Disaster Relief Shelters for
Hurricane Victims in Puerto Rico

An immediate and temporary design with a lasting impact
for remote victims.

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1.0 Abstract

Natural disasters, on a global scale, are increasing in severity and frequency yet rural communities, the most vulnerable, are still suffering in the aftermath of hurricanes simply because effective help does not come fast enough. A more immediate solution is needed in order to keep people safe and stable as they wait for professional aid. Because disaster shelters are not a new concept, this study analyzes multiple precedents that have been used throughout the world. Through this research, the study looks to find what is being done well, and what is not. What do current models of disaster relief look like? Why do some work well while others fail? What does the specific context of Puerto Rico have to offer, and what does it lack? What types of shelters have worked in similar locations and what is successful or unsuccessful about them? Why? What are the unmet needs of hurricane victims in Puerto Rico and why do they remain unmet? How can a design empower a community?

Through an analysis of contextual factors, related literature, and observation, I distilled parameters to evaluate current common disaster relief models as well as through my own contribution to the field. By considering factors such as climate, government, and local culture as well as functionality, a more accurate set of parameters are established and beneficial solutions will be reached. To determine this framework, I analyzed existing immediate and temporary disaster relief shelters from around the world to identify why certain elements were successful and why some were not. By combining effective systems from these shelters, I was able to come up with a design that met all of the established criteria for hurricane victims in Puerto Rico. With this information, I began prototyping and testing materials. Through extensive trial and error of material combinations and construction systems, I created a compact, effective, and unique temporary shelter.

As it stands, in failing disaster relief models, victims remain victims. I aim to change this outlook by empowering families and communities to provide their own small scale shelters. By allowing people to contribute to their own wellbeing, buying their own emergency shelter prior to an impending disaster, a shattered economy can begin to rebuild faster, community spirit is enhanced, and local culture can flourish.

1.1 Introduction

Disaster response and reconstruction in the United States suffers from a number of issues. All of these slow recovery, to a point where it can last for months or years from the date of disaster. This is particularly true in poor remote communities that are susceptible to the greatest damage. While there are a plethora of examples of slow recovery around the globe, Puerto Rico is an excellent case to study because it is an extreme. The islands are directly exposed to severe tropical storms and are constantly suffering from various infrastructural and political issues. Depending on the preparation prior to the event and the severity of the storm itself, it can take weeks or months before aid is able to access some hurricane victims, if they even know where they are. After Hurricane Maria in 2017, the archipelago of Puerto Rico was left helpless for days. In some rural areas, it took months for aid to arrive.. Puerto Ricans expected aid from the United States, but instead, some were left to fend largely for themselves. In the disaster recovery efforts, there were two fundamental problems: the lack of immediate aid and the utilization of a top down approach. As a result, residents were stripped of their responsibility, and were left feeling powerless and desperate. As hurricanes are projected to increase in severity and frequency, adequate disaster response, specifically pertaining to housing, is becoming more urgent than ever. Disasters will continue to occur, and without a system that involves and appreciates the victims it is designed to help, death counts and poverty levels will continue to increase. RPRAC, the Resilient Puerto Rico Advisory Commission, released a plan in the summer of 2018, to build back better, rather than just replacing broken systems. RPRAC executive director, Malu Blazquez Arsuga stated, “The Commission firmly trusts that the set of recommendations presented in the ReImagina Puerto Rico project provides an initial and clear route to the long-term recovery and reconstruction of Puerto Rico” (Fiol-Costa, 2018). Though they aim to increase resilience, there will inevitably be a time after each hurricane when people do not have a place to live, whether it be a single night or far longer. The question remains unanswered. What will be done to shelter families in this time of limbo, after a storm, but prior to government intervention?

adjunas

guaynabo

1.2 Research Question:

Having identified a significant problem in major disaster relief efforts in Puerto Rico, the question becomes, *'what can we do about it?'* The government cannot, and should not, be responsible for fixing 100 percent of the aftermath caused by a disaster. This means people need to help themselves. In order for this to be possible, people need to be willing. Luckily, this has been witnessed repeatedly in post-disaster scenarios. However, in order for individuals within communities to be able to begin contributing to the relief effort, they need to feel relatively comfortable and safe. This starts with shelter.

How can we create effective temporary structures to help remote hurricane victims provide immediate shelter for themselves, rather than relying on external aid throughout a disaster?

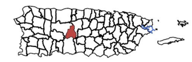
An effective shelter is safe, comfortable, functional, and easy to use. As a temporary shelter, it must be able to perform its functions for at least a month, but should be prepared for longer uses in extreme scenarios. Remote victims are those who are not easily accessible to traditional aid and can more easily become stranded after a disaster. As an immediate system, the shelter should be deployable within minutes of need caused by any weather event. External aid is considered to be any help from individuals or organizations outside of a community, from supply deliveries to evacuation coordination. As a temporary shelter, it should only be expected to be used until external aid arrives. This should be considered around one week, but in extreme situations should be usable for longer.

2.0 Context

2.1 History of the Caribbean

White sand beaches dotted with palm trees, turquoise waters, and endless sunshine are often what comes to mind when one thinks, "Caribbean." But one season every year, Mother Nature threatens to ravage those islands. The sun is blocked, waves surge and crash into the coast, and beaches disappear under rubble and debris. As the climate crisis progresses the threat of devastating hurricanes is becoming stronger, preventing necessary economic and infrastructural growth. This has become the norm for the Caribbean islands, and they have become accustomed to dealing with this on their own, despite being major suppliers of multiple resources used by the rest of the world. From slaves to sugar cane, the

Carribean has been exploited for their natural resources since settlers first arrived. Because most of these lands are, or were, colonies of other countries (i.e., Puerto Rico being a commonwealth of the United States) and have historically been ragdolls, at the mercy of their respective ruling governments. “The island’s people and land have been treated like a bottomless raw resource for the mainland to mine for over a century, never mind the devastating economic consequences. Interestingly, the global climate crisis, which is now hitting Puerto Rico with disproportionate fury, comes from a strikingly similar logic” (Yeampierre and Klein, 2017).



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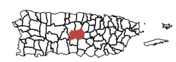
2.2 Culture + Politics of Puerto Rico

As a commonwealth of the United States, the federal government and the government of Puerto Rico have been intertwined for over 100 years. Their relationship has been rocky, and there are multiple instances that provide evidence of deeply rooted structural issues. Founder of WAI Think Tank and Puerto Rican architect, Cruz Garcia, states, “It has been a sort of semi-autonomous government. We pass laws, but there is no sovereignty, so we can’t trade, which makes it impossible to grow the economy in a sustainable way because of all the limitations.” He continues to say, “Real-estate development [and] even tourism are hampered by this colonial condition, too. Efforts made to develop areas with wealthy tourists, while marginalizing low, and moderate-income locals, to the risk-prone margins” (Gendall 2017). The Jones Act of 1920 restricts the shipping of goods between the coasts of the United States to exclusively U.S flagged vessels, rather than allowing trade from foreign vessels. After Maria, President Trump refused, for multiple days, to lift the ban on foreign trade and delivery of aid to Puerto Rico, despite having immediately waived these restrictions to increase aid deliveries to Texas and Florida when they were faced with a similar disaster.

Increasingly extreme climate events tend to reveal socioeconomic disparities. In Puerto Rico, Hurricane Maria did just that, exposing the vulnerabilities of disadvantaged populations. “There were so many poor people living in flood-prone areas,” explains Garcia. “In areas developed on former river beds, which are the first to flood, people put poor people there,” he adds. “Puerto Rico has had a very laissez-faire attitude to development. Whoever has the money makes the decisions, so they put the most vulnerable people in the most vulnerable places.”

This abuse stems from the long standing debt crisis that Puerto Rico has been dealing with. The power of local officials is decreased, simply because it is seemingly impossible to build a local economy, keeping money within Puerto Rico rather than allowing foreign investors to siphon their profits back out. Because the government is financially vulnerable, they are not able to focus their efforts on policy that will better both their housing and disaster relief situations. If people's basic needs are not met, it is impossible for people to turn their efforts to develop other pressing long term political solutions. On top of this, it becomes increasingly difficult to acquire and distribute disaster relief funding. When funds are acquired, it is given to those who can most quickly increase tourism and other sources of income, rather than the most vulnerable and helpless population, the poor. Building codes are weak and often not followed, increasing the damage incurred by 'natural disasters'. "There's no such thing as natural disasters; they're all man-made because we build where we shouldn't—like in flood plains—and defy Mother Nature," says Miguel Del Rio (Smith, 2019). "As architects and designers and planners we need to identify which areas we shouldn't continue to build upon and find a higher plain or higher elevations or more stable grounds so we can minimize the damage. The events are going to continue to happen" (Budds 2018). The Puerto Rican people, unfortunately, have seemingly become accustomed to this negligent treatment, but have since developed a culture of love and comradery. They are proud of what they have, regardless of how much or how little it is. For instance, upon visiting the islands, I witnessed a man working tirelessly under the sun with his friend to polish his car, despite it being covered in rusted out holes and patches of peeling paint. In another case, I saw a man tending meticulously to his lawn and garden, despite his house not having a roof. In the instances of disaster, forced to fend for themselves, communities bound together, offering what labor and resources they could muster to help their neighbors. After all, anything helps after being leveled by a hurricane. This can include painting the house and fence posts or clearing debris from the yard just to make it feel like home again.



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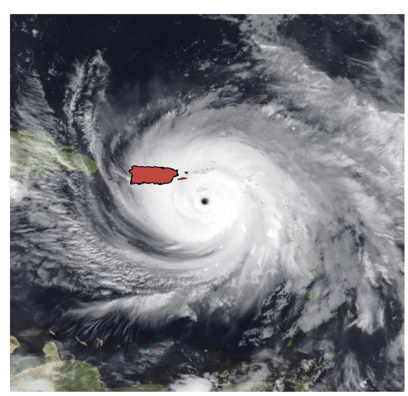
2.3 Post Maria : Nuestra Maestra : *"Our Teacher"*



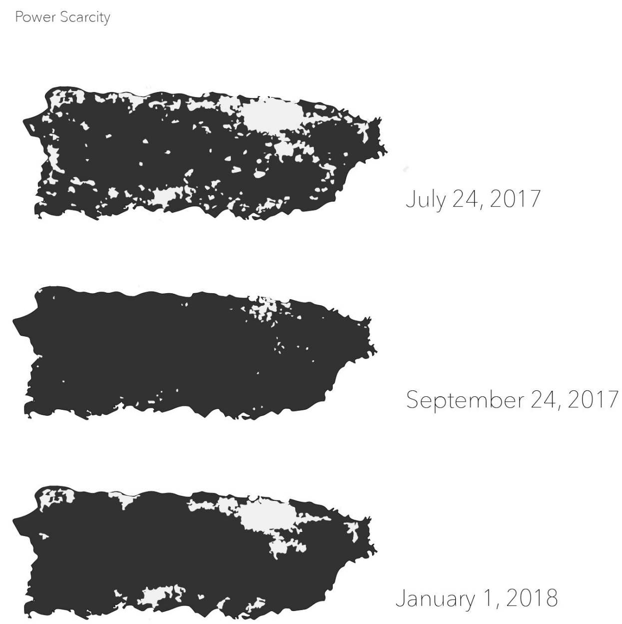
As skies cleared and people emerged to assess the damage from the storm, it became clear that Puerto Rico was in a situation they had never before faced. Maria had lingered for more than a full day causing unprecedented damages, both physical and emotional. Heavy winds and rainfall - over three feet in some areas - led to destruction of homes, widespread flooding, and landslides. Eighty percent of crops were destroyed, valued at over 780 million dollars (Robles and Ferré-Sadurní 2017). 100 percent of the power grid was destroyed, leaving all 3.4 million residents without power (Grant 2017). Some municipalities reported that 80-90 percent of all buildings were destroyed, with an estimated 9,000 people seeking refuge in FEMA shelters, with many being turned away (Grant 2017). Although the exact numbers are still highly disputed, in all Hurricane Maria caused damages estimated to be worth 90 billion dollars on top of contributing to the death of close to 3,000 citizens (Darrah 2018).

Relief and recovery efforts were slow, not only because of the scope of disaster, but because funding was painfully slow to reach victims. The United States government allocated 40 billion dollars for recovery in Puerto Rico, but the bulk of that money did not reach the island for months, "mostly due to the time-consuming process put in place that requires its officials to submit a series of plans that outline how they expect to use the money and await federal approval" (Acevedo 2019). This was only the beginning of the problem. Forty-four percent of Puerto Ricans live below the poverty line, over a million citizens live in informal housing, and 55 percent of all of the homes in Puerto Rico are not built to code. (DADS 2010**).** These are the people which Maria hit the hardest. These factors led to difficulties for victims in receiving aid from FEMA. Because their homes were built informally, many people had no official title or deed to their property. Some did not have an address. These, among others, are requirements to receive FEMA funds.

arecibo

The 1920 Jones Act, a law that requires ships carrying goods between U.S. ports to fly the American flag, follow American laws, and be built, owned, and operated by American citizens, prevented supplies from reaching Puerto Rico. The government waived the Jones Act for ports along the Gulf Coast after hurricanes Harvey and Irma, but put up a fight when it came to Puerto Rico. On September 25, five days after the hurricane made landfall, eight members of the House of Representatives wrote to President Donald Trump, requesting he waive the Jones Act for a year. Three days later, he waived the Act for 10 days, allowing the delivery of much needed emergency supplies. However, this raised a new problem once on land. How would these supplies be delivered? Roads were impassable, trucks did not have fuel, and there was no communication accessible to determine where the greatest needs were. Over 10,000 shipping containers, full of supplies, fuel, and food, sat uselessly at the Port of San Juan because the islands' infrastructure would not allow for transportation further inland. If they had fuel, truckers were still unable to navigate what was left of the roads, through landslides, downed trees and powerlines, flooded rivers, and countless other hazards. These factors left much of the initial relief in the hands of local communities. While FEMA supplied their unmistakable blue tarps to those who qualified, local brigades formed to begin their own restoration efforts.

The relief process in Puerto Rico, after Hurricane Maria, was painfully slower in comparison to other U.S. based disasters. From the time the Hurricane made landfall in Yabucoa, it took three days to reopen the Port of San Juan, five days for any FEMA administrators to visit the victims (Brock Long, former American Emergency Manager and Administrator for FEMA, visited for less than 12 hours), eight days before the aid ship, the USNS Comfort, was deployed, and another week before it arrived. It took nearly two weeks for the President of the United States to visit the island, where he reportedly tossed rolls of paper towels and candy into a crowd of Puerto Ricans (Meyer 2017). Three months after the disaster, forty-five percent of Puerto Rican electricity customers, more than 660,000 U.S. citizens, still did not have power. Customers were comforted only with predictions of another eight months before the network was back up to full capacity (Schlanger 2018). See the *Power Scarcity* diagram to the right, illustrating a satellite photo of which parts of the islands had power at night, on certain days.



The prolonged period of time in which victims remain without shelter or other common utilities increases the impact of the initial disaster exponentially. Currently, aid trickles down from high up in the government until it reaches those in need. This strategy is unorganized and slow, rendering it, in some cases, ineffective. If the recovery system is to continue operating in the same way, the need to provide a more easily accessible and usable shelter is increasingly pressing. This is only possible with a community based, bottom up approach. By eliminating, for a time, the need to locate and trek to a public shelter, the hope is that people can more quickly begin to undertake recovery tasks in their own communities. The faster this is done, the less time people will remain in such dangerous conditions. “Public health officials and health-care providers must recognize that the mortality and morbidity risks associated with hurricanes extend beyond the impact phase. Efforts to minimize injury and other health risks for both disaster-relief workers and the general population are crucial. These risks include electricity hazards, floodwaters, lacerations from storm debris, operation of motorized vehicles, use of sump pumps and generators in confined spaces, and exacerbation of existing or unknown medical conditions as a result of fatigue, stress, or unavailable medical support” (MMWR 1989).

2.4 : Contextual Conclusions

Through the analysis of Puerto Rico's history, culture, politics, and experience with Hurricane Maria, I have made several conclusions as to what elements would create a more useful and beneficial shelter. First, a shift of the general approach to providing a shelter to the victim is necessary. Instead of forcing families to walk for miles through dangerous conditions to reach a public shelter, providing a shelter they can use without relocating will improve morale and increase the speed of local recovery. Secondly, the speed with which this happens depends on how quickly the victim feels comfortable and safe. To ensure the greatest maximum speed at which this can happen, I propose that the shelter is accessible prior to the disaster event, starting in the hands of the end user. Next, the shelter should be designed primarily to benefit those in the least accessible areas of the islands, the mountainous regions. Recovery is slow and unorganized, sometimes leaving people stranded for months. Because of this, the design should also allow for additional reinforcements to be added to the structure or the structure be modular or additive itself. Lastly, as the government is not likely to change their structure in terms of how they deal with these disasters, this shelter must be affordable to the user. As they will purchase the shelter for themselves, using inexpensive and durable materials, the final cost of this product should be reasonable, relative to the median household income of around $20,000 per year or less (DADS 2010**)**.

3.0 Literature Review

3.1 Introduction

We often think of disasters as statistical phenomena in that their severity is quantified by wind speed, seismic force, financial cost, and death toll. However, due to the scale of the events and their aftermath, we cannot as easily quantify their physical, psychological, and emotional repercussions. The reconstruction of houses and humanity cannot be addressed by simple statistics.

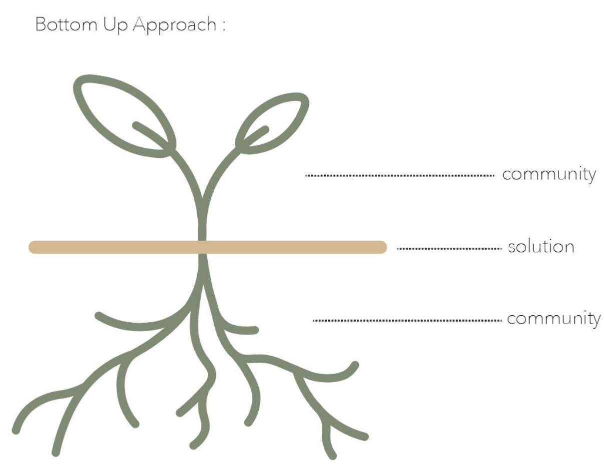
Disaster shelters have been a topic of design for quite some time, bringing about many different systems and strategies for relief, though nearly all of them come from the outside-in. Analyzing the most innovative and effective shelter systems, as well as precedents in humanitarian design, allows me to provide an immediate post-disaster design that helps remote victims of hurricanes in Puerto Rico construct shelters easily and quickly, and store to reuse, themselves, rather than being exposed to the elements as they wait for external aid.

I have organized my sources into four main categories representative of the phases of design and their application on location. These categories encompass the entire process from creation to deployment that determine how effective or beneficial the product will be to the end user. These categories include the approach, design and construction systems, materials, and the post-disaster timeline. The approach section focuses mainly on the lenses used to approach designing for victims in underserved communities. The design systems section focuses on different strategies and projects aimed to benefit a similar demographic, using passive systems to create mobile, temporary, effective, and simple designs. The materials and construction systems section analyzes different materials and construction methods used in designing for immediate relief for disaster victims. The post-disaster timeline section outlines the current way we respond to disasters, highlighting a need for a better system. Though not structured as such, each of these sections feeds into the others, responding to the effects of each factor on the overall design process.

3.2 Bottom Up Approach to Recovery

"Relying on government aid is perpetuating the colonial Band-Aid"

- Jonathan Marvel



Currently, disaster recovery takes place in various stages and to different extents depending on the level of organization in the affected area (Alexander 2002). The process in many cases, such as New Orleans after hurricane Katrina, is far from perfect (Wachter and Birch 2006). Though it may seem like an obvious element in the design process of disaster shelters, the designers' duty to serve the target community responsibly often gets overlooked (Epps 1998 and Pelling 2012). Shigeru Ban noticed the apparent detriment to the community that disaster shelters were causing when he visited Rwandan refugees in 1994 (Aspen Art Museum 2014). Afterward he began an entirely different approach to disaster relief, one with social responsibility at the forefront of the design.

After a disaster, or any situation in which people are left homeless, it is important to think about what happens to the culture and spirit of the victims. "The integration of culture, art, architecture, economy, ecology, health, and education, are absolute necessities," in approaching disaster relief (Chun 2015). The effects these elements have on the victims, especially children, in recovery is significant yet often overlooked (Epps 1998). In order to ensure the needs of the target communities are met, the best practice is to utilize a socially inclusive and geographically focused design strategy. There are a multitude of components involved in designing for a disaster that are specific to each affected location that an outsider would not even consider. Using a community focused, bottom-up, process involves the victims, producing not only a better design, but one that provides a sense of empowerment in the community (Day 2003).

There have been instances in Puerto Rico, for example, that communities have been forced into adopting this approach, simply because external aid never reached them. After Maria, groups of locals formed groups called Brigades and walked around their communities and to neighboring towns, helping wherever they could. Similarly, Centros de Apoyo Mutuos, or CAM's, were formed by communities, for communities (Crabapple 2017). This is a rapidly growing network of autonomous, self-managed aid *projects* that now exist all across the island in towns like Caguas, Río Piedras, San Juan, Mayagüez, Utuado, Lares, Naranjito, and Yabucoa (Crabapple 2017). These people, and organizations, know the effects of the shock doctrine and the systematic oppression of disaster stricken communities, but often find themselves powerless, despite their efforts (Klein 2007 and Bonilla and Lebron 2019). The bottom-up approach often involves a local workforce (Chun 2015), that can stimulate a disaster-shocked economy by involving local work forces and buying local materials (Aspen Art Museum 2014 and Serageldin 1997). This often gives the victim the feeling that, by being involved in their recovery, they are therefore in control of their fate (Aquilino 2011). Putting power in the hands of the affected community has all the aforementioned benefits, as well as potentially creating a more sustainable solution. Rather than waiting for a solution from an external source, local systems and materials can be used immediately (Aquilino 2011 and Chun 2015).

Our current approach to disaster relief is flawed. To more effectively provide immediate shelter in post-disaster scenarios, involving the affected community, not only in the planning and design but in its construction, is a necessity. Efforts are being made to design post-disaster housing to make more of an impact than a simple shelter. Stimulating the economy, utilizing local labor forces, and constructing with locally sourced materials, the bottom-up approach is a more effective and more sustainable way for victims to begin to help themselves, rather than relying on external sources of aid.

3.3 Design + Construction Systems

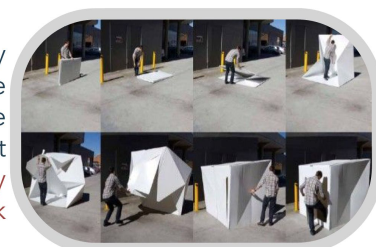
Assessing the damages of a hurricane, designing a plan of action for recovery, then actually implementing the plan, takes time. During this time of limbo there are people struggling without resources, specifically shelter, making it a vital time of need (Hany Abulnour 2014). Having an immediate shelter solution for the affected community is critical, not only to their physical safety but also for their psychological stability (Hany Abulnour 2014). The thought and process of designing for the first hours and days of recovery is often not thought through prior to the event, and therefore is rarely successful (Crabapple 2017). Involving the community in planning for, and recovering from, disasters has many benefits in addition to speeding up the process. "Communal participation helps establish a strong identity relationship between the occupants and their new dwellings" (Hany Abulnour 2014). Being comfortable and enjoying the feeling of safety stimulates action for further recovery, physically and emotionally. This, "should be encouraged to begin immediately at the soonest disaster aftermath occasion and not postponed to later phases" (Hany Abulnour 2014). These dwellings are often not intended to last more than a couple of weeks, at most, but depending on the situation, victims can find themselves there for much longer than anticipated (Borges, Mitchell, Garcetti, et al 2018). In order to react to unstable conditions, it is becoming more common practice to design for mobility. Homeless people, or disaster refugees, benefit from mobile shelters by being able to move to various locations if they desire to be closer to friends or family, or simply if their initial position becomes unsafe (Craven 2003). Due to the likely lack of power experienced in the wake of a natural disaster, passive design strategies are both practical and necessary for comfort. Regardless of a shelter's mobility, or lack thereof, there are ways to utilize natural sources of heating and cooling to improve the dwelling's desirability, without using energy (Osborn 1983). Orientation to the sun, air circulation, and the utilization of shade are all easy to accomplish (Crosbie 1998), and their impact is astronomical (Osborn 1983). By being conscious of the multitude of necessities required in a comprehensive and immediate disaster relief shelter, it is possible to make a large scale difference in the lives of the victims without much effort or energy (Borges, Mitchell, Garcetti, et al 2018).

In order to create a design that is safe, comfortable, and able to be used instantly, I have analyzed four precedents that utilize different strategies to accomplish the same goals. These precedents are as follows:

bottom up approach
sustainable
locally sourced materials
unskilled labor
time intensive
labor intensive

Temporary Shelter, Nepal : Charles Lai and Takehiko Suzuki

easy assembly
reusable
mobile
compact
poordurability
weak



Compact Shelter : Alastair Pryor

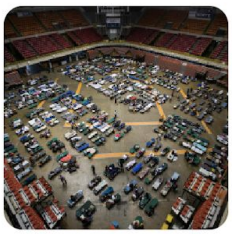
sustainable materials
waterproof
versitile
easy assembly
compact
reusable
expensive material
weak

Accordian reCover Shelter : Matthew Malone

bottom up approach
sustainable
locally sourced materials
unskilled labor
time intensive
labor intensive

Temporary Shelter, Nepal : Charles Lai and Takehiko Suzuki

These solutions provide benefits to the user that traditional shelter alternatives fail to yield. The most widely known and frequently used strategies such as public shelters, FEMA tarps, shipping container homes, and SIP homes fail to account for some of the most basic needs and restrictions of these hurricane victims. For instance, elements concerning privacy, sanitation, safety, price, and speed of deployment make these common efforts unappealing to both consumers and end users.

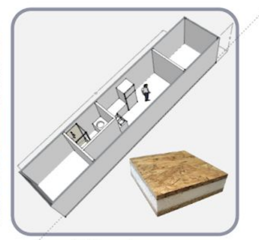


public shelter

public shelter

FEMA tarps

shipping container home



SIP box home

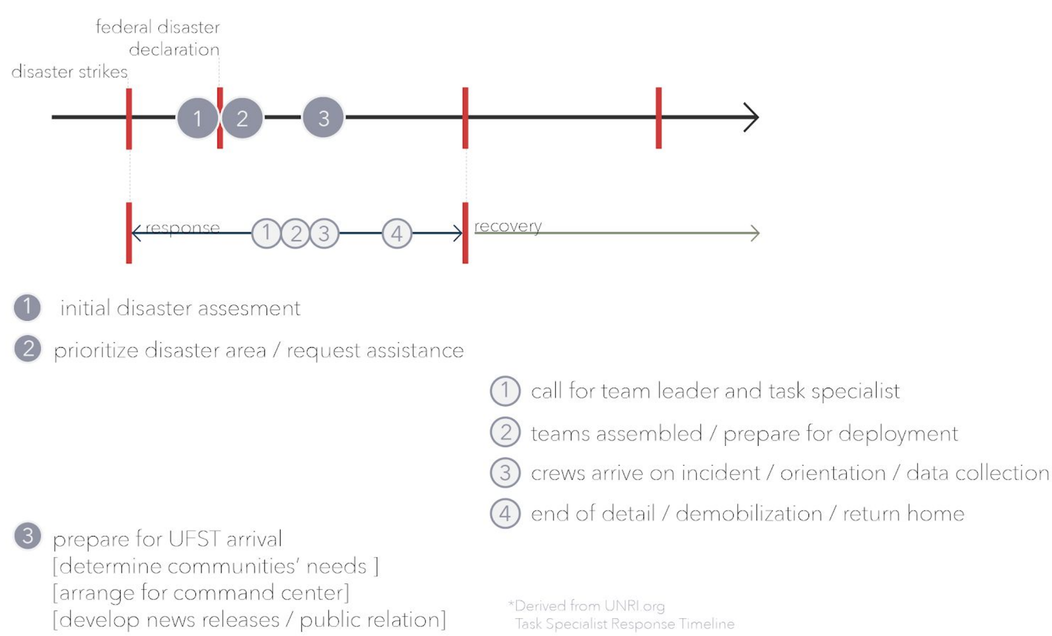
There is a need for temporary shelters in the immediate aftermath of hurricanes, because the majority of current solutions come far too late. By reducing the time it takes for a victim to get to a shelter, you increase their safety. When that shelter is either inside of or next to your house, you increase your potential productivity toward communal recovery. In addition, designing for mobility is paramount in these situations, as conditions are often unstable and potentially unsafe. Finally, utilizing passive design systems can provide additional comfort and utility in a post-disaster shelter.

3.4 Materials

There are countless materials that can be used in a temporary shelter, but some are better than others for various reasons. Shigeru Ban is known for using paper, bamboo, and plastic bottles (Ban, Miyake, Luna, et al 2009) in designs of all scales. He and his team are now making a positive impact in the field of humanitarian design (Aspen Art Museum 2014 and Serageldin 1997). By using paper and cardboard, the design becomes cheaper, more accessible, and more dynamic (Hovesepian 2013). *Cardboardigami*, the folding of cardboard to create shelter, is being used successfully for cheap and mobile dwellings for the homeless (Hovesepian 2013) and can be applied easily and effectively to disaster shelters (Aspen Art Museum 2014 and Serageldin 1997). Regardless of the target location, local materials can be used for short or long term use (Stohr and Sinclair 2009). Materials such as bamboo and plastic or aluminum sheeting, in addition to waste cardboard, can be collected and used in construction (Stohr and Sinclair 2009 and Lai 2015). These local materials can be sourced faster, using local laborers, and more cost effectively (Lai 2015) while stimulating the economy and providing a more sustainable recovery solution (Borges, Mitchell, Garcetti, et al 2018 and Lai 2015). Cost is a major limiting factor in disaster recovery shelter design in Puerto Rico as some of the most vulnerable communities are the least financially stable (Stohr and Sinclair 2009). Often victims do not want to put their money toward a shelter they will only be living in for a short amount of time, leaving them exposed to the elements as damages are assessed. Constructing reusable and dynamic systems for as little money as possible is a must (Malone 2008). “Affordability of the dwellings is a main issue that has to be addressed especially in economically vulnerable disaster communities” (Hany Abulnour 2014). Different design strategies are determined primarily by the available resources, accessibility, cost, and obviously the needs of the victims (Stohr and Sinclair 2009 and Borges, Mitchell, Garcetti, et al 2018). By utilizing systems such as flatpacking or additive modularity, the design can become more versatile and useful to larger populations (Malone 2008).

Unconventional materials, such as paper, cardboard, or plastic, have proven themselves to be useful, yet underrated, resources when it comes to temporary disaster design. Because they are cheap, durable, and dynamic, they will help to keep costs at a minimum while providing the best possible solution to hurricanes in Puerto Rico. They will require waterproofing or other treatment in order to ensure it withstands the tropical climate. Other locally sourced materials, such as bamboo or corrugated zinc, can build upon a cardboard skeleton to maximize stability and security.

3.5 Post-Disaster Timeline



While disasters, such as hurricanes, can be predicted to a certain extent, the wrath they bring is almost always astonishing. During the storm, people are naturally uncomfortable. There is shock, fear, and confusion; all leading to disorganization. Disaster response ideally kicks in during this phase with, for example, evacuating people from unsafe conditions or simply comforting those in a panic. In our current disaster management model, immediately after the disaster is when evacuation and search and rescue efforts begin. It is also the time to begin damage assessment and restoration of basic infrastructure. The problem with our current model, however, lies in what does not begin immediately.

Disaster response teams do their best to provide instantaneous assistance in any way they can in order to maintain life, improve health, and increase morale of the victims. Unfortunately, in some cases they are hindered by logistical failures caused by the storm or the government systems in place. These failures are surprisingly common, and exponentially catastrophic, as they drag out the relief process and waste precious time. In the case of Hurricane Katrina, which devastated the Gulf Coast in August of 2005, we saw unprecedented federal failures which led to the exacerbation of death and damages. First, there was confusion from the top with people not knowing what role they played in recovery and who was in charge. Following the recovery efforts, in 2006 a bipartisan House report on their initiative stated there was, “general confusion over mission assignments, deployments, and command structure” (Edwards 2015). Second, the government was simply unprepared for a disaster of this scale. Despite being warned by meteorologists a year prior of the ramifications of a hurricane like Katrina, the government did not act. There were some supplies distributed strategically prior to the storm; but they misjudged where and how much they would actually need. In some places, victims waited for days before necessary supplies, food, and medicine arrived. “FEMA also paid for 25,000 mobile homes costing $900 million, but they went virtually unused because of FEMA’s own regulations that such homes cannot be used on flood plains, which is where most Katrina victims lived” (Edwards, 2015). Third, there was a lack of communication and decisiveness among the authority parties leading recovery. Communication was hindered by faulty equipment and system failures. This led to further confusion about where people needed help, what kind of help, and how much. FEMA blocked deliveries of emergency supplies from the Red Cross, Walmart, and other countries. They also turned away volunteer doctors, evacuation assistance, and other private relief efforts. Despite all of these failures, the Katrina relief efforts were regarded as a success as countless lives were ultimately saved by the actions of a few government agencies.

comerio

In the case of Hurricane Maria and Puerto Rico, we saw many of the same failures exaggerated by inefficient political apprehension and segregation. As a commonwealth of the United States and home to over three million US citizens, Puerto Rico should be treated as another state. However, political tension between the federal government and the officials of Puerto Rico led to a rocky relationship in regard to recovery. “We can't fail to note the dissimilar urgency and priority given to the emergency response in Puerto Rico, compared to the US states affected by hurricanes in recent months," said Leilani Farha, the UN special reporter on housing (Sanchez 2017).. As tourism is a major segment of Puerto Rico’s economy, a large portion of funding is allocated to rebuilding and developing tourism infrastructure. Basic housing needs end up being put on hold while hotels, resorts, golf courses, and other private sectors thrive. Despite 44 percent of the population living below the poverty line, access to food, water, education, housing, and social security was largely undermined by the outstanding financial crisis that predated the hurricane. “For the President to vocally oppose and target aid to the most vulnerable in Puerto Rico is shameful, heartless and inexcusable," said Rep. Nydia Velázquez, D-N.Y., a Puerto Rican.

A faster action time to help the powerless, however, is not necessarily always better. Brad Pitt’s Make It Right Foundation acted quickly to begin building houses for victims of Hurricane Katrina. By 2016, they had spent 26.8 million dollars to build 109 homes. The homes were not designed to properly account for the climate of New Orleans, and quickly began to accumulate mold, rot, and collapse (Zadrozny, Ramgopal, and Farnoush Amiri 2018). This goes to show that poorly planned relief efforts can cause more harm than the benefit they provide. It is crucial to properly plan for the event, evaluate the situation and determine specific needs, and execute a plan that aptly accounts for these.

As it stands now, our disaster relief timeline calls for two phases: response and recovery. It begins with preparation of supplies, such as food, water, or shelter, positioned in warehouses prior to an event. “After a natural disaster impacts an area, the impacted state gathers information about the severity of the damage and determines if its resources are sufficient to handle the clean-up. Usually within 72 hours the governor of the state will ask the U.S. president (through FEMA) to declare the area a federal disaster” (UFST Advisory Committee 2011). After this declaration, a task specialist calls for a team leader who puts together teams and prepares to mobilize to the location. Once the teams arrive, data collection and eventually relief efforts are initiated. Once the communities’ immediate needs are met and survivors are safe, the recovery phase begins. This process, though it is intuitive and can be effective, is prolonged by centralized bureaucracy and inexperience. “You don’t get efficiency, learning, innovation, and quality performance from top-down command. Indeed, increased centralization and complexity is a disease of the modern American government that is causing endemic failure” (Edwards, 2015).

Post Disaster Timeline :

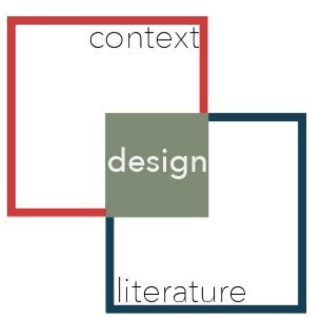
To mitigate the inefficiencies inherent to our current model, a new way to approach disaster relief, stemming from local experience and contextual knowledge, is necessary. Local governments need to prepare for the storm by alerting communities as to what they can expect to happen and how they should react. FEMA recommends items that should be stored in a ‘stay-bag’ in case victims become stranded for long periods of time, though this does not include an alternative shelter should their home be compromised. FEMA also stores emergency supplies, like food and shelters, in anticipation of disasters, but what happens if those stocks are compromised by water damage or rodents, as was the case during Hurricane Maria? People should be in control of their own emergency supplies, including shelters, prior to an event that could leave them stranded for an indiscernible period of time. This allows disaster relief to begin immediately. In other words, Zero Response time. By putting temporary shelters in the hands of those who need them, before they need them, the time wasted determining who needs aid and where to send it is completely removed. This allows people to immediately focus not on securing a roof over their family, but on contributing to community relief efforts such as search and rescue, debris removal, and rebuilding infrastructure to allow external aid to be utilized more quickly and effectively. After FEMA or other agencies arrive on site, First Response action begins. This includes all the same actions - setting up large scale shelters, cleaning up communities, and addressing other immediate needs of the victims - that the current disaster relief model includes, but people are not left to suffer unprotected while a plan is devised. Finally, the Second Response phase begins as the current recovery phase would with architects and planners being brought in to assess the damages and provide a stronger solution, rather than simply rebuilding.

3.6 Literature Review Conclusion

The way we currently view disaster recovery, primarily top-down, is not a sufficient strategy. A new strategy, focused more on a bottom-up approach is necessary for a fast and effective recovery to take place within a community. The bottom-up approach will stimulate each community to begin working to fix itself, rather than becoming a government charity case. In this way, communities may maintain their unique microcultures rather than succumbing to the power of various investors or stakeholders. With this approach, by maintaining control over personal health, well being, and ultimately their future, the people feel empowered by taking care of themselves and owning the responsibility to help their community recover mentally, physically, and emotionally. Similar to liking a Facebook post pertaining to a given disaster and expecting change to come of it, individual victims are relatively powerless. Until they band together, they will not experience the power of a community effort. When a community holds little responsibility to work to fix their predicament, a bystander effect can take place, further prolonging the time it takes to return to normal conditions.

Specific design systems, construction systems, and materials must respond to the climate and weather patterns of the site and the capabilities of the victims in question. In Puerto Rico, a tropical rainforest, the climate is hot, wet, and windy, meaning certain mainstream tactics may not work as well as those designed for the area. Considerations such as a low price point, the ability to be reusable, storable, durable, and additive are driven by the design and construction systems used, while materiality drives what can be done with these systems. All of this aims to accomplish the goal of speeding up the traditional disaster recovery model and dealing with shelter immediately, in Phase Zero. This shelter, due to the unknown amount of time it will be used for, should be designed for up to a month of use. This time could be extended, but additional protection may be used and repairs may have to be made.

4.0 Methods



To conduct this research thoroughly and effectively, I utilized multiple methods in research, design, and testing. All of these, however, were conducted through a case study lens on the islands of Puerto Rico. I acquired data through an analysis of related literature and local context, through participant observation, materials and systems testing, and design based evaluations. For three weeks in the summer of 2019, I visited the islands and lived with a young Puerto Rican man in his apartment in San Juan. He was able to show me around the island and give me a real, informed, and honest experience. His diverse set of connections allowed me to learn about what several different communities did during the storms, what they needed, and other more general cultural necessities. While this research focuses specifically on Puerto Rico, it is important to remember that these methods can, and should, be adapted to respond to similar or different contexts dealing with similar or different problems.

4.1 Research Methods

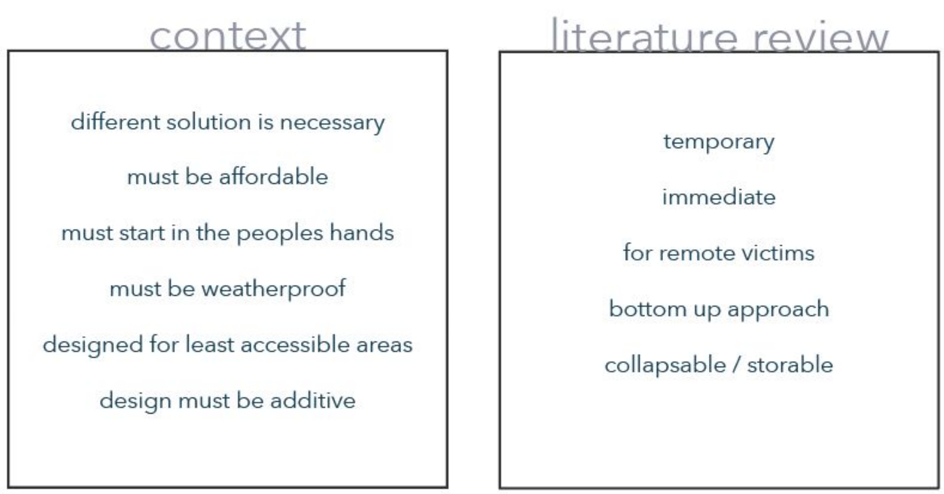
Because I wanted to learn the opinions of the locals on past solutions and what worked versus what did not, I went to various parts of the island. I spent time in Adjuntas, Arecibo, Canovas, Cayey, Jayuya, Old San Juan, Orocovis, La Perla, San Juan, Utuado, the University of Puerto Rico in San Juan, and the projects south of Loiza. In these places I met and spent time with locals performing participant observation and basic contextual analysis to inform decisions I would later have to make. From my findings, I was able to identify what factors on which to focus in my research. This study aims to determine what kinds of systems provide effective shelter, based on contextual necessities such as cost, durability, and approach to application. To gather and analyze precedents, I set my parameters as follows:

1. *Location of precedent similar to climate of Puerto Rico*
2. *Cost of fabrication representative of target population's ability to spend*
3. *Materiality based on local or easily available materials*
4. *Materiality based on performance in climate of Puerto Rico*
5. *Approach to design based on benefit to target community*
6. *General adhesion to USAID Shelter and Shelter Management: Reference Guide*

This approach provides an opportunity to analyze the benefits and limitations of multiple precedents qualitatively through a contextual lens of Puerto Rico. With precedents having been selected through the applied lens from above, I studied how precedents were designed and built, out of what, and when. I then combined what I thought were the most successful physical and theoretical features of each based on the parameters I defined.

Though this method provides an in-depth analysis of many different strategies, limitations remain. First, due to the limited time frame of this research, I did not consider all of the possible relevant precedents, leaving potential solutions unaddressed. Second, the parameters are based on my observations and contextual analysis rather than surveyed needs. Though I have evidence and research to back my decisions, I cannot be positive that these are the only requirements an effective shelter needs meet. Third, weather disasters are unpredictable, meaning that we can never be certain what the future needs of a disaster shelter will be. This method is based on past events, and provides a justified prediction for the future, but certainty is not absolute. Finally, the method also relies on generalizations related to victims' willingness to utilize my design. For example, we can not be certain that a storable shelter will make people want to use it more than any other shelter design. Through the precedents collected and analyzed through this method, however, I was able to identify key elements that could be utilized in my own design.

4.2 Design Methods

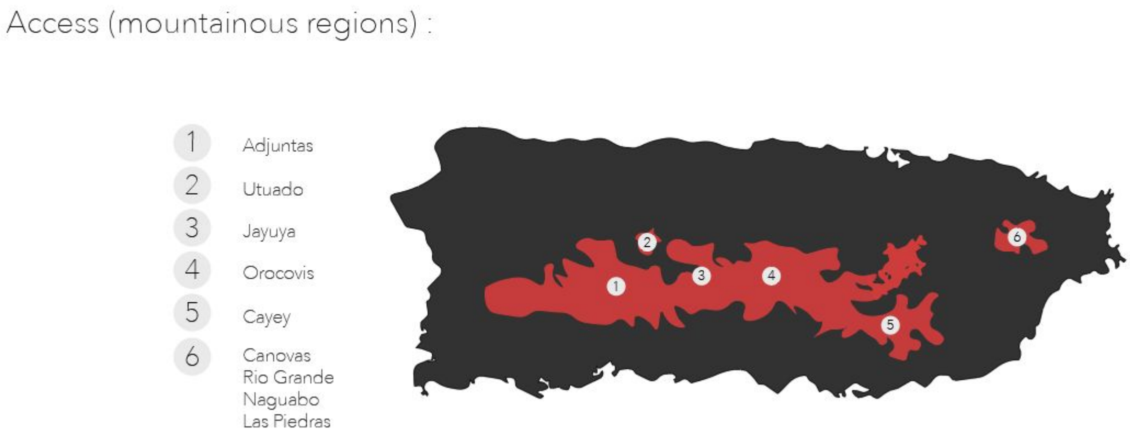


Approach of Solution

It is clear, through the findings of my research, that we need a new way to approach disaster relief shelters. Primarily, they are slow to reach the end user. If the victims were to have my design on hand and easily accessible, the time it takes to seek shelter would be decreased significantly. On top of increasing the users' safety, they benefit from being able to stay near their homes, families, property, and neighbors. This was demonstrated in Haiti after hurricane Matthew in 2016, as well as amidst many Hatian earthquakes. People prefered to set up camps near their homes, rather than making the potentially dangerous journey to the white-sheeted public shelters provided by the government. Restricting the number of people using damaged or unsafe infrastructure, such as debris-filled roads, decreases the potential for individuals or families to be injured as they make their way to a shelter. By remaining in a place in which they are familiar and comfortable, the mental recovery process becomes easier than if they were to have to move physically, from their home, and theoretically, out of their comfort zone.

Potential users of this shelter would purchase the full kit far prior to a natural disaster so they can utilize it as soon as it becomes necessary. This is different than most disaster recovery plans, in that it is not donated, simply because it is preemptive. The added benefits, however, with buying the shelter, rather than it being donated, are that not only anyone who *needs* one can have one, but anyone who *wants* one can have one. With personal sacrifice of hard earned money, the user gains a sense of responsibility to their personal situation. These benefits will snowball as more and more people utilize the shelter, because rather than evacuating, more people are able to stay put and begin to help rebuild their own property as well as their community. The greater number of people staying in their communities increases normality, that would otherwise never exist in a disaster scenario. Puerto Rican communities in the past, following previous disasters, proved their ability to work together in order to better their environment and their neighbors' situations. I am providing an opportunity, through a bottom up approach, for more people to engage with this mindset.

Terrain



Puerto Rico, the third largest island in the United States with over 3,500 square miles of territory, is home to a diverse combination of terrain. From cliffs and beaches on the coast to inland mountains and rainforests, the geography of the main island is both beautiful and problematic.

The capital city of San Juan is located on Puerto Rico's northeastern shore and serves as a primary port for the entire archipelago. Being situated so close to the ocean, port cities like San Juan, Arecibo, and Yabucoa, amongst others, suffer hurricane damage from wind, debris, and extreme surges from the surf. This makes importing aid difficult, and in some cases impossible for a period of time. Once aid arrives through one of these ports, transporting it to the people in need poses a whole other problem. Supplies that are ready for distribution, already on the island, are distributed by trucks. Without the necessary diesel fuel which is in short supply because it is being used to run generators, the trucks cannot run and the supplies remain in place. When shipments of fuel are finally offloaded, and the trucks can run, they cannot navigate streets still covered in debris.

Moving toward the center of the island, the mountains make for winding and often more poorly maintained roads and bridges. "The mountains also exacerbate the rain and flooding. When you have a circulation of a tropical cyclone, wind and moist air are lifted up over the mountains," says Stacy Stewart, senior hurricane specialist at the National Hurricane Center. "Like a washcloth through a wringer, the mountains squeeze more rain from the system — at least on the order of 10 to 30 percent compared to moving over flat terrain" (Resnick, 2017). After a hurricane, the ease of access to these areas drops significantly. Fallen trees or telephone posts, rubble from houses or landslides, and flooding from the numerous rivers that carve through the mountains halt transportation between these cities and the rest of the island. Depending on the severity of the damage in a certain location, it is possible that a family may not even be able to access their next door neighbor. For example, after hurricane Maria, to compensate for a bridge that had failed, a community in Utuado was forced to rig a shopping cart to a cable crossing a river that had flooded, blocking any movement into, or out of, their village.

Though it may seem counterintuitive to form settlements in high risk areas, such as these mountainous rainforests, they are beautiful areas and sometimes the only locations people can afford to live. Villages are created constantly and often informally, making it even more difficult for officials to locate and address their needs. Maps of the island pose a weakness in a post-disaster scenario. Remote areas, where the forces of a hurricane often produce the most damage, are largely unknown and entire communities may not exist in the eyes of those trying to help. Private companies, making maps of these areas, do not have the resources or incentive to include these sometimes informal communities. In addition, the Puerto Rican government does not have the resources to accurately update their existing maps, as these neighborhoods could constantly be changing, and perhaps even changing the landscape around them through farming or methods of irrigation.

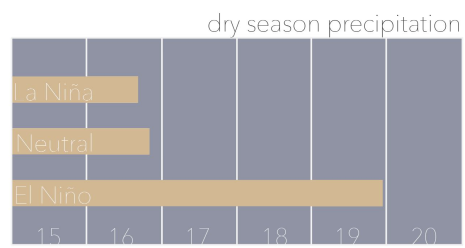
Weather

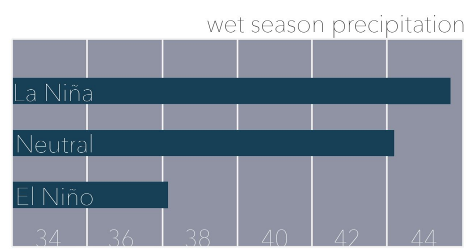
"There's no such thing as natural disasters; they're all man-made because we build where we shouldn't and defy Mother Nature,"

-Miguel Del Rio.

When dealing with the effects of a hurricane, it is important to understand the impacts of weather patterns and the changing climate. Seasonal patterns, as well as annual patterns, affect the quality and severity of weather. Similarly, the effects of this weather relate to the individual contextual elements of the location in question, and the amount of damage sustained by an event. By understanding these weather patterns, and their effects in different areas across the archipelago, we can begin to understand what roles a temporary shelter needs to perform. This is true for our current situation as well as predicting future needs.

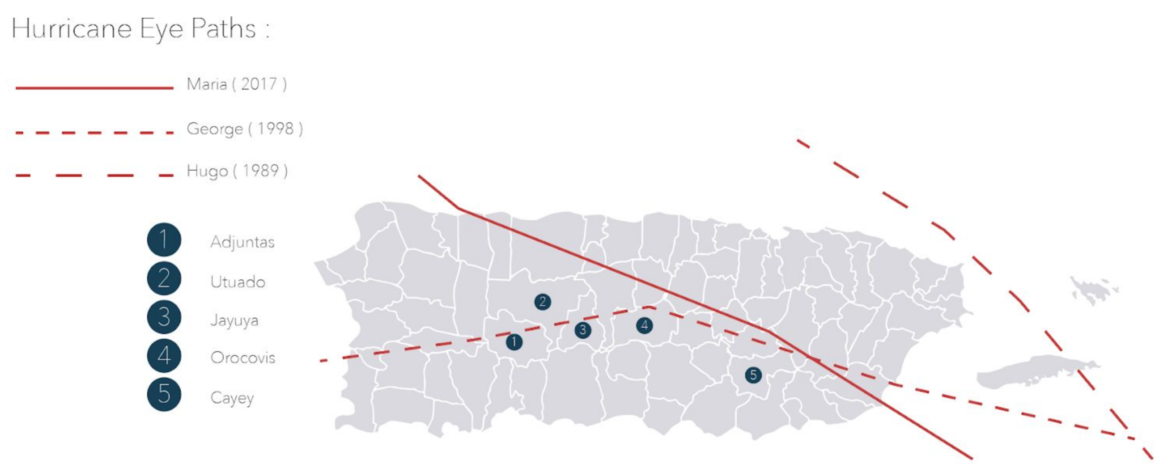
Puerto Rico falls predominantly in the category of tropical rainforest, as defined by the Köpen Climate Classification, the most widely used international climate classification system. As a tropical rainforest, temperatures are relatively high throughout each year, with an average between 70°F and 85°F depending on elevation. High elevations mean low temperatures, while the low elevation mean high temperatures (US Department of Commerce and NOAA 2018). Puerto Rico also experiences the effects of the dry and rainy seasons. The rainy season, from April through November, brings over 75 percent, or 42 inches, of San Juan's average rainfall, while the dry season brings only 12 inches on average. However, due to the irregularity of the terrain, the amount of rainfall varies tremendously throughout the regions of the archipelago. San Juan, for instance, has only 199 days of rainfall amounting to 56.4 inches per year on average, while Pico Del Este, averages 328 days of rain totaling 172.5 inches (NCDC and NOAA 2010). While they are 25 miles apart as the crow flies, their elevations vary by 3,500 feet, accounting for the drastic difference in rainfall. Related to elevation and rainfall, but also proximity to rivers, the risk of flooding is present in nearly every one of Puerto Rico's municipalities. This is a product of their inability to govern which places are safe to build, out of the reach of overflowing rivers and lowlands, and those which are not.





In addition to normal seasonal differences in temperature and precipitation, the island is affected by less frequent, but more impactful, weather patterns; El Niño and La Niña. "El Niño/La Niña Southern Oscillation (ENSO) is a periodic oceanic atmospheric phenomenon that occurs across the tropical Pacific and is recognized to have worldwide impacts" (USDC and NOAA 2016). El Niño is typically associated with a warm phase, and can be a predictor for increased precipitation in the dry season, while La Niña is associated with a cold phase and produces more precipitation than average in a rainy season. In a study of 55 years of ENSO data, the National Weather Service declared, "During the dry season, significantly more precipitation accumulated during El Niño years versus La Niña years (approximately 13% more precipitation fell during El Niño years). During the wet season, significantly more precipitation fell during La Niña years versus El Niño years (approximately 14% more precipitation fell during La Niña years). In both cases, the years which were defined to be ENSO neutral (years where at least 70% of the months of a season were not defined as either El Niño or La Niña years), observed precipitation values that fell in between those of the El Niño and La Niña averaged values” (USDC and NOAA 2016).

Easterly trade winds, blowing from across the Atlantic, are consistent for Puerto Rico. In fact, these winds are often welcome as they work to cool the island. In La Niña years, however, the trade winds act differently than they usually do. In 2016, we witnessed a record setting El Niño season, creating the perfect conditions for an unusually strong La Niña season. Weather expert Anthony Barnston stated, “In a nutshell, El Niño’s burst of warm water has slackened the trade winds across the tropical Pacific Ocean, and pushed the atmosphere there into an unsustainable setup” (Holthaus 2016). La Niña acts as a buffer to offset the wind shear, common in the tropical Atlantic, which allows the force of the winds to increase significantly, rather than diminish almost entirely. Lower levels of shear allow waves to organize and grow, setting up the conditions for powerful tropical storms, while increased shear, common in El Niño years, tends to prevent the organization of waves and the creation of hurricanes.



In 1989, one of the strongest La Niña years, category three Hurricane Hugo tore through the carribean with sustained winds up to 160 mph. This came as a surprise to most people, as the storm had not grown much on its journey across the Atlantic. Hugo made its first Puerto Rican landfall on the morning of September 18th, on the island of Vieques, before moving through the rest of Puerto Rico. Killing 12 people, the Hurricane ravaged tens of thousands of homes and properties, totalling around one billion dollars in damage. On top of property losses, two of the island’s staple crops, coffee beans and bananas, were completely destroyed.

Hurricane George struck on September 21, 1998, another strong La Niña year. While it was only classified as a category one hurricane, it tracked the entirety of the island with consistent rainfall and wind, causing the greatest amount of infrastructural damage the island had ever seen. The CDC reported, "all 78 civil divisions in Puerto Rico reported damage to homes, and 416 government-run shelters were housing approximately 28,000 persons. Approximately 700,000 persons were without water, and 1 million had no electricity." (MMWR 1989). Within two days, the island faced 30 inches of rainfall, leading 100 percent of the rivers to outgrow their banks, which caused erosion and the development of an entirely new floodplain. Nearly the entire banana and coffee crops were destroyed, 96 percent of the electric grid failed, and 75 percent of the island lost access to clean water and sewage services. In the two days of the storm, nearly 2 billion dollars in damages were incurred on the main island alone (MMWR 1989).

September 2017 brought perhaps the worst hurricane damage Puerto Ricans have ever had to endure. The destruction began with Hurricane Irma on September 6. Though the storm did not hit the island directly, the sustained category five winds of over 180 mph left over one million people without power and the torrential rain threatened everyone with flooding. However, this disaster was only a taste for what they had in store. On September 20, category four Hurricane Maria, one of the most intense hurricanes to ever make landfall in the United States and its territories with sustained winds of 160 mph (National Hurricane Center), found land on the southeast coast of Yabucoa and wreaked havoc on the rest of the island for more than 30 hours. Meteorologist Jeff Weber, of the National Center for Atmospheric Research, made the comment, "It was as if a 50 to 60 mile wide tornado raged across Puerto Rico, like a buzz saw" (Resnick 2017). Within 24 hours from initial landfall, the storm produced over two feet of rain, causing widespread flooding and even further elimination of power. While it is hard to get an exact estimate of houses damaged by the storm, as informal development seems to be more of a rule than an exception, housing secretary Fernando Gil estimates that over 300,000 homes sustained severe damage (Viglucci 2018). There were communities in which 80 to 90 percent of the homes were totally lost.

** Beginning on December 28, 2019, there were reports of a string of earthquakes, most with magnitudes reaching five or greater, ravaging the islands of Puerto Rico. This was after I had begun the design phase of my Honors Thesis. As such, I have not accounted for earthquakes in my analysis of the weather in Puerto Rico. This is relevant to my research, however, as thousands of the islands' residents have been without shelter for at least 2 months (Robles and Erika Rodriguez 2020). I will need to conduct further research and tests in order to account for more environmental requirements.*

Materiality:

In this next phase of the design process, I needed to know what materials could be used to fit the necessary functions of my product in the given context. To do this I used my research to identify materials and systems used previously in similar projects, and tailored the systems to the needs of this project. Material selection was based on the following criteria:

1. Durable
2. Cheap
3. Local
4. Healthy

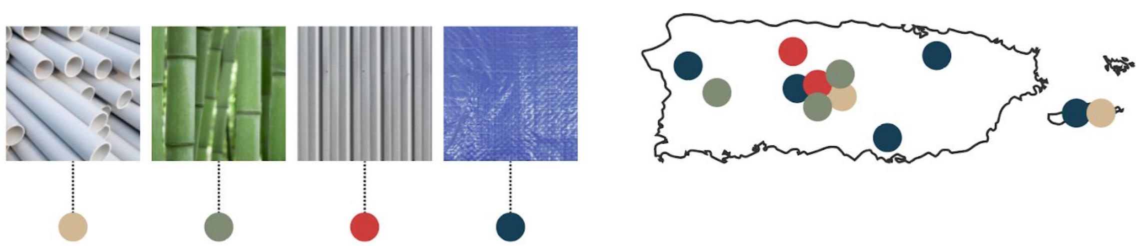
With these parameters, I was able to further think about how the design systems I selected can be built to withstand the contextual forces of the target location. What materials work? How do they work? Do they need additional treatments? Are they effective as they are?

Though it may not seem likely, cardboard has been tested and used successfully around the world as a construction material. It is a recycled material, made from waste paper and card, and can be further recycled and made into more card. “These processes of recycling involve less energy and clearly less raw material than the production of most other mainstream building materials. It has better performance, in structural and fire terms, as a material than might be expected, and is relatively cheap in its raw form” (Cripps 2004). Cardboard, however, being made from paper, requires some additional treatments before it can be used, with confidence, as a structural material in a building.

Through testing, while cardboard does perform quite well, it does not sustain its performance over long periods of time under stress (Cripps 2004). With sustained periods of high winds or rains, the cardboard used for this shelter needs to be manually reinforced to prolong its ability to perform under stress. An additional top layer should be used to cover the cardboard, slowing fire from spreading unit to unit. Cardboard, surprisingly, does not go up in flames like other paper might. Instead, it smolders and chars more slowly, allowing a greater amount of time for egress in a fire scenario. Obviously, left untreated, the cardboard would deteriorate in the wetness of Puerto Rico, but by adding waterproofing layers to the material, it becomes water tight in the short term. However, the threat of long term damage is still very real. Ultraviolet light, weather, and various critters, all contribute to the weakening of the cardboard. To increase the longevity of its water resistance, a form of waterproof overcladding should be used to protect and seal the more vulnerable material (Cripps 2004).

Cardboard is a cheap material that is easily available practically everywhere on the island, even in the world. It can also be used successfully as a building material. It is lightweight and relatively durable on its own. Applying a sealant coating to the cardboard improves its ability to resist water, only on flat surfaces, not the holes on the side. If used in a layered system, an additional sealant, like duct tape, would be required to prevent water from getting inside of those gaps. Corrugated plastic is also a viable material to be used in a shelter as it is commonly available, waterproof, and structurally sturdy. However, it is significantly more expensive than cardboard, making it less attractive for my specific price parameters.

Puerto Rico is home to many useful resources, both natural and man made, that could potentially be used in a post-disaster scenario to either create, or reinforce, a shelter unit. Though there are many other possible resources with countless uses, I have focused on those more commonly found in less affluent communities, especially after a devastating storm: Bamboo, corrugated aluminum, FEMA blue tarps (distributed after a disaster), and other plastic debris.

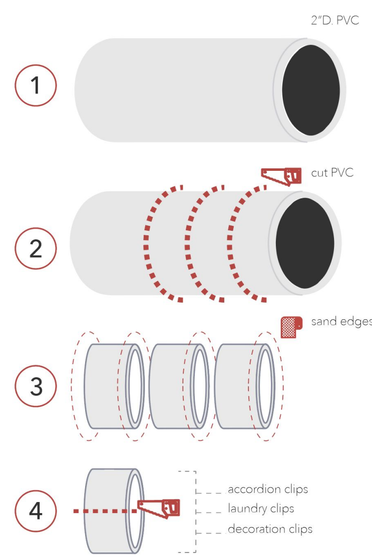


Bamboo is an incredibly strong and fast growing grass that has been used across the world as an architectural material given its abundance and price. Though bamboo is not native to Puerto Rico, it was imported while the island was under Spanish rule and now grows naturally in many areas across the island. Places like Utuado and Jayuya, where bamboo is abundant, are located centrally in the mountainous region of the main island. Often these regions suffer from restricted access in the aftermath of hurricanes. However, depending on the circumstances of the aftermath, bamboo could be harvested on foot by individuals to reinforce a structure, as support beams or columns. Or, if treated correctly, the bamboo could be used as lashing between other materials while costing nothing for the user. However, issues come with the harvesting of the material. Cutting down the bamboo, and lugging it out of the forest, is labor intensive and time consuming which could cause problems for potential users.

Corrugated aluminum sheeting is currently used as siding and roofing for both houses and sheds, and could be used in a similar manner in a disaster shelter scenario. The characteristically high winds of tropical storms and hurricanes often rip the sheeting from the existing structure, sometimes carrying it long distances from where it originally belonged. After previous hurricanes, recovery brigades recovered these aluminum sheets from the mountains and repurposed them to repair roofs and walls in their communities.

FEMA tarps, as they are commonly referred to as by locals, given to victims after hurricanes are simply blue plastic tarps used to act as a roof while the homeowner works to repair or replace a permanent roof. The problem with these tarps, however, is that while they are distributed to many, they are not distributed to all victims. There is a long list of qualifications in order to receive one of these tarps, making it difficult for everyone with the need to actually acquire one. One of the restrictions, as stated on FEMA's website, reads, "To qualify for Blue Roof services, damage to the roof must be less than 50 percent and the area to be covered must be structurally sound for a crew to work on. In order to have plastic sheeting placed on their roofs, homeowners must complete a right of entry form to allow government and contractor employees on their property. For the center location in your county call toll free." FEMA assumes that people have phone service after the hurricane, in order to make that call. These tarps are shipped from the mainland United States. Time is wasted in the transportation process, restricting them to reach those in need within a timely manner, if they even have enough in stock. These tarps are a valuable resource for those trying to keep water, wind, and debris out of their house, and could potentially be used to reinforce a more temporary structure should a qualifying victim acquire one.

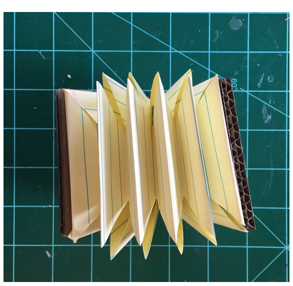
Plastic debris, such as PVC piping or corrugated plastic sheeting, could be found among piles of rubble or debris from destroyed buildings. PVC pipes, depending on their size and quality, could be modified and used as clips, perhaps for a clothesline, or as posts to increase the sturdiness of a temporary shelter. Corrugated plastic, as is found in waterproof yard signs, could be used to supplement or repair structural integrity of roofs or walls and waterproof seals.



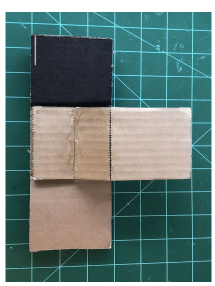
Systems:

Through contextual analysis and conducting an analysis of precedents I concluded that a storable, durable, and cheap design is necessary. I analyzed elements of precedent structures and design systems that complement a contextual need or meets literature review derived requirements. From this analysis I found that accordion, flatpack, and foldable styles of design compact easily and provide the most usable space once erected and can allow for attachments that may be needed if temporary becomes more long term**.** I then combined the applicable elements in a cohesive design that perform to complete the given requirements. In order to certify that the final structure is effective for its intended user in its intended context, I have defined the system parameters as follows:

1. Sturdy
2. Reusable
3. Transportable
4. Modular
5. Lightweight
6. Additive



A.1



B.1

B.2

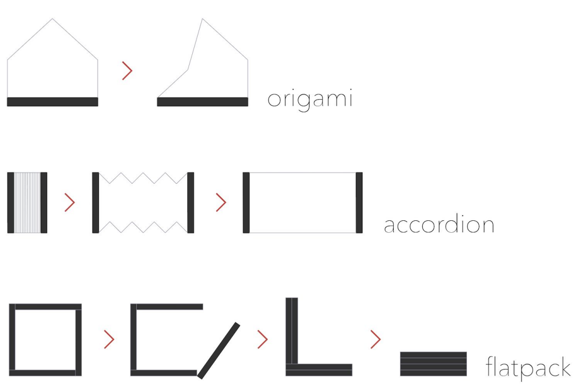
C.1

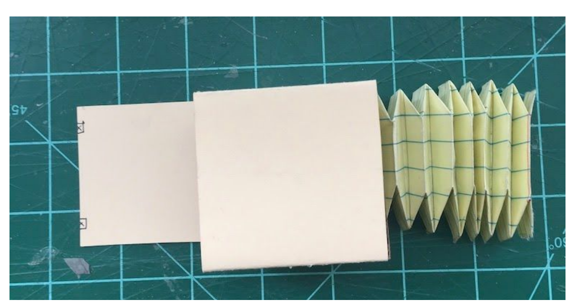
A.1 - *Accordion* : The accordion system is drawn from the Malone shelter design. I wanted to test its ability to be compressed, how it can be made, and if it would work with paper or Tyvek so that it may be collapsed easily. Further testing of other materials that are better suited for a tropical and wet climate is needed. The accordion will also require support columns or beams, which means more parts that could potentially break. Depending on the material used, it may be difficult to make in a way that is durable enough to withstand wind and various types of debris common in a hurricane.

B.1 - *Flat Pack (Box)* : A primary goal for this design is maintaining its ability to be compact. This design folds up into itself, allowing for both ease of compression and erection. This design could be supported further, after it is erected, with other materials such as bamboo or corrugated zinc, found in the target area.

B.2. - *Flat Pack (Dome)* : I wanted to test the feasibility of multi-component construction. Using separate attachment pieces, I was able to be more creative with the shape of the shelter, rather than being confined to simple folds. This design is more sturdy than B.1 but allows for less adaptability and requires a more complex assembly. Because of its many parts, this design may also be weaker in the long run. This system would also require a larger packed size.

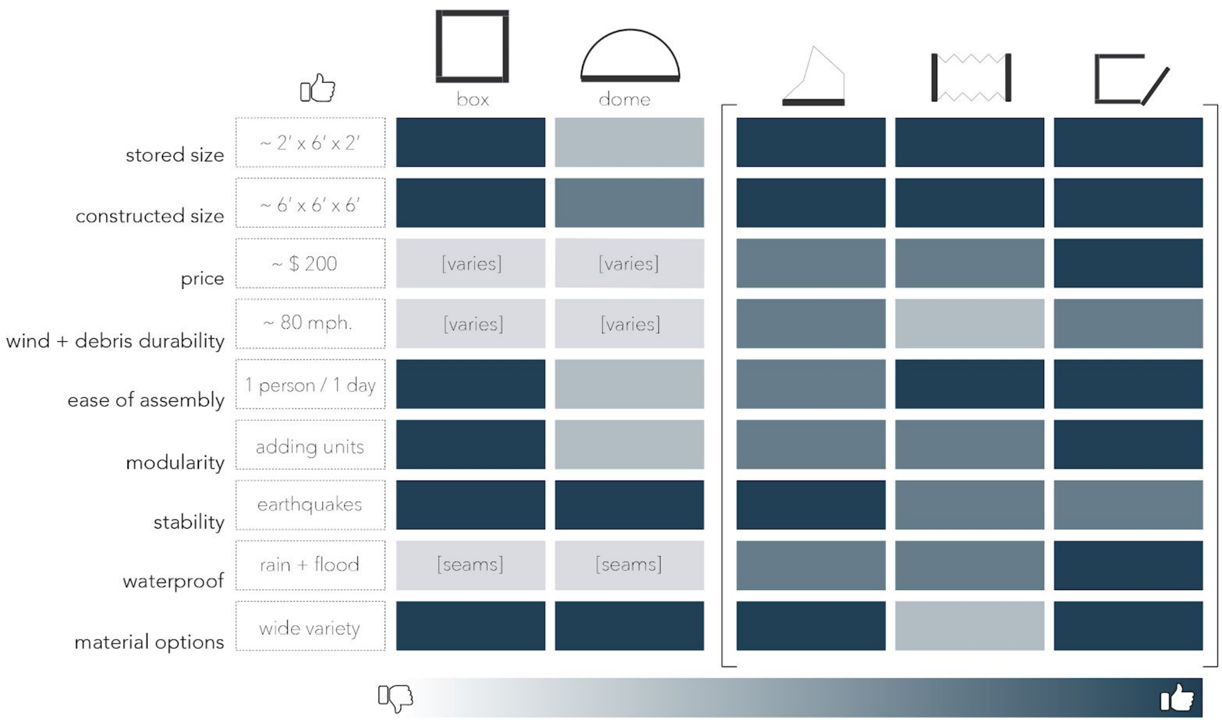
C.1 - *Foldable* : This design is meant to test the ease of construction using a more interesting folding form. This design would make it more difficult to incorporate the other systems; however, it is a more visually appealing structure. This design would not easily be compacted, other than laying open and flat, unless it was distributed in multiple parts. However, the more parts there are, the more difficult construction will be.





I chose the accordion system for its ability to expand and enlarge a space without requiring excessive room when stored. The flatpack box system was chosen for its ability to create a sturdy structure once erected, but maintaining a small footprint when stored. The flatpack dome is stable and flexible allowing it to perform well in earthquake and hurricane scenarios. The foldable system is appealing to the eye and easily constructed, ensuring ease of use for the victim. I have combined these systems in a way that utilizes all of their positive capabilities in a tentative final design. The success of these systems largely relies on the type of material used. I will test these systems and material options and make modifications where necessary.

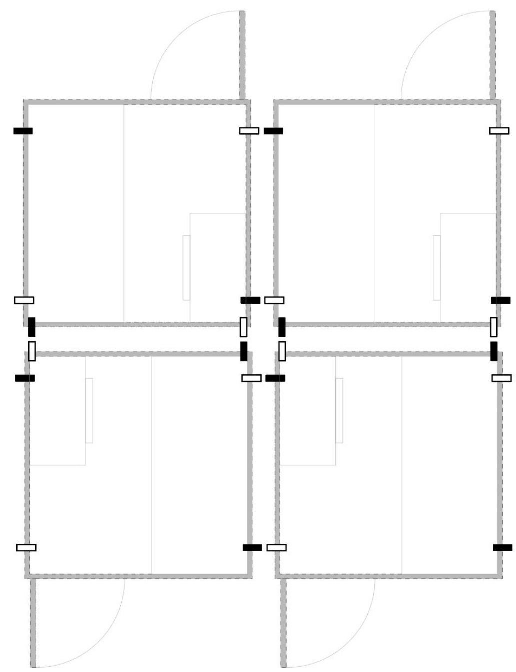
4.3 Testing Method



To ensure the functionality of this shelter I performed multiple tests using parameters derived through my research. This includes my analysis of local contextual requirements of the highest risk population, literature pertaining to both common and uncommon current disaster relief models and other related humanitarian efforts. Unfortunately, there is very little information currently existing relating to how immediate and temporary shelters are critiqued. In order to overcome this and get the most accurate and beneficial parameters, I took into consideration the way in which more common large scale disaster relief shelters are analyzed, as well as other analysis and shelter management guides, to create my own set of terms to analyze small scale temporary shelters in Puerto Rico.

Size

In order to determine how big the shelter needed to be when stored, I looked into how residents of my target towns most commonly get around with cargo. With this information, I decided the compacted shelter should be able to fit into the bed of a pickup truck, or around 18 square feet, and two feet deep. This size also allows for up to four shelters to be stacked easily and safely inside the bed of the truck. A unit of 3’ x 6’ x 2’ also fits easily under a bed or in a closet for convenient on hand storage. This is crucial, as a key requirement for the shelter is that it is rapidly deployable. By having a shelter stored in their home, victims may seek refuge immediately and locally.

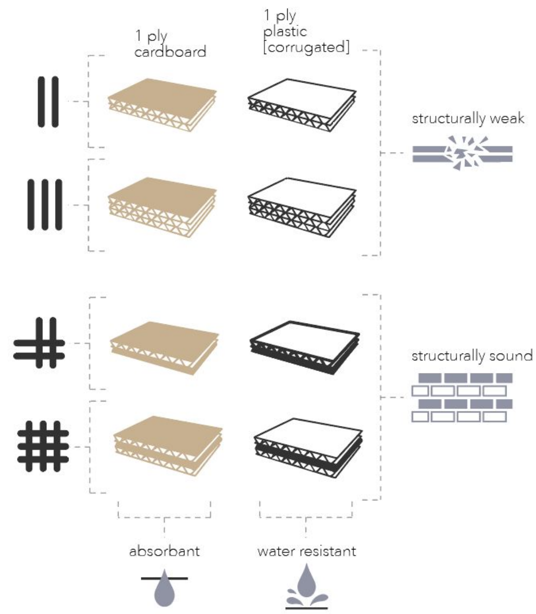


With the compacted size established, I looked into the number of people per household per capita in my target towns, and determined that Adjuntas (3.2), Canovas (2.9), Cayey (3.0), Jayuya (3.3), Orocovis (3.3), and Utuado (3.1), contained an average of 3.1 people, while the whole of Puerto Rico houses slightly fewer, at 2.9 people (DADS 2010). Because of this, it became apparent that it would be difficult to create a shelter that collapsed into the size required, while also being comfortable for an entire household. Utilizing modularity, I came up with a system that allows multiple shelter units to be connected using male and female connectors of PVC piping. This adds privacy for the occupant, as well as maintaining comfort in a small space. The units can be laid out two deep, porch wall to porch wall, and in an infinite row, capped only by the restriction of a large enough flat site. When tested, it worked well as a connector, as well as additional ventilation, as the porch wall needs to be closed for connections.

An empty box does not provide a very high level of comfort, so I created simple collapsible cardboard furniture to meet basic needs. These articles include a bed with built in storage, a desk, and a chair. These are not necessary pieces, and can be easily replaced with furniture already on hand.

Durability

By testing the durability of waterproofed paper and Tyvek in the accordion system, I determined that it does not meet the requirements of my shelter. Neither material could withstand the wind forces, airborne debris, or any kind of debris flow. It was also hard to create a durable floor underneath the accordion that would fit in the required compacted size. Because I wanted to be able to expand the shelter, to increase square footage, I turned back to the foldable and origami systems. By hinging one of the walls so that it may flip upward, I created an open porch space that increases ventilation while providing a structurally sound and durable roof that is held up by four (2" D.) PVC pipes.

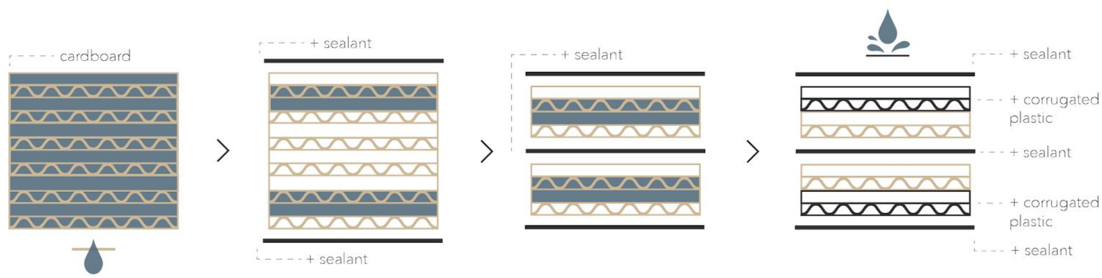


In order to ensure debris will not puncture or damage the shelter, I created an inch and a half thick wall of cardboard and simulated projectile hurricane debris. The cardboard was stacked in line first, meaning the corrugations were parallel all the way throughout the unit. I asked four 22-year-old men to throw heavy objects at this sample panel. Objects included a metal lamp, metal chairs, tree branches, full soda cans and an eight inch knife. The cardboard withstood all of the impacts, except for being stabbed at point blank range. Even then, the cardboard stopped the knife before it pierced all the way through. After this test, in order to further enhance the structural integrity of the cardboard, I rotated every other layer. The alignment of the corrugations became a cross hatch pattern, with each corrugation supporting another. This increases not only its ability to withstand impact, but improves its strength against wind and the persistent weight that would come from people walking around inside the shelter.

I also tested corrugated plastic in a similar way to how the cardboard was tested, and found that it is significantly stronger in compression, tension, and against projectile debris. It is also made of plastic, so it is inherently waterproof. While this is an appealing option for materiality, it costs far more than cardboard, thus making it impractical within my parameters.

Repairs to damage caused on both the interior and exterior can be made easily by the occupant by using duct tape or other local materials specified previously.

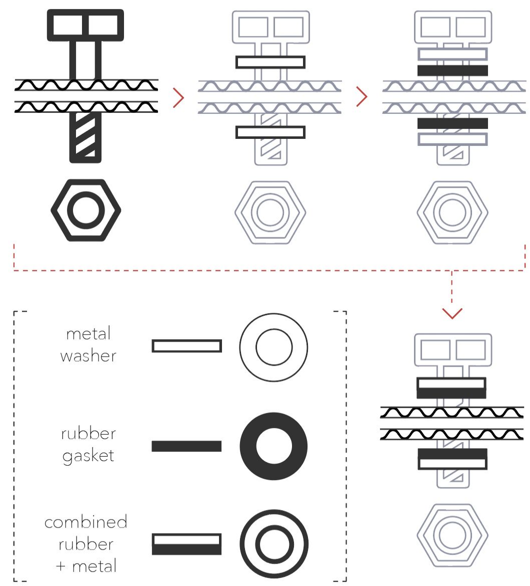
Waterproofing



Because cardboard is not inherently waterproof, but was one of the best options for the material of the shelter, I needed to know if it could be made to stand up to Puerto Rico's weather. I applied two layers of PlastiDip, a rubberized spray coating, to the outside (2) layers of cardboard. However, the sealant was not strong enough and slight abrasions made the layer of rubberized coating peel off. Next I tried FlexSeal, another brand of rubberized sealant. This brand worked better, and did not peel when scratched. If the outer layer of cardboard were to be pierced by a piece of debris, however, water would get inside of the cardboard and rot out the rest. Because of this, I added a third and fourth layer of sealant to the middle piece of cardboard to prevent extreme leakage in the case of damage. It became clear that preventing debris from puncturing the outer layer was of utmost importance. I added a layer of corrugated plastic, which is stronger and more waterproof than cardboard sheeting to minimize the chance of debris breaching the seal.

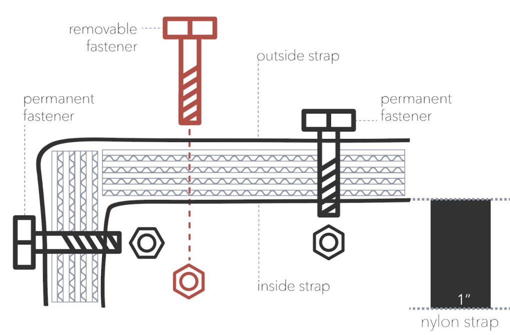
Duct tape was used to seal the open edges of the wall units. It is a durable, cheap, and common material that performs outstandingly under stress and in wet conditions. It creates a waterproof barrier between the elements outside and the comfortable space inside. If the duct tape should be damaged or leak in any way, it can be quickly and easily repaired. Similarly, duct tape can be used to repair the interior and exterior surfaces to maintain its water resistance should the wall be pierced or damaged.

To hold the pieces of cardboard together, while minimizing weight and maintaining structural integrity, rather than using glue, I decided to use bolts in each corner and midway through each wall unit. I drilled holes through the wall units to insert the two-inch hex bolts. While tightening the nuts onto the bolts, the head of the bolts began to tear through the surface layer. To combat this, I added a washer on both sides to increase the surface area of the hex bolt on top of the wall. This improved the durability of those points, but did not maintain its ability to prevent water from getting in the seams. I added a rubber washer under the metal washer to create a watertight seal. To minimize the number of parts used in the final design, I combined the two washers and used a roofing washer. The four part connection unit (bolt, metal washer (2), rubber washer (2), and nut) became a three part connection unit (bolt, roofing washer (2), nut).



Assembly

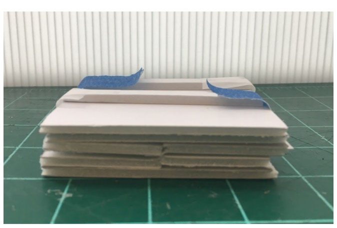
In order for this solution to be viable in practice, it needs to be constructed easily and quickly. Throughout testing, I was constantly aware of every opportunity to minimize moving parts in the final design. The more moving parts there are, the more likely it is that the shelter could fail and not be able to be repaired. One goal of this design was to be able to erect the shelter with only one pair of hands in under one hour. While it is possible, it would be more accurate to say that this shelter can be put together with two people in one hour, or with one person in a few hours. This is still a faster deployment time than many of the immediate temporary disaster shelters on the market today. The hardest part of the assembly is adding modular units together. In order to ensure a snug fit, it takes two people to set the female connector around the male connector. Once completed, however, the sturdiness of both shelters combined improves the overall strength of the shelter. Nylon straps on both interior and exterior will be used as dynamic hinges for each of the wall connections. This material is durable, cheap, and will not shrink or stretch like a cotton or rubberized strap.

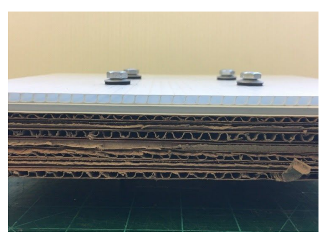


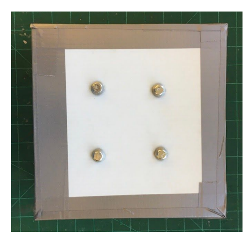
Product	volume for 1 shelter		Wholesale $ /	Unit	total $
1 Wall Cardboard	96	36"x72" sheets	$0.99	sheet	$95.04
Duct Tape	1	rolls	$0.72	roll	$0.72
1 Wall Plastic	12	36"x72" sheets	$2.00	sheet	$24.00
Flex Seal	0.25	gallons	$60	gallon	$15.00
2" Hex Bolts	72	bolts	$0.12	bolt	$8.64
Roof Washers	144	washers	$0.02	washer	$2.88
1" Nylon Straps	50	feet	$0.31	foot	$15.50
2" D. PVC	25	feet	$2.50	foot	$62.50
Connectors and Caps	48	connectors and caps	$0.25	cap	$12.00
					total
					$236.28
					* wholesale prices from alibaba.com

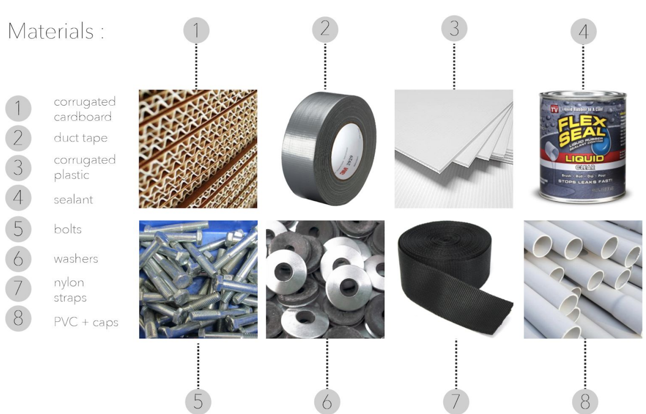
The overall price to build one shelter, is far higher than if I were producing these at a larger scale. In order to gauge what the price would be, I have diagramed the scenario if I were to be building these shelters at scale and buying wholesale products. The figure I computed is $235 per shelter. This figure can be expected to decrease, however, as I sourced all of the products from alibaba.com. Further research into better suppliers would cut these prices further, making it even more appealing for the consumer. This price is also significantly lower than any other similar products currently on the market.

Final solution

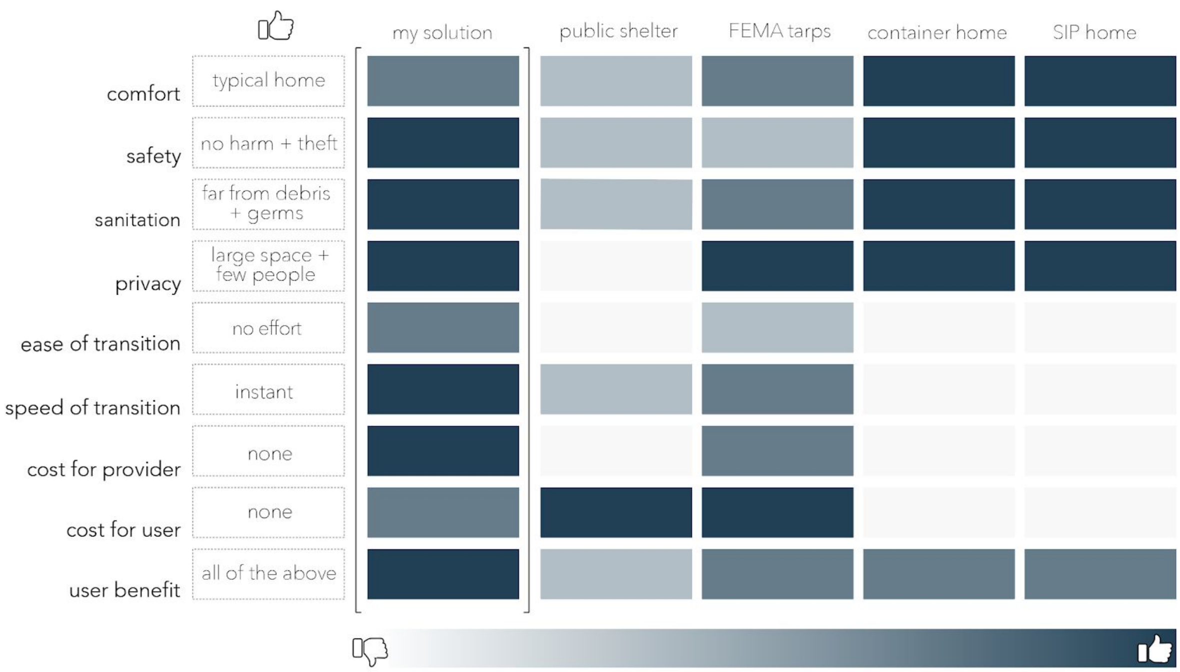








Using the information distilled from the previous research and rounds of testing, I have created a better framework for shelter a system that reacts to local contextual factors and the needs of a specific victim. Since very little information exists pertaining to the analysis of the benefit and success of temporary and immediate disaster relief shelters, I compared my solution against what analysis systems do exist, with common terms. Most documented analysis systems are written for large scale, more common, federal recovery plans (i.e., local public shelters and other FEMA resources). These documents include the USAID Shelter and Shelter Management Reference Guide, The International Hurricane Research Center's Shelter and Component Testing of Transitional Shelters: Materials, Techniques and Structures, and Care Emergency Toolkit's Shelter Assessment Checklist. From these documents I was able to appropriately place myself within the conversation of disaster recovery shelters. I then used my own parameters, as were defined in the research described previously, to create another set of parameters. These were used to analyze the designs against more common solutions, highlighting its many benefits.

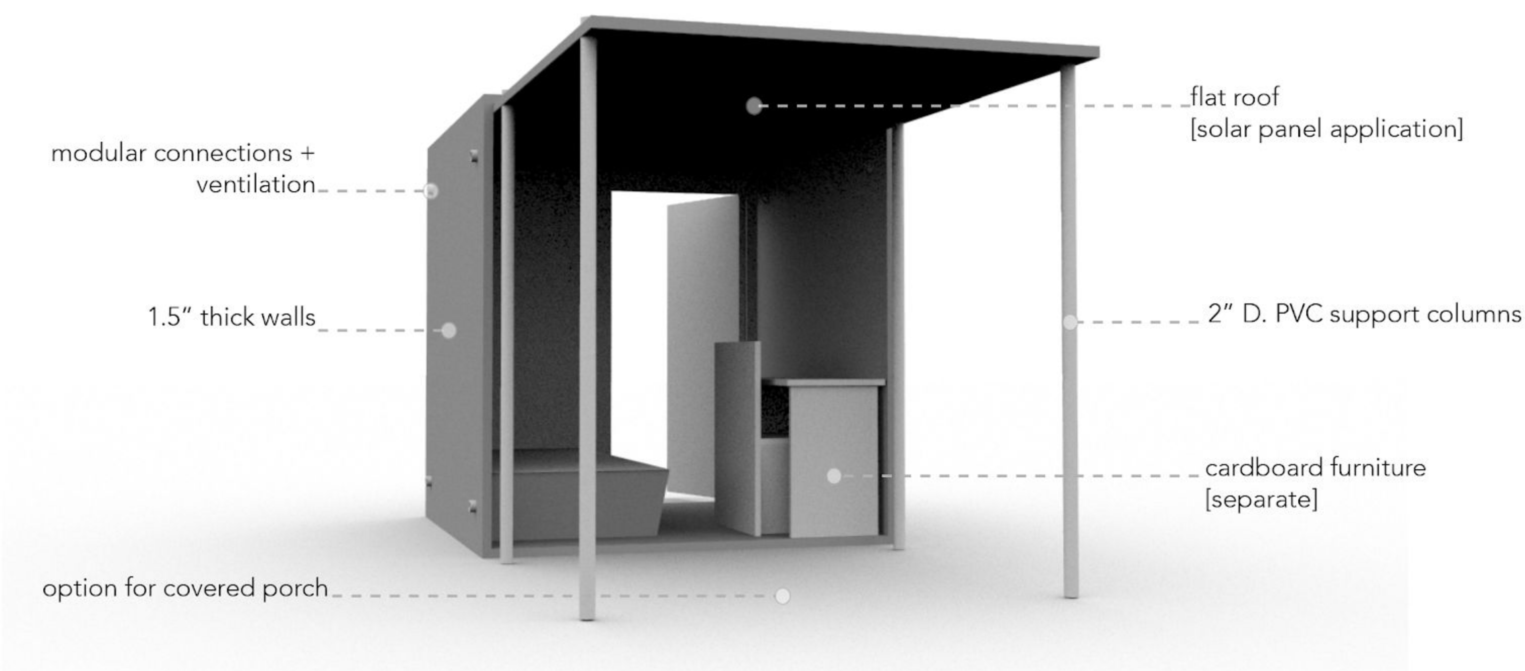


I am unsure if these parameters include all of the key requirements of an adequate post-occupancy type test, simply because there are no established examples of this type of evaluation for immediate temporary emergency shelters that I could find. I used examples from organizations like FEMA, USAID, and the Care Emergency Toolkit Organization to get a basic outline, but I cannot be sure they are an effective guide when it comes to smaller scale personal, temporary, and immediate shelters.

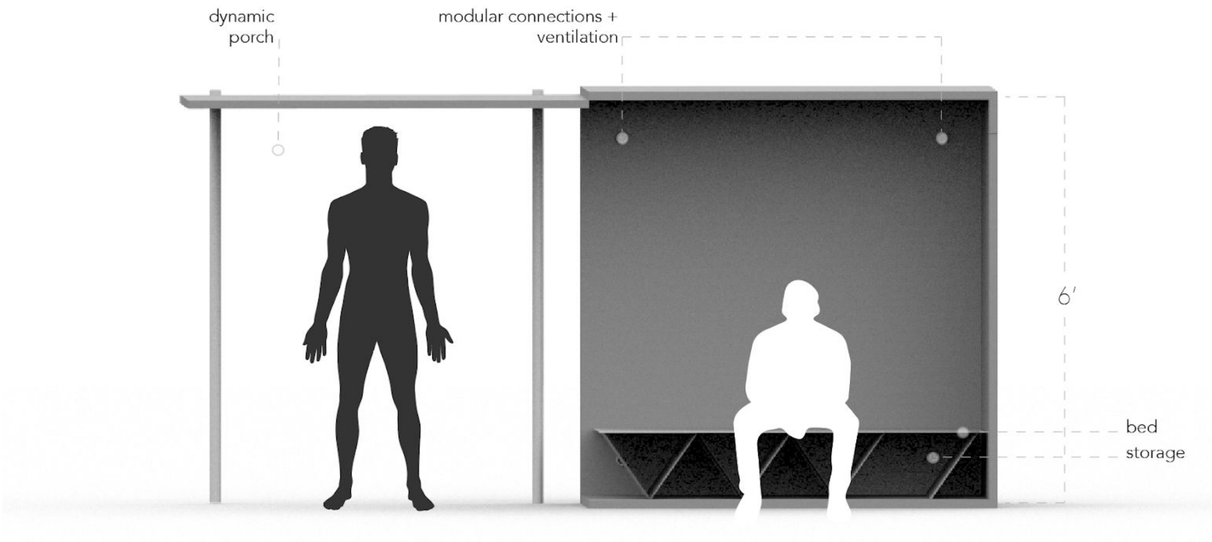
In the scope of my thesis research, I have focused on Puerto Rico as a recent and extreme case of failed hurricane disaster recovery. These islands are not the only place in our world that experience the same problems and are in similar financial standing. This design may not be successful in all locations globally, but it should be effective in tropical climates, specifically those dealing with hurricanes, though I have not tested it on site, or in legitimate circumstances. The way in which I achieved my design, however, can be scaled to any location to provide a more effective solution based on local contextual needs.

Weather is inherently unpredictable, especially as today's climate crisis continues to worsen. This causes difficulty while predicting the needs of victims, in terms of severity of storm and level of protection required. I also only looked at emergency shelters that fit the basic requirements that I had defined. This means there could be other elements, utilized in other shelter systems, that I could have taken advantage of in my own proposed design. These are potential questions for further research.

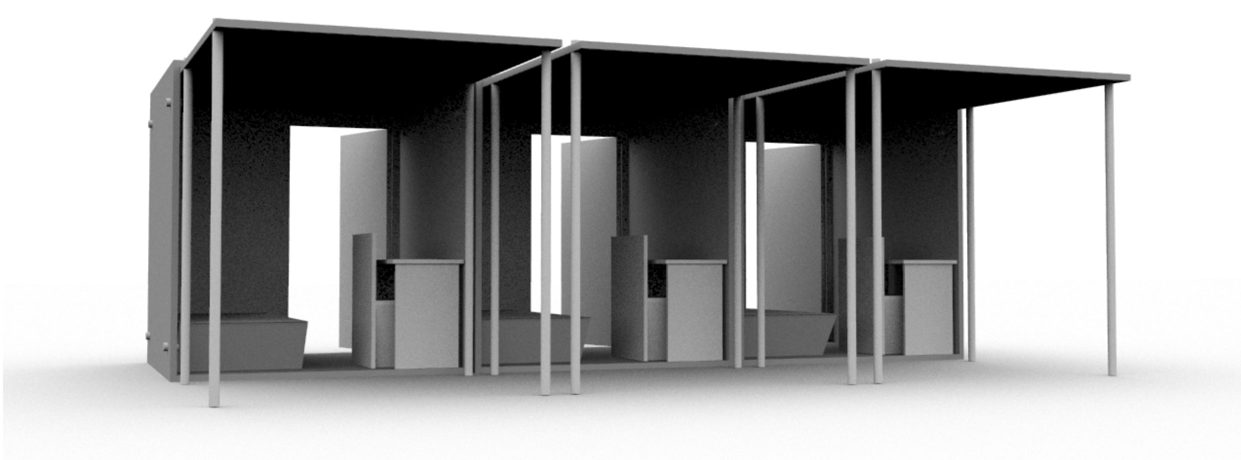
5.0 Solution

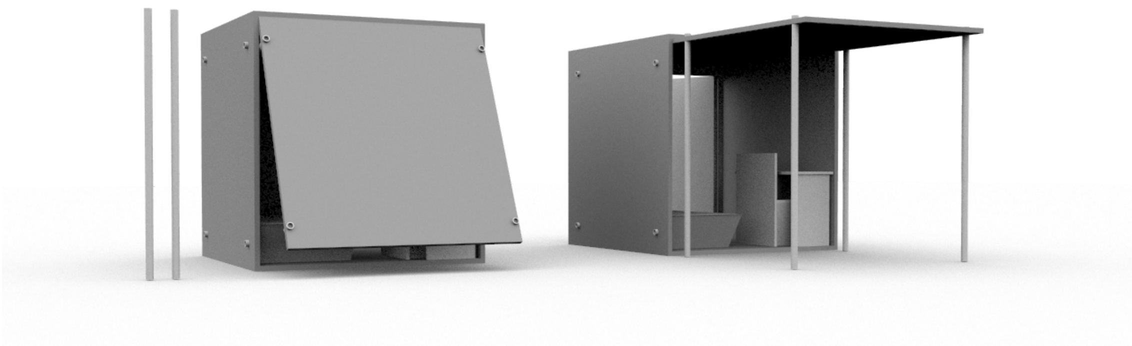


Design



When constructed, the proposed shelter is a 6’x6’x6’ box, with 1.5” thick corrugated cardboard and plastic walls. The average household in the target towns, Adjuntas (3.2), Canovas (2.9), Cayey (3.0), Jayuya (3.3), Orocovis (3.3), and Utuado (3.1), contains 3.1 people, while the whole of Puerto Rico houses a slightly fewer 2.9 people (DADS 2010). In order to maintain its ability to be folded, stored, and transported easily, I decided that a personal scale shelter would be best, as long as there is an option to become modular. Because it is a personal shelter, it is modular and can be connected, on 3 sides, to other units in rows two units deep and as long as necessary. With the help of 4 PVC posts, a hinged wall gives this shelter the ability to extend its footprint by 100%. This is an uncovered expansion and opens up an entire wall. In poor weather, this wall/roof would be lowered to act as support for the roof and other walls. The structure can be secured to the ground much like a camping tent. Four loops on each of the bottom



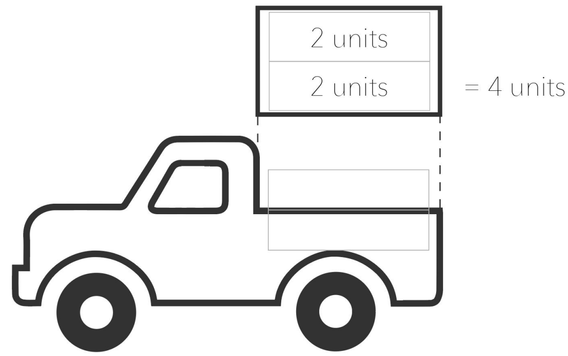


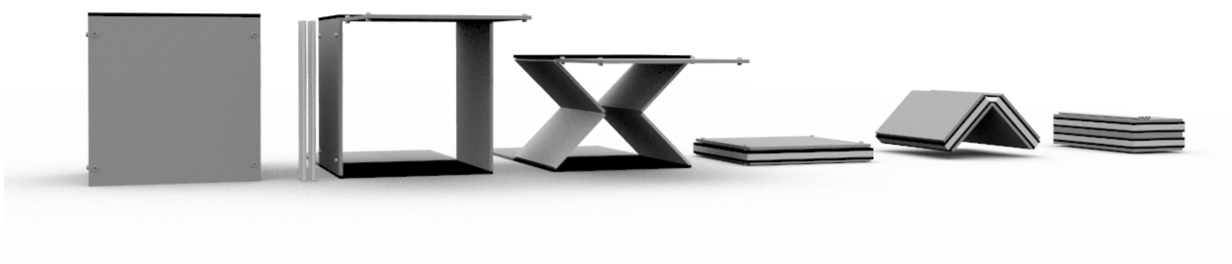
panels, eight total, are used to secure the structure to stakes driven into the ground. Because they would have it on hand prior to the storm, a victim of a hurricane and their family or whoever may be in the household would be able to set up their cluster of shelters immediately as it becomes necessary. In the case that a roof is blown off of a house, this design, because of its relatively small size, allows the shelter to be set up inside the walls of the house to increase safety and add protection from high winds. In the case that the inside of the house becomes unsafe due to broken walls, roofs, or foundations, the proposed shelter may be constructed outside and will perform in moderate to severe weather. I have planned and designed for the furniture inside to be made out of cardboard, to keep costs down and maintain the unit's ability to compact. However, should the user wish to use other furniture, or make their own, they can easily do so.

Fast
Cheap
Durable
Compact
Reusable

Meant to be used for ~7 days, but can be used for longer
Allows people to stay near their homes and in their communities
Creates time for productive community development after disaster
Can be stored in a closet or under a bed and reused.
Transports easily in truck bed
Can be repaired easily and effectively with duct tape.
Flexible uses and modularity

The shelter would come with four (2” D. x 6’) PVC posts, and 3’ x 6’ x 2’ flat packed walls that can be unfolded and erected by one person, though it is easier with at least two. After the shelter is used, it could be cleaned, repacked, and easily tucked away until the next use. Packed size of the proposed shelter was determined so that it may be stored in a closet or under a bed, and transported in the bed of a pickup. This is intended to maximize the accessibility for the user, ensure convenience of storage, and increase their chances of benefiting from the product.





Eventually, the shelter’s life cycle must come to an end. This is estimated to be around 5 hurricane seasons when used for up to one month each season, when treated properly. However, if it is used for shorter periods of time (ie., 7 days), it can be used a greater number of times. Additionally, repairs and additions to walls, ceilings, or surrounding structures could extend this lifespan significantly. When it finally loses its structural integrity, develops mold, etc., the shelter can be disassembled and disposed of. It is 90% recyclable, and the parts which are not recyclable can be saved to use as repair parts if they decide to repurchase the product.

6.0 Unaddressed Problems

As cutting edge, environmentally sustainable, and regenerative energy, water, transportation, telecommunications, and other infrastructural solutions are implemented at a growing rate globally, our technical ability to mitigate risks posed by climate and natural disaster continues to expand. Yet inequitable and insufficient networks of public services prevalent in disaster-prone

locations such as Puerto Rico continue to be stressed to their limits by hurricanes, earthquakes, and floods. A roof overhead, provided by my design, is only one piece of a much larger relief process, but it allows for the victims to begin asking bigger questions. With further research, my shelter design could be tweaked, in order to further maximize the potential of innovative systems, build even stronger networks, and empower communities even better.

6.1 Water

Water is a vital component of human health. As such, it is necessary that people can access clean drinking water, especially in a disaster scenario. Water contaminated by animals, chemicals, and other waste, can carry germs and disease that cause even deeper issues in the wake of the storm. My shelter does not currently offer any way to gather or harvest drinking water, but further research and testing could change this. Aftermarket systems can also be easily applied to the shelter, as it is. The flat roof offers itself to the potential application of rainwater collection systems. These could lead to gravity filters and water basins for easy use. This has been done many times before in off grid living, and has proven itself to be successful.

As was mentioned previously, these are aftermarket systems, and can be applied to this shelter as well as to normal homes. If people who live in disaster prone areas were to utilize a rainwater collection system, they would be able to collect as much water, for free, as they wanted. They would do this all year in preparation for hurricane season. When the hurricane comes, they would pull the system, and the water, inside. Preparation is the most critical step of a disaster recovery plan, whether it is a sturdy roof overhead or clean water to drink.

6.2 Electricity

Countless deaths after hurricane Maria came, not from weather, but from some sort of lack in electricity. Hospitals were without power for days or weeks, dialysis machines were not working, people were afraid to travel through streets riddled with downed power lines and rubble. On top of this, communication across the island was cut to almost nothing. My shelter does not possess any way to create electricity, though with more research and testing it could easily adapt to work with new solar technologies. The flat roof and walls of my design can be easily adapted to harness solar energy. Because it does not need to be sunny for these panels to work, at-risk individuals who are dependent on electricity will not be forced to worry about yet another life threatening predicament.

Puerto Rico has been exploring solar energy options for years, but to little avail. It has become an issue less about providing energy to the people, but making money off them. The scope of my thesis does not involve these policies; however, personal or regulated solar power hubs could further benefit the victims potentially using my shelter.

6.3 Food

Food is not only an essential element for human health, but also for morale. In my experience, this is especially true in Puerto Rican culture. Food is a way in which a community, at some scale, is able to gather and connect. Without food, general morale, thus social productivity, is halted. Though Puerto Rico has fertile soil, and it is home to a wide variety of fruit trees, they are stripped bare by the hurricane's wind. The same thing happens to many edible crops across the island, except for root vegetables. The soil protects the food from the storm, allowing it to remain even after many of the other crops have perished. If people were to grow root vegetables in their own gardens, they would have a source of nutrition at their fingertips immediately after a hurricane. With my shelter, these people would be able to stay near their gardens and be able to sustain themselves, at least for a while, as they wait for support to come.

Dalma Cartageña, a top Puerto Rican agroecologist, has been teaching young children how to grow food in schools so they may take it back to their parents. This is all in hopes that they, or their parents, become excited about producing their own healthy food. Cartageña, along with other agroecology 'brigades' are equipping entire communities with the resources to help sustain themselves. In a disaster scenario, this could be a matter of life or death.

7.0 Contribution

"An ounce of prevention is worth a pound of cure"

- Benjamin Franklin

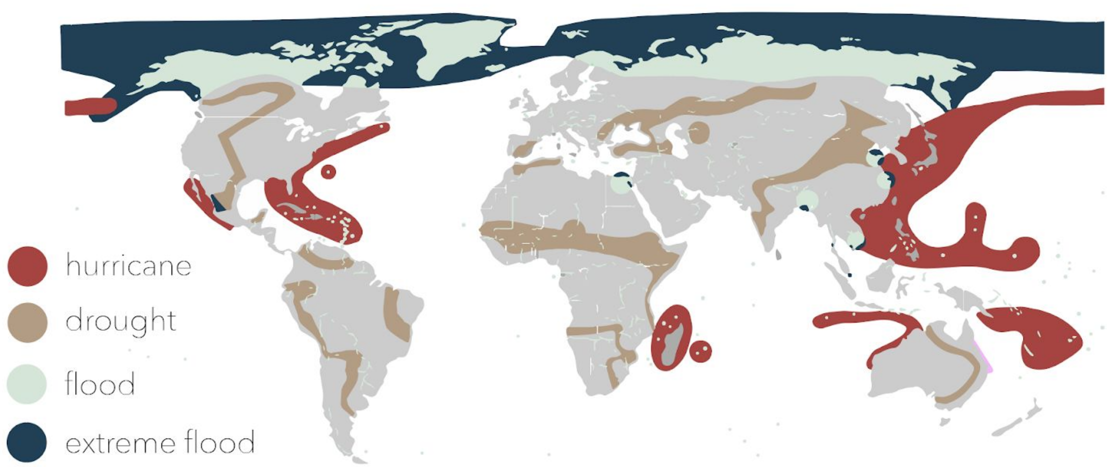
After the 2017 hurricane, Maria, the island of Puerto Rico was left helpless for days, and in more rural parts, for months. These people were expecting aid from the mainland United States, or anyone else in the world. Due to inability to communicate with or access these areas, however, they were left to their own devices for an unacceptable period of time. Through observation, conversation, and the analysis of literature and data, I determined the most critical requirements of an effective shelter. Using these criteria I designed a comprehensive, temporary, and immediate emergency shelter system. By designing for a local context and educating at risk populations on proper preparation, whether it be food, water, power, or this shelter design, remote victims of hurricanes can begin to provide these necessities for themselves, rather than relying on outside sources of aid. This research and the design framework for this shelter improves the ability to self sustain for a week or as long as a month, without external resources, in hopes that by then the community has had the chance to begin rebuilding on their own terms. This bottom up approach improves both morale and social responsibility. Without this design, residents can be left feeling desperate and powerless. As hurricanes increase in severity and frequency, adequate disaster response is becoming more important than ever. Disasters will continue to occur, and without a system that involves and appreciates the victims it is designed to help, death counts and poverty levels will continue to increase.

Because I used Puerto Rico as a case study, the physical result of my research was a shelter that will truly benefit Puerto Rican hurricane victims in a way that current shelters and disaster recovery systems do not. The success of this shelter is rooted in the approach in which I designed for these people. By understanding the inherent benefits of a bottom up approach, my methods can be utilized across any culture or community. This approach affects individuals on a personal level, which allows each person to contribute to a community effort. Rather than focusing on larger scale needs, one solution that can sort problems in most places, it may be beneficial to focus on individuals' needs based on their specific surroundings and circumstances. The way in which I determined what was important, or not, can be scaled to any location for any disaster need, and the product is easily modified to fit each new parameter.

The current Puerto Rican post-disaster housing situation needs help. After almost every hurricane season, thousands of US citizens are moved to temporary shelters, given mere tarps to fix entire roofs, or are simply ignored. I have designed this shelter for the people of Puerto Rico. consequently, it considers critical elements specific to Puerto Rico, and may not respond to cultural or climatic factors of alternate location. However, it offers a way in which people can provide assistance for themselves and their families, without having to uproot and change locations. This comes with many benefits, but the primary role this plays is allowing people to contribute to the betterment of their situation, giving them a sense of purpose and responsibility in a time where these are necessary. By allowing this feeling, people can begin to repair their permanent living quarters, move back in, focus energy on community needs, and eventually return to normal routines. Rather than evacuating people from their homes and islands, this solution provides them with an opportunity to better the situation for themselves and for each other.

By replicating my methods and responding to local cultural and contextual needs, the general speed and quality of disaster relief models can be improved. The process in which disaster shelters are designed and delivered is currently flawed, but this research has provided a framework in which to think about how we can better design for humanity in the future. By being aware of, and consciously reacting to, local contexts, a shelter begins to be more effective in its given target location. By coming from the bottom, the community becomes engaged and empowered. By doing both of these, we can begin to solve the problems surrounding inadequate disaster relief procedures. This comes at a critical time as the climate crisis will continue to demonstrate its snowballing fury across the globe. Tropical zones are experiencing more powerful hurricanes, just as more arid climates are experiencing more intense droughts. The trend is the same in every climate, and as such, there is a growing need for productive and effective disaster housing. From one disaster in Puerto Rico alone, thousands of people were stranded without a home for months at a time. This is the first step to keeping these people safe, happy, and healthy.

Type and Location of Natural Disasters [last 50 years]



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