Defense Doughnut

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Mission Statement:

Our mission is to design a shelter for the displaced persons of Myanmar. The cause of the displacement is damage and flooding due to Cyclone Nargis. These shelters will be versatile enough to house a family of at least six or to establish business in the new community. The target market for this design is the displaced people in Myanmar, the secondary market is the International Federation Red Cross and Red Crescent Societies that did substantial amount of relief work in Myanmar after the cyclone hit. Also included in our secondary market are other displaced persons in similar situations. The shelter must be low cost and be able to withstand heavy rainfall and high winds. Lastly, a goal is to provide a safe and comfortable living space and help the displaced people develop a sense of community outside of their own homes.

Context

Our group chose the natural disaster of cyclone Nargis in Myanmar because of the large number of people that were affected. This offers a unique opportunity to design something that could be mass-produced to help many people. Another reason is that Myanmar in 2015 had the highest risk index with a 6.8. Risk index accounts for physical vulnerability and socio-economic fragility. Considering this area of Myanmar is prone to storms, this design could potentially be reused for more disaster relief (“Myanmar: Disaster and Risk”). The International Displacement Monitoring Center states that the duration for the displacement took “at least 6 years” for the internally displaced persons (IDP) to go back to their villages (Yonetani 99).

Part 1:

In 2008, Cyclone Nargis devastated the Ayeyarwady Delta region of Myanmar. More than 2.4 million civilians were affected by the storm (Casey). The floodwaters were as high as twelve feet and spanned about twenty-five miles. Approximately 53,800 people went missing and 84,500 people were confirmed as dead (“Myanmar: Cyclone Nargis”). Ninety-five percent of buildings over thirty-seven townships were destroyed (Casey). The Red Cross relief encompassed an area of about 18,000 square kilometers. Over the three years they spent in Myanmar, they constructed 12,404 homes for the displaced people (“Myanmar: Cyclone Nargis”).

Part 2:

Myanmar (Burma) is located in the western part of Southeast Asia. It has a population of 51.6 million that reside in numerous villages. Myanmar gained its independence in the year 1948 from the British colonies, after which the constitution has been amended several times. The latest constitutional alteration happened on May 29, 2008 (Steinberg). In that same month, the worst natural disaster in the history of Myanmar
happened. Cyclone Nargis struck Myanmar on May 2nd, 2008, making landfall in the Ayeyarwady Delta region. The Category 4 cyclone turned into a Category 4 storm with wind speeds reaching a maximum of 132 mph. Nargis crossed through several townships including Yangon, the largest city, before exiting from the eastern mountains.

Labutta is the town we chose to build our shelters in because the displaced persons from the rural villages in the Delta region were sent here to live on the outskirts in a refugee camp. Labutta is within close proximity of the Bay of Bengal, which is considered one of the seven tropical cyclone basins. The altitude in the Ayeyarwady Delta region does not exceed 60 feet. Labutta is subjected to seasonal monsoons receiving more than 200 inches of precipitation annually. The average daily temperatures range from 79 to 81 degrees Fahrenheit. The ethnic group that resides in the Ayeyarwady Delta region is the Burmans who account for 68% of the population. Buddhism is the main religion that is practiced in Myanmar. The official language of Myanmar is Burmese although the dialect slightly differs with region (Hadden 5-24). Surprisingly, at first the Burmese government rejected international aid and made it difficult for volunteers to get visas. The UN Secretary General Ban Ki-moon stated that only one quarter of those affected received aid. However, after several meetings with the government they finally agreed (Vinck and Stover).

After the cyclone hit and political issues were worked out, the people residing in Labutta received aid such as food, water, and healthcare. Now, thirteen communities have clean water due to the rehabilitation and construction of ponds and the cleaning and installation of rain collection tanks and tubes. Along with clean water, the economy of the region has regained strength including agriculture and small business (“Myanmar: Cyclone Nargis”). Despite this effort though, “Many in the villages, including pregnant women and children, have substandard diet. Across Myanmar, “about 40% of children fewer than 5 years have stunted growth and about 30% are underweight” (Lateef). Members of the Red Cross taught the people how to become healthy and stay healthy for themselves and their surrounding communities (“Myanmar: Cyclone Nargis”). After the Red Cross left the general well-being of these communities dramatically declined. According to Lateef, “There was a general lack of medication and if available, there was often sharing and splitting of these medications with others, making prescribed treatment ineffective”.

There are transportation options, but they are not adequate, as the dirt roads are very small. The main form of transportation is in the form of passenger busses that are small-motored vehicles carrying much more people and items than it can safely fit. There are many resources in Myanmar, and “timber logs are the most valuable and currently provide a substantial proportion of national income” (Allan). This resource could provide important means of repair for shelters that are used in this region.

Customer Needs:
In the design of our shelter, we took customer needs into consideration. We separated the needs into three different categories. The first category, things that were absolutely necessary. Our shelter had to have doors and windows for easy access and natural lighting on the inside. The shelter must be able to be repaired with local materials. The shelter must be weather resistant because the main reason these people are displaced is because of flooding and heavy rains. The shelter must be low cost because the people that desperately need these places to live do not have a large amount of money, if any, to devote to this. The shelter must have the space for at least six people to comfortably live. The second category, primary needs. The shelter should have a floor, so people are not walking on the dirt or mud. The shelter should be lightweight for ease of assembly and repair. The shelter should have locks for privacy and protection. The shelter should be easily mass-produced to reduce the cost.

The third and final category is secondary needs. These needs are “amenities” to the existing shelter that is already livable. While these things are not necessary for survival, they are to keep the people living in the shelters comfortable. As stated previously, a large number of people were pronounced missing after the cyclone. Many of these people have no way of knowing if any of their family members are in the camp or where they are located in the camp. A solution to that is a shelter identification number. Each shelter will have a number near the door. When the shelters are assigned to each family or group of people, the names of the people will be documented and put in a directory for public use. Another secondary need is the capacity for electricity. The area in Labutta where the camp is located is not wired for electricity. Therefore, the shelters will not have access to electricity, but the shelter itself does have the capacity to be wired for electricity if it becomes available. Flooding is a big problem in the area of the camp, so flood resistant was something that was put into consideration. The design has five “feet” raising it off of the ground. These feet hold the shelter three-tenths of a meter (about 1 foot) off of the ground.

Secondary Customer

The charity chosen as the secondary customer is the International Federation of Red Cross and Red Crescent Societies, with a chapter known as the Red Cross in United States. They operate in 190 countries that are members of the federation and whose societies are still forming. Countries with still forming societies are all over the world, in Africa, the Americas, Asia Pacific, Europe, and Central Asia. From 2004 – 2011, they served 160 million victims of natural and manmade disasters (“National Societies”). Most recently, they have assisted in Nepal after two large earthquakes hit them in April 2015. They were able to respond quickly and distributed pre-portioned relief supplies, and provided emergency medical attention and transportation on the dangerous roads prone to landslides after the earthquake. In total, they assisted 620,000 people after the earthquake. In addition, they provided temporary shelter and camps to people who were displaced by the earthquake. Now, they are focusing on providing water, sanitation, and permanent
homes that will be resistant to future earthquakes (“Six Months”).

The Red Cross typically responds to disasters with immediate relief, including food, temporary shelters, and essential hygiene products. They also provide emergency health service for those injured, water and sanitation, and family tracing services. They have a program for shelter for displaced people, and they have criteria that must be followed. Directly following a disaster, they are mainly concerned with saving lives. To achieve this goal, they focus on rapid shelters, such as “tents, shelter kits, or materials to build or repair homes” (“What We Do”). After saving as many lives following the disaster as they are capable of, they focus on how long it will take to rebuild the affected community based on the scale of the disaster and provide more sturdy shelters if needed. The key considerations for these shelters are “providing protection from the climate, ensuring privacy and dignity, and providing personal safety and security” (“What We Do”), taking into account both the climatic and social conditions. If someone wishes to volunteer with this organization, they can join the society in the country in which they reside. This will provide opportunities to help those in need. (“Become a Volunteer”)

**Concept Generation**

To begin, we each brainstormed unique shelter designs individually. This gave each group member the freedom to draw out of the box sketches without the influence of others. Sometimes, teammates can negatively impact the design process by immediately shooting down others thoughts. Crazy designs have the potential to be the best possible solution. In our group, each team member had developed structures with unique amenities. Some amenities, such as a roof that collected water and rooftop with a garden, were thought of individually by different team members. When we reconvened as a group after brainstorming, we agreed that these similar amenities should be included in our final design.

We came together as a team and selected five designs to assess in the concept scoring matrix. We made sure each design had unique characteristics that would assure varying scores in the matrix. The Doughnut, Standard, Prism, Attic, and Rooftop Garden designs shown in Figure 1 were given scores between 1 (being not met the criteria at all) - 5 (being satisfying the criteria) in five criteria categories.
Our number one priority was creating a cheap, yet stable structure. So, cost and durability were given the highest weight of 30% in our matrix. Cost is the category our design was scored the worst. We assumed that the cut out in the center would be an expensive addition. On the contrary, we believed our chosen design to be the most durable. Due its many sides, it is aerodynamic and will not be moved during storms. Next, we assessed the extra amenities and privacy of each design with a 15% weight. Again, the Doughnut design scored the highest because of its outdoor privacy space. All designs were decided to have a lockable door and sealable windows, so the personal space outside set it apart. The space is also a great amenity for gardening or cooking. Lastly, we rated the ease of assembly at 10%. We do not know the practicality of assembling each design so we looked at the number of faces the user would need to put together. Although our design did not receive a high score in ease of assembly as well as cost, it still resulted with the highest score when we multiple the 1-5 scores by the criteria weight and added them together. The results of each designs assessment can be found in Figure 2.
In order to assess if the shelters met the criteria, we needed to set specific requirements that met the customer’s needs. For an example, the customer needs a shelter they can afford, so we said the price of our shelter needed to be under a $1. It needed to withstand being dropped 4 times from 7 feet high and be dividable for at least 6 people to live inside. These are just a few of the requirements, please see Figure 3 for more specifications Prototype 1 needed to meet.

**Figure 2**: Table used for the scoring matrix.
**Figure 3**: Table used for testing prototype 1.

**Test Summary for Prototype 1**

Notice: The following tests results can be found in Figure 3.

<table>
<thead>
<tr>
<th>User Need / Feature / Requirement</th>
<th>Describe Test</th>
<th>What is &quot;pass&quot;?</th>
<th>Materials / tools needed to run tests</th>
<th>Result</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Efficiency</td>
<td>Square footage of material used</td>
<td>under 4 ft²</td>
<td>Ruler</td>
<td>0.72 ft² foam 3.25 ft² pressboard 3.91 ft² total</td>
<td>PASS</td>
</tr>
<tr>
<td></td>
<td>Mass of structure</td>
<td>Less than 0.3 kg</td>
<td>scale</td>
<td>0.27 kg</td>
<td>PASS</td>
</tr>
<tr>
<td>2. Strength</td>
<td>Can withstand several drops from a height of 7 ft</td>
<td>No deformation for at least 4 drops</td>
<td>Chair</td>
<td>Slight deformation after 4 drops</td>
<td>FAIL</td>
</tr>
<tr>
<td></td>
<td>Withstand a crush test</td>
<td>Withstand 30 lbs</td>
<td>Ruler, scale, and crush test</td>
<td>Withstood 55 lbs</td>
<td>PASS</td>
</tr>
<tr>
<td>3. Water Test</td>
<td>Handfuls of water dropped on mini model</td>
<td>Less than 1 in² on bottom of model</td>
<td>Water faucet</td>
<td>½ in² of water accumulation on bottom</td>
<td>PASS</td>
</tr>
<tr>
<td>4. Cost</td>
<td>Total cost of materials</td>
<td>under $1.00 of materials used</td>
<td>Ruler, calculator</td>
<td>$0.83 from pressboard $0.34 from foamboard $0.87 total</td>
<td>PASS</td>
</tr>
<tr>
<td>5. Ease of Transport</td>
<td>What size box could all materials fit in</td>
<td>Fit in a cereal box (nothing larger than 12 in)</td>
<td>Ruler</td>
<td>13 in x 6 largest length</td>
<td>FAIL</td>
</tr>
<tr>
<td>6. Ease of Assembly</td>
<td>How many parts are used in the design</td>
<td>not more than 20 different parts</td>
<td>N/A</td>
<td>16 parts</td>
<td>PASS</td>
</tr>
<tr>
<td>7. Privacy</td>
<td>How many individual spaces in the structure are there?</td>
<td>3+ divided rooms</td>
<td>N/A</td>
<td>4 rooms</td>
<td>PASS</td>
</tr>
<tr>
<td>8. Security</td>
<td>What security measures does it include? - door? - lock? - sealable windows?</td>
<td>at least 2 of these security measures can be implemented</td>
<td>N/A</td>
<td>Door, lock included</td>
<td>PASS</td>
</tr>
<tr>
<td>9. Ease of Repair</td>
<td>Easily repaired</td>
<td>Only 2 materials are needed to repair</td>
<td>Repair materials</td>
<td>Only tape and glue used</td>
<td>PASS</td>
</tr>
</tbody>
</table>
After hours of work and iteration, our prototype was complete. The first test required us to find the area of the materials used. We used 0.72 ft$^2$ foam and 3.25 ft$^2$ pressboard. This was under 4 ft$^2$ so the design passed. The materials were lightweight and weighed less than .3kg. We only used 33 cents of pressboard and 54 cents of foam board resulting in a price under $1. So the design passed the cost test. However, it failed the transportation test. We wanted all materials to fit in a cereal box which has a max side 12 inches and one of our dimensions exceeds this at 13 inches. However, it has less than 20 parts and can be divided into 3 or more rooms.

Next, we needed to make sure the structure is secure and can withstand the weather in the local area. We made sure that our design had two or these three security measures: a lockable door, sealable windows, or a shelter identification number. In Figure 5, we tested the seals and made sure water kept out of the shelter. In the second picture in Figure 5, the little spot of water was from a wet floor not from water seeping into the structure, so the test was passed.
Lastly, we needed to test the durability and structure of prototype 1. First we dropped the structure from 7 feet high, four times. We did this to test the materials and see if the structure deforms. As shown in Figure 6, it did.

**Figure 5**: Structure before testing (left) and after testing (right).

**Figure 6**: Durability test (left) and the damage to the structure (right).
This also helped us test the easiness of repair. We only needed a hot glue gun to connect the faces back together. Even with the earlier damage, the structure was still able to exceed the 30lb requirement and hold 50 pounds of paper. See Figure 7.

**Figure 7**: Prototype 1 undergoing crush test.
Concept Refinement

**Figure 8:** Final rendered design (left) and cross-section (right).

After testing Prototype 1, areas of improvement were recognized for the making of Prototype 2. We refined the size of the structure: the wall faces were constructed to be the same size, as seen in Figure 8. This would make the structure more like the original idea, making it more aerodynamic in order to resist the strong winds. New features were added that were not in the original prototype in order improve the shelter and better meet the defined customer needs. The first noticeable feature that added was the slanted roof. Another additional feature to the second Prototype is the skylights in the slanted roof. The third significant feature is the cutouts on the bottom of the base of the shelter. These are square, instead of circular in order to more easily cut the wood available in Myanmar.
Figure 9: Water collect concept used in final design.

Test Summary for Prototype 2

The features added to Prototype 2 will better meet the defined customer needs. The slanted roof, in Figure 9 will allow the residents to collect water from the roof runoff, allowing them to productively use the natural resources. This was proposed during brainstorming but was not constructed on Prototype 1. The windows on the top of the roof, seen in Figure 9 will provide natural light inside the shelter, and are also safer than windows on the side of the shelter because they are less accessible for thieves. This meets the need for safety as well as light indoors. The cuts from the base of the shelter allow the feet on the bottom to be more secure; instead of simply attaching the feet to the bottom, they will slide in the cut-out to be held in place.

Cost Analysis

The estimated cost of prototype 1 was calculated using the prices for the materials used in class. For our test, we wanted the cost of the prototype to be under $1.00. It was calculated to be only $0.87 and passed the test. For prototype 2, the Solidworks model was rendered in a generic dark plastic. However, the material of prototype 2 is not the material we would want to mass produce the shelters out of. In our actual manufacturing process, we chose a fiber-reinforced plastic (FRP). This plastic is extremely strong, which will help the durability of our shelter. Another plus is that it is sold in many different shapes and sizes and can be customized according to customer needs. We can order these panels in bulk with a large discount being taken at 5 panels or more. Our design has 25 panels of
varying shapes and sizes. By using the bulk price for generic panel size of $51.38, the calculated price of this shelter is $1,284.50. However, the size of most of our panels are smaller than the normal selling size, so the price would most likely be lower, estimated around $1,000 per shelter. Producing these in bulk, would inevitably lower the price because many companies offer bulk pricing ("Flat Sheet"). The lifts on the bottom of the shelter will be made from wood which is easily obtained in Myanmar due to the thriving lumber industry.

The average cost of repairing the shelter over ten years would be about $400-$500. This would mostly come from wear and tear on the plastic due to harsh weather conditions. Replacing a panel would cost up $50, depending on the size of the panel. That is where most of the cost would come from ("Flat Sheet"). The wooden lifts would be inexpensive and easy to get a hold of because lumber is a thriving industry in Myanmar. Obviously, the lumber would be provided in the country. The plastic, however, would have to be shipped from either the United States, or a another country that has FRP manufacturing.

Consideration of Human Needs

In the shelter design, human needs were taken into consideration at every step of the design process. The basic human needs like food and water were taken into consideration first. The area in the middle of the shelter is open for private use. It can be used for a garden and an outdoor cooking space so people do not have to have smoke in their homes. Water collection systems can easily be added to the slanted to always guarantee access to fresh water. Safety was taken into account and each door can be fitted with locks for privacy and safety. Also, the outdoor space in the middle of the house is only accessible from inside the home so it is secure. The space in the home can be divided into separate rooms so everyone can feel like they have their own space. Another concept unique to the design is the shelter identification number. Each shelter is assigned an identification number that is recorded in a directory that is accessible to the public. People will be able to easily find each other, as well as “lost people” being able to reunite with their families. The shelters can also be arranged a beehive pattern to create small neighborhoods to have a better sense of community. These areas can also be used to establish small markets or other businesses to normalize the area and make it feel like their previous home.
Consideration of Overall System/Camp

Each shelter is the exact same size, dimensions and all. So, once the people learn to build one, they will be able to build all of them. In a larger community, the shelters would ideally be arranged in a beehive pattern to create a small area shared between multiple homes (Figure 10). This would be efficient for space because you can put these patterns back to back and not worry about space between them because it is the back of the home. Putting the shelters in endless rows makes people struggle to find their homes, and it is not as personal as having your own neighborhood and space. As mentioned before, the shelters can be used to establish business to jumpstart the economy and so people have a local area to go do their shopping, like it would have been at home. The charity was also taken into consideration during the design. The design is very versatile and can be used in other tropical areas prone to flooding. Also, the lifts can be taken off and the shelter can be placed on the ground for places that do not have heavy flooding. The charity will be able to get much use out of this shelter because of the versatility.

Redesign Ideas

For prototype 3, storm shutters would be a great addition as an extra source of protection against the heavy storms that go through the area. Another idea would be providing the capacity for electricity in the shelter. Right now, the area the shelters are located in is not able to be wired for electricity. If electricity becomes available, people will want to have access to it in their homes. Lastly, instead of curtains as room dividers, a great idea would be plastic dividers that fit onto the walls for even more privacy.
A good change in this product would be the use of additive manufacturing to make our final prototype. It would be a great tool for presenting the final project. Another idea is access to different materials, like wood, when doing our original prototypes. Since wood may be the final material used for some prototypes, it would be beneficial to actually build it in that material.

Conclusion

To conclude, the shelter design is useful in the area it was developed for. The design considers the primary customer needs of the civilians as well as the secondary customer needs of the Red Cross. It can be reused not only for other disasters that occur in this area, but disasters across the globe. This shelter is a versatile and comfortable in design, perfect for helping people cope with the disaster that has uprooted their lives.
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