bigger companies found it easier to subcontract a lot of the work allowing more smaller companies to participate in the reconstruction efforts. Smaller companies were able to keep their employees busy with the new jobs, as also discussed in Section 4.6 Opportunities Created by Reconstruction, to the point of hiring and growing their companies. Every company was fearful, however, of growing too large because of the lessons learned in the last economic downturn. As

a result of the lack of skilled labor, there was a push for vocational schools to provide classes for training of unskilled labor.

4.6.3 Opportunities with Equipment

The opportunities related with equipment were predominately available to companies that owned their own heavy equipment. With the road clearing being the priority post Hurricane Maria, heavy equipment and machinery were in high demand. As discussed in Section 4.4 General Reconstruction Findings. Also, the FEMA funded debris removal was more financially appealing to the equipment operators than their previously contracted aggregate transportation. Not only would the FEMA funded debris removal be more lucrative in value, but the debris weight being transported would be three time less than the aggregate weight. This meant the equipment suffered less for the same amount of usage.

Initially following Hurricane Maria, the available work was predominately exclusive to the debris removal from the roads and highways. This, created an influx in the demand of heavy machinery and equipment operators, as discussed in Section 4.6 Opportunities Created by Reconstruction. This created a major opportunity for the subcontractors that owned heavy machinery as they were able to perform the work themselves or be subcontracted by a different company. Some were even able to upgrade their machinery after selling some their older equipment at a greater price due to their high demand. Some subcontractors used this opportunity to sell larger equipment that had higher costs associated with the mobilization, training, insurance, maintenance, and depreciation.

4.6.4 Opportunities with Materials

The research discovered that the Jones Act restriction, the act mandating that only U.S.-flagged ships be used between U.S. ports, coupled with the congestion of the ports caused a great challenge for material availability and increased material lead times, as discussed in Section 4.5 Challenges Created by Reconstruction. This however, made owners accepting and understanding of schedule delays. A material related opportunity associated with the Jones Act was that higher quality materials were used for construction in the island as they were coming from the United States. This created a cycle of opportunity between the United States and Puerto Rico where the federal funds allocated for Puerto Rico by the federal government would be used to directly help Puerto Rico and indirectly help some business in the United States.

4.6.5 Other Opportunities

Reconstruction opportunities created new endeavors for companies to explore. Companies that previously never ventured into a different field of construction were now able to because if the increase in reconstructive work. This saturation of work also created the ideal contractor market with a work backlog of over a year, something that had not happened in the island in nearly ten years before the economic downturn.

Another opportunity discovered by the research was that most heavy civil projects on government related contracts received an initial automatic schedule extension of three months to offset the challenges with labor, materials, and equipment as mentioned in Section 4.5 Challenges Created by Reconstruction. These schedule extensions were then re-evaluated on a project by project basis to determine how the storm affected each project specifically and be adjusted accordingly.

4.7 Changes to Typical Business Practices

The effects of Hurricane Maria also caused changes to the typical business practices to the companies involved with reconstruction efforts in Puerto Rico. The research participants responses were analyzed and categorized into five categories; Financial Changes, Changes with Labor, Changes with Equipment, Changes with Materials, and Other Changes.

4.7.1 Financial Related Changes to Typical Business Practices

This research discovered that there were a number of changes that occurred to the typical business practices as a result of Hurricane Maria. Contracting methods, such as project delivery, changed significantly during this time. For example, prior to Hurricane Maria, Design-Bid-Build was the traditionally approved project delivery method; however, during the reconstruction process Guaranteed Maximum Price (GMP) and Design Build were being accepted as a new norm. For instance, one contractor described their process on a Design Build project; "we received a request for Proposal (RFP) from the owner, then our estimating department provided an estimate. In a matter of hours, the owner would issue a notice to proceed with the instruction of using previously accepted means and methods to perform the work." This Design Build process is shown in Figure 4-15 below. Specifically, this type of change was necessary for the rebuilding to move forward quickly and ultimately sped up this project by six times. However, this method was only successful with contractors who had previously performed work with an owner, and the owners were comfortable using the previous means and methods as an acceptable benchmark for the work.

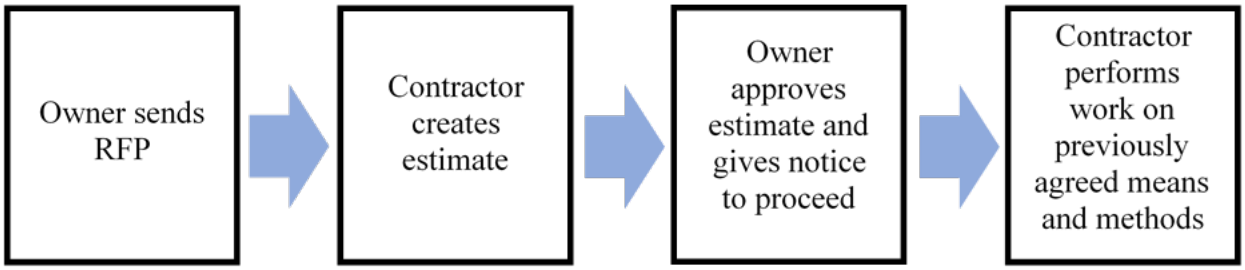

Figure 4-15: Design Build Process

Another financial related change to the typical business practice was the volume and price of bids increasing with profit being around 10% instead of breaking even. Surprisingly, before the storm, contracts had price adjustment clauses, but they did not specify whether or not they applied in a hurricane event.

4.7.2 Labor Related Changes to Typical Business Practices

The labor related changes to the typical business practices found in the research were related to the amount of available labor. Some companies increased in size and were able to have their own skilled labor on payroll by paying competitive rates. Other companies were able to pursue more work by subcontracting as much work as possible. This led to an increase in employee personnel.

4.7.3 Equipment Related Changes to Typical Business Practices

The equipment related changes to the typical business practice found during the reconstruction process included a shift to heavy equipment ownership in lieu of rentals. The purchasing of equipment for contractors that lacked the cashflow for these purchases led to acquiring debt to perform the transactions. This was a dangerous practice that proved fatal for some companies in the past. A tenured subcontractor said in the past “when the industry has its

surges, any individual would claim to be a contractor and take out a loan to buy some construction equipment. This would ruin and inundate the market with lots of heavy equipment. When the industry would level out or another downturn came, the [companies] would have to sell their equipment at a loss and destabilize the economy even more." Fortunately, the banks and lending institutions have implemented stricter requirements prior to lending that have helped stabilize the market by only allowing the most qualified subcontractors to enter. The amounts of debt a construction company has can cripple the economy. If debt is acquired to purchase the equipment, then the company will be forced to make drastic measures when the market slows down. If the equipment is owned and the company does not have debt, then adjustments can be made by reducing the work hours, personnel, and even equipment to avoid the drastic measures and stay afloat.

Another equipment related change caused by Hurricane Maria was the increase of large commercial generators being used by businesses. With the unreliability of electricity caused by the damages to the power grid, as discussed in Section 4.5: Challenges Created by Reconstruction, many owners incorporated backup generators into the design of their ongoing and future projects. This was done to diminish the number of blackouts experienced after the electrical grid was restored. An example of this is shown in Figure 4-16 below. Some owners took additional measures beyond installing generators by incorporating a combination of solar panels and batteries into the electrical design of their buildings with the hopes of mitigating the risks associated with another potential fuel rationing event that would limit the amount of fuel needed to power their generators.

Figure 4-16: Generator Being Installed in a Mixed Use Development

4.7.4 Material Related Changes to Typical Business Practices

Changes related to material in the typical business practices came about during the reconstruction process. As previously mentioned in Section 4.5 Challenges Created by Reconstruction, material delays were a challenge due to the congestion at the ports. This led to material substitutions with similar shorter lead time items and materials being approved to replace the longer lead time items and materials. In cases where the material could not be substituted, schedule extensions were granted and were given on a case by case basis. Some contractors benefited from the twenty-five to thirty percent increase in material prices due to the markups that were already included in the contracts.

4.7.5 Other Changes to Typical Business Practices

Design parameters were also affected as a result of Hurricane Maria. Architect and Engineers have raised their minimum design standards and are now designing buildings to sustain 200 MPH winds. These were owner driven changes and were implemented in ongoing construction projects at the time of the hurricane.

The lack of communication caused by the damage to the communication towers in Puerto Rico changed the way tests and inspections were handled. For a time, aggregate, rebar, and concrete tests and inspections were not able to be made due to lack of available personnel and communication. This helped reduce further delays in the reconstruction process but left the door open for challenges in quality. Some of the owners, such as the Federal Highway System, had no choice but to trust contractors, due to the of lack of inspectors, if they wanted their projects to move forward. As a result, several audits were held once the communication systems were back online and the day to day operations resumed.

4.8 Industry Professionals' Recommendations

The interview participants had future recommendations based on their experience with the reconstruction process. Below are some of the most common recommendations for construction companies given by the research participants.

- Be prepared for the unknown. Have an emergency action plan in place prior to the disaster taking place. Parts of the emergency action plan must include a determined meeting place where the personnel can meet after the storm and fuel storage system.
- Electrical power will be affected. Make sure an alternate source of power is available for the business, such as a generator.

- Communications will also be affected. Consider investing in more satellite phones prior a future disaster event.
- Have enough cash to be able to maintain business operations. Cash will be crucial at this time as electronic transactions will be limited due to the lack of electricity.
- Avoiding debt is crucial to surviving in times of economic slowdowns. Having the equipment paid off will help avoid going under during these times.
- Fuel will be limited so have sufficient gas and diesel storage distributed with the equipment before the storm hits.
- Allow employees to take home the heavy equipment before the storm or allow them to pass the storm at the office so they can help clear the road debris after the storm. This will allow the employees to partake in the reconstruction process earlier by pairing the equipment with the operator faster.
- Heavy equipment will be in high demand during the initial reconstruction efforts. Consider owning heavy equipment so normal business practices are not affected.
- The construction industry will boom during this time. Companies need to be able to prioritize to avoid lower quality control by being stretched too thin.
- Reconstruction management is a learning experience. To avoid making the same mistakes in the future learn from the challenges that will arise and apply the lessons to the typical business practices.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Research

The purpose of this research was to identify some of the challenges and opportunities that were encountered within the Puerto Rican commercial and civil construction industry during the reconstruction efforts following Hurricane Maria. A comprehensive literature review was conducted in order to determine and understand the damage that occurred to the island following hurricanes Irma and Maria. The literature review also explored what academic related efforts had been performed in understanding what was going well with the reconstruction efforts in Puerto Rico and what areas still needed improvement. For this research, the reconstruction events occurring with the first year after the passing of Hurricane Maria were used as a case study, and interviews were conducted with individuals directly involved in the reconstruction efforts. The data from these interviews was sorted in order to extract results and draw conclusions. Judging from the results contained in this research, it was evident that financial, labor, equipment, material and further challenges and opportunities were encountered within the construction industry of Puerto Rico during the reconstruction efforts. The research found how the commercial and civil construction industries have been affected by the reconstruction efforts in Puerto Rico and highlighted the strategies and processes used by the construction industry professionals that have been effective and/or ineffective in rebuilding the island following Hurricane Maria.

5.2 Lessons Learned

The extensive and consistency of affirmative responses regarding the financial impact of Hurricane Maria on the commercial and civil construction industry of Puerto Rico informs us that the storm was overall a positive event for the construction industry of the island instead of a negative one. Prior to the storm, Puerto Rico's economy was in a recession and limited amounts of construction work was available and companies were employing the minimum amount of personnel needed to maintain daily operations. After the storm, the large amounts of reconstruction related work boosted the economy of the industry and companies began growing in size and employing more personnel to fit their business needs.

The vast amounts of reconstructive work created by Hurricane Maria identified a deficit in skilled labor in Puerto Rico. Due to the low availability of work prior to the storm, many industry professionals emigrated the island in search of employment opportunities. This helped balance the labor force in the island with the number of available jobs. When Hurricane Maria made its landfall on Puerto Rico, the supply of trained industry professionals available in the island were not sufficient for the demand created by the reconstruction. Most companies invested time and resources into creating training their personnel and initiated a push for vocational schools to provide training classes to better prepare the unskilled labor force.

Immediately following the storm, all the reconstruction efforts were focused on the debris clearing and removal from the roads and highways. This created an ample demand for heavy equipment and machinery throughout the island. Because the debris weighed less than the typical aggregate use, the heavy equipment could be used longer without the wear and tear associated with aggregate transportation. Companies that owned their own equipment were able to take the most advantage of this opportunity. These companies did not have to pay the inflated rental and

lease prices associated with the higher demand and were able to sell the older equipment at a better rate than rates previous to the storm.

Material availability was limited, and their lead times were increased directly because of Hurricane Maria. Two factors played a major role in contributing towards this situation: the tax placed on inventory by municipalities and the congestion at the ports following the relief efforts of the storm. The tax on inventory hindered the availability of storing materials before the storm as companies only kept enough inventory to maintain progress on their current projects to avoid any financial penalties. This led to companies not concerned with acquiring the post hurricane materials that are typically needed after every storm. Following the storm, the ports were overburdened with the influx of relief shipments coming into the island. At this time, the power was given to the Federal Emergency Management Agency (FEMA) whose priority was on basic supplies, such as food, water and medicine, for those affected. This impeded any progress from being made on projects that were ongoing prior to Marias's landfall.

5.3 Implementation of Research

Centered on the responses given by the research participants the following suggestions for companies to explore in the event of another hurricane were made. These recommendations were based upon the general consensus of the research participants and may be applied in preparation to other natural disasters besides hurricanes.

Every company had issues with communication after Hurricane Maria's landfall in Puerto Rico. The issues with communication were a result of the damage to the telecommunications infrastructure. Being prepared with different communication methods in place was the most mentioned response to overcome the challenges associated with this issue.

Companies should implement practices like having a predetermined meeting location and time established before the storm, the use of generators to electrically power their place of business and its communication systems, and the use of satellite telephones to diminish the challenges associated with an inoperative telecommunications infrastructure.

It is recommended that construction companies take advantage of their resources following a hurricane disaster. Heavy equipment for debris removal and pickup is in high demand and the majority of the hurricane response efforts are dedicated for this task. Companies should place their heavy equipment in strategic locations, such as the homes of the equipment operators, to condense the amount of time needed to get their business operational after a storm. This allows the operators to have access to the machinery and ease the execution of a company's emergency action plan.

As the construction market is on an upward trend following a hurricane disaster, some construction companies may consider it the time for growth and expansion. Though this strategy may allow the company to take on more projects, growing at a more cautious pace may reduce risk of being oversaturated in personnel when the market slows. More work typically led to companies hiring more personnel to fulfill some roles, but the participants suggested that companies need to have a long-term mindset during this time and be attentive of the loyal employees and the repeat business clients.

5.4 Study Recommendations

Based on the findings of this study the following suggestions were made for different entities involved in the reconstruction process following another hurricane disaster. These

recommendations were based upon the interpretation of the findings and may also be applied in the preparation processes regarding other natural disasters besides hurricanes.

In disaster reconstruction cases that take place in the United States, FEMA typically reimburses the states after the reconstruction is done. This study found that FEMA would have to pay the contractor directly because Puerto Rico had no cashflow at the time of the reconstruction efforts. This significantly slowed the reconstruction efforts as FEMA needed to audit the companies they released the funds to, in order to know that the work was completed. Having an existing relationship between the owners and contractors helped speed up some aspects of the reconstruction process, particularly in projects dealing with road and bridges repairs. Because FEMA will be managing the funds for the reconstruction efforts, it is recommended that a pre-approved list of local contractors that underwent the audit process be made available to FEMA prior to the storm. This list may also include pre-approved construction means and methods as an acceptable benchmark for the reconstruction.

In the year following the reconstruction efforts of Hurricane Maria, the research found that a shift to design build project delivery, in lieu of design-bid-build, proved to be more efficient at reducing the turnover time. It is recommended that this tactic be established as the norm in times of non-emergency so these benefits may be enjoyed continuously. Other project delivery systems may also be explored to determine its efficiency in comparison to the traditional design-bid-build delivery system.

The Stafford Act also proved helpful as the funds made available by the federal government aided the reconstruction efforts. The study found that the local AGC chapter enforced this law with the use of local contractors to the best of their abilities to fulfill the law's purpose of having businesses functioning on their own after a disaster. It is recommended that

the Stafford Act continued to be enforced, in this manner, but also allow other contractors from the mainland United States to aid when needed. This will be more beneficial for the industry in the long run as the local contractors will benefit from the boost in the economy.

Payment delays from the state government kept several companies from participating in the reconstructive efforts funded by the state. The companies expressed a lack of motivation in helping in future events because the payments had taken so long to be made, and in some cases, they were still awaiting payment from previous work. It is highly recommended that any entity acting as the owner and funding the reconstruction effort prioritize making efficient payments following completion of work. One tactic that the research found to be successful in this scenario was awarding jobs via a letter of contract where they reconstruction contractors could bill up to a specified amount.

The Puerto Rican tax on inventory and stored materials has created negative consequences in the reconstruction process as it led to empty warehouses without extra material and limited inventory after Hurricane Maria. Waiving this tax during hurricane season or exempting certain materials that are fundamental to the reconstruction efforts is recommended to avoid this challenge in future hurricane disaster events. Extending the period of time before the equipment is taxed may also help increase the amount of materials that are readily available after a hurricane event.

5.5 Research Contribution

The literature review for this research revealed that relief funds are available to provide resources that facilitate disaster response and coordinate recovery initiatives after a natural disaster event. These funds can be used to alleviate the financial burden to the affected area as

well as for financing the reconstruction efforts. This research sought to discover how commercial and civil construction industry professionals and their businesses were affected during the reconstruction process. The research further explored what practices proved to be most successful for the construction companies during this time. It was discovered that there were both challenges and opportunities related to the reconstruction that can obstruct or facilitate the way the reconstruction is managed. These findings show practices that companies can implement to better manage the resources including the disaster relief funds. This is important for places, like Puerto Rico, that have large amounts of debt because it helps to establish a lean reconstruction process where waste can be eliminated leading to a minimum cost and maximum value by considering the nation's needs.

5.6 Future Study Recommendations

This research was exploratory in nature. It focused on using qualitative methods to identify the effects and strategies following Hurricane Maria in the commercial and civil construction industries of Puerto Rico, rather than testing an existing theory used in managing hurricane reconstruction efforts. Future research can carry out the next step and study the effectiveness that specific strategies have on post hurricane effect management. This study should be performed with the use of quantifiable data and statistical evaluation.

Another recommendation for additional research would be to study the effects Hurricane Maria had on other industries of Puerto Rico. This would involve looking at other industries that may or may not have benefited as much from the storm as the construction industry did. Studying this more in depth and comparing those results to the results found in this research may give a clearer understanding the overall effects hurricanes have on a nation's economy.

It is recommended that future research be conducted to analyze other types of natural disasters and their effect on the construction industry. With the focus of the research being on Hurricane Maria, the reconstruction data gathered was focused on disasters related to strong winds and flooding. An additional study may focus on different types of disasters that are prominent in the island.

It was discovered during the interview process that most of the research participants had experience with hurricanes prior to Hurricane Maria. These previous hurricanes also affected the construction industry of the island. A deeper study exploring the repetitive process of building and rebuilding through multiple hurricanes might reveal how the effects of previous hurricanes compare with the effects from Hurricane Maria as well as provide a better understanding of the cyclical effects on the construction industry and the rebuilding processes.

The research discovered that a successful tactic one company practiced to overcome the availability of skilled labor in the island was to hire the relatives of the current employees and use them to train the new personnel. A future study could attempt to replicate this finding and evaluate it as a potential solution to the worldwide skilled labor crisis.

Finally, future research comparing and contrasting the unique nature of disaster reconstruction for a United States territory island compared to the response in the mainland United States where hurricanes have hit in the past would be of benefit to the construction industry. Part of this exploration would include a more detailed investigation into the way that funds are allocated and paid through a state versus a territory that was cash strapped.

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