Design Project 1

The “House” Shelter

Erupters Team 7
EDSGN100 Section 22
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Mission Statement
Mount Sinabung in Indonesia has been erupting sporadically for the past three years, and volcanic activity persists today (“Sinabung”). These eruptions have been the cause of the displacement of over 20,000 people (“Indonesian”). The goal of building these shelters is to provide relief and shelter to the victims that were displaced due to the volcanic eruptions. The shelters will be made with cost in mind in order to be made affordable for victims who may have lost everything in the disaster. Some assumptions of the design of these shelters are that the displacement has been caused by the volcanic eruptions and will be used in Indonesian terrain, along with the fact that the shelters will used for a finite amount of time. The stakeholders will be the displaced people, manufacturers, and investors.

Context and Customer Need Development
In order to properly design a relief shelter for the displaced people of the Indonesia volcano disaster, research was conducted. Specifically, societal norms and practices of the Indonesian people were studied, along with the history of the volcano activity. The cultural research provided important information regarding the design process. The relocation area for the victims is in the Karo District, which is located in Indonesia, meaning the displaced people remain in country. Indonesia is composed of 17,508 islands, 6,000 of which are inhabited. Indonesia is the fourth most populous nation which results in a diversity of languages and religions, however the official national language is Bahasa. There are six religions recognized by the Indonesian government (Islam, Christian Protestants, Roman Catholics, Hindus, Buddhists, and Confucians) but 88% of the population practices Islam, the particular sect being Sunni Islam. Indonesians also value hierarchy. Superiors, elders or people with status are revered and are referred to as “bapak” or “ibu” (“Indonesia-Language, Culture”). It was necessary to keep the values and culture of the
Indonesians in mind while designing the shelter. This aspect is crucial because the product needs to be well accepted. Another aspect of the research process was the severity and longevity of the volcanic eruptions. Mount Sinabung first erupted in 2010 after being dormant for 400 years. These eruptions persist today and have caused an increasing amount of damage and displacement to those affected by the eruptions (“Sinabung”). The volcanic eruptions caused severe displacement and recur frequently meaning the design of the shelter would need to be for an indefinite amount of time, therefore they must be well built and maintainable. These factors all played a significant role of the design process. After research was conducted regarding culture and background, secondary customer research was conducted.

The secondary customer chosen is the Red Cross and Crescent Foundation. The reason for this choice as a secondary customer is because this particular organization is a non-profit organization of large magnitude that operates globally. According to the 2014 Red Cross and Crescent Foundation annual report, 63,000 disasters were responded to, 1.1 million items for relief were distributed globally, and 66,300 health concerns were addressed (ANNUAL). The Red Cross and Crescent Foundation is an exceptional secondary customer due to its activity globally, and the scale in which it operates. While keeping the secondary customer in mind, a set of user needs was developed in order to aid in the design process of the shelters.

There are a few basic characteristics the shelter must encompass in order to be an effective product that is well received by all customers, primary (displaced people) and secondary (Red Cross and Crescent Foundation). Some requirements these shelter must meet are ease of assembly, strength (for life longevity and weather protection), comfortability, cost, and durability. These needs and requirements are kept in mind in order to create the most effective and efficient shelter.
**Concept Generation Summary**

A few basic methods and approaches were taken while developing the first prototype. Initially each team member brainstormed basic structure types and drew ideas for shelters individually. This was followed by a team collaboration on which ideas were feasible, realistic and practical. Next, specific aspects were addressed regarding the necessities of the shelter. The table below illustrates the needs as assessed by the group. The target specifications are the descriptions on how the need will be applied in the design process of the shelter.

**Customer Needs Assessment**

<table>
<thead>
<tr>
<th>Customer Needs</th>
<th>Target Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Assembly</td>
<td>30 minutes to assemble prototype equates to 2-4 hours of real shelter assembly</td>
</tr>
<tr>
<td>Strength</td>
<td>Hold its own weight and withstand winds from fans to stimulate storms</td>
</tr>
<tr>
<td>Comfortability</td>
<td>Interior dimensions provide enough room for comfortable living per person</td>
</tr>
<tr>
<td>Lightweight</td>
<td>Parts are not too heavy so that assembly is not made burdensome</td>
</tr>
<tr>
<td>Cost</td>
<td>Cost less than $5 for prototype equates to less than $1000 per shelter</td>
</tr>
<tr>
<td>Durability</td>
<td>Withstands torture tests to stimulate life longevity</td>
</tr>
</tbody>
</table>
The concept matrix depicted above in figure 1 was helpful in determining which type of shelter to build. The matrix aided in the evaluation of pros and cons of all the ideas, and ultimately allowed for an accurate comparison between each shelter. Above are some of the original sketches and ideas for the preliminary design process as depicted in figures 2 and 3. Figure 3 illustrates initial ideas compiled together. This shelter got the highest rating based on the concept scoring matrix. Another idea that scored high but was not the highest was the shelter on stilts (Left picture).
Test Report Summary for Prototype 1

Table 1. Summary of Prototype 1 Testing

<table>
<thead>
<tr>
<th>Customer Need</th>
<th>Test</th>
<th>Testing Result</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly</td>
<td>Test time it takes four people to assemble the shelter with premade parts</td>
<td>Time taken for assembly: 30 minutes</td>
<td>Pass</td>
</tr>
<tr>
<td>Strength</td>
<td>Must free stand, hold its own weight, and withstand winds from a fan</td>
<td>Held approximately 113.6 kg, with 568 weight efficiency. Withstood two fans</td>
<td>Pass</td>
</tr>
<tr>
<td>Comfortability</td>
<td>Measure the interior dimensions and equate space per person</td>
<td>Dimensions allow for approximately 3.6 square feet/person</td>
<td>Pass</td>
</tr>
<tr>
<td>Lightweight</td>
<td>Weigh the prototype</td>
<td>Weight= .2kg</td>
<td>Pass</td>
</tr>
<tr>
<td>Cost</td>
<td>Determine the cost of the materials used based on area</td>
<td>Prototype cost $2.17 (without interior walls)</td>
<td>Pass</td>
</tr>
<tr>
<td>Durability</td>
<td>“Torture Tests” to observe projected durability (Wind/Water Tests)</td>
<td>Two fans on high speed did not affect the prototype. When exposed to water interior remained dry</td>
<td>Pass</td>
</tr>
</tbody>
</table>
The table depicted above summarizes the testing results for prototype 1. When it was tested, it passed all of the simulations and tests for the standards that were determined for a scaled prototype. One thing to note is that during the crush test the shelter corner failed when two people (approximately 180 kg) stood on it at the same time as shown in figure 8. This failure was most likely due to an unequal distribution of weight, specifically on that corner. Regardless, the weight efficiency ratio of almost 570 is exceptional and exceeded the team’s expectations. When the shelter was tested for water resistance as shown in figure 6, the roof dispersed water away from the sides of the shelter and the inside remained dry. This rendered a “pass” for the water
test. When exposed to the winds of two fans the shelter did not move, and this was to stimulate high wind situations for the real shelter. This is illustrated in figure 5. This test was also passed. The comfortability test was conducted simply by measuring the dimensions and determine the amount of square meters per person (scaled to 1:15). The pass for this test was to allow every person 3.3 square meters which was determined to be the comfortability threshold. This test was passed as the inside dimensions when scaled to real dimensions amounted to approximately 3.4 square meters.

**Concept Refinement Summary**

After the development and testing of prototype 1 revisions for betterment were conducted. After assessing the results of the tests, the team concluded that requirements were met, but improvement could be made for a second prototype. The main aspect that needed revision from prototype 1 was the interior of the shelter. Initially the prototype lacked interior walls. Although the comfortability rating passed due to the interior area, the team decided that interior walls would allow for privacy, and this privacy would be valued in the Indonesian culture since the concept of hierarchy is adhered to. The second prototype was the same overall dimensions, the only difference was the inclusion of interior walls which created five separate rooms inside as depicted by the final sketch of prototype 2 shown below in figure 9.
Test Report Summary for Prototype 2

As testing was not available for the second prototype, knowledge of the first prototype and qualitative assessments will be used to analyze the prototype 2. This prototype should behave the same as the first when exposed to testing because the exterior dimensions and materials have not changed. All of the previous tests would pass; the strength has an exceptional weight ratio, it is lightweight, easily assembled, cost efficient and provides enough space to comfortably fit six inhabitants. The only difference made was a change to the interior design. However, this alteration in design is projected to be better received by the customers as it provides privacy, and offers a sense of “being at home”. It will slightly raise the cost of production due to increase in materials, yet it will only be minimal.

Cost Analysis

The estimated cost of the first prototype was $2.17. This cost can be broken down into the components used for each part of the prototype. The base was made from foam board which costs $8.07 per square meter. The base of the prototype was .2232 square meters which cost a total of $1.80. The roof was made from cardboard which costs $2.69 per square meter and .1365 square meters were used in prototype 1. The cost of the roof was $.37. The cost of the second prototype only varies for the interior walls. The interior walls would be made from cardboard, and would have a total a .11 square meters of material (cardboard). This would be an additional $.30, so prototype 2 would cost $2.47. The real shelter is projected to be made with a combination of plywood, particle board and lumber ( (4) 2x4). The total amount of plywood needed is approximately 81 square meters. According to Lowe’s, one square meter of plywood costs $8, so the total plywood needed would cost about $650. The amount of particle board needed would be about 24.75 square meters, and this costs the same as plywood. The total cost
of particle board will be about $200. Four 2x4s at $2.61 each will cost about $10. The total estimated cost of the materials for one prototype is $860 (Lowe’s). The cost for one shelter is very high compared to bulk production of shelters. With bulk pricing for 1000 shelters, the materials will cost exponentially less. At wholesale price, the cost of 93 square meters of plywood is approximately $325. This means that if 1000 shelters are built, the plywood for each shelter would cost $283. Since plywood and particle board have the same retail, it can be estimated that particle board will also cost $3.5 per square meter, meaning the cost of particle board per unit at bulk price is $86.5. (“Plywood”). If the 2x4 lumber is bought in bulk, a reasonable estimate for wholesale pricing is 10% off retail (Lowe’s). This means that the 2x4s for each shelter will cost $9, and the total cost for the lumber of 1 shelter when bought in bulk is $378.5. This is less than half of the retail price for one shelter. Nails for the shelter will also be a cost, however compared to lumber the nails are a minimum. Each shelter will use at most 50 nails, and this cost comes out to be $2 per shelter according to Lowe’s pricing (Lowe’s).

Maintenance over 10 years on these shelters will be minimal. The shelters are expected to withstand wind and rain, but may eventually rot due to the nature of the materials. In this case the roof and exterior walls may need replaced once during 10 years which will cost about $325 (Lowe’s). No maintenance is expected for the interior walls, as they will be kept dry due to the roof and exterior walls.

Consideration of Human Needs

During the design process there was a large consideration of human needs for this shelter. Maslow’s hierarchy of needs was a base driving force for the different aspects and needs that were considered for this shelter. The first matter to be addressed are the basic needs of displaced people. For this specific displacement situation in Indonesia food and water is being provided for
those displaced. “‘They have enough food to eat (In the shelters)’” (‘Indonesian Eruption’). The next concern that was addressed is safety. The initial prototype was made without doors cut out, however for the drawings of the second prototype two doors were included in the shelter. This is not only for convenience but for safety reasons in case of a fire. The shelters are also designed with a gap between the roof and base to provide proper ventilation and sunlight. This will not be an issue for the climate because Indonesian climate is tropical, and does not reach low temperatures (‘Indonesia Weather’). The next aspects considered were the sense of belonging and community within each shelter. The second design included 5 rooms, one of which can be designated as a common area, and this was to give the shelter a “home-like” feeling. The separation of rooms (for sleeping purposes) was to accommodate the Indonesian culture and adhere to the importance of hierarchy within in shelter.

**Considerations for Overall System/Camp**

One decision made to ease distribution and set up was the choice to obtain timber domestically in Indonesia. This not only stimulates Indonesia’s economy and creates jobs, it eases the transportation phase for the materials. With the timber being locally distributed to the displacement sites, it eliminates transportation, which will ultimately save money for production. Another choice that made set up of the shelter easy was the simplicity of the design. The design is not intricate, so there is less room for error during assembly. The design consists of square walls with a roof. The prototype assembly time (30 minutes) proved that assembly can be made easy. This particular design will scale very well to a larger community because of its design. The uniformity of each shelter will provide a sense of equality among the displaced, while respecting the individual hierarchies of each family in the shelter. The shelter’s efficiency on space allows
for many shelters to be placed in a concentrated area without taking up much land space. A square base was used in order to maximize the area of each shelter, and a comfortable amount of room was allotted per person in each shelter. The combination on space efficiency and area per person will provide an ideal large scale community. The design process and shelter tried to incorporate accommodations for community needs. This was done through the communal “house-like” design chosen as the prototype. This accommodates to the human needs of the displaced people. Accommodation of the secondary customer was achieved by choosing to obtain the materials (lumber) in Indonesia. This helps the Red Cross and Crescent Foundation by eliminating international transportation. Rather, the charity is in charge of transportation from the wood mills to the relocation sight, and from there assembly can be commenced.

**Re-design Ideas/Thoughts and Conclusion**

Some suggestions for future testing is to test different materials to best choose one that will suit various factors such as climate and weather, cost, and ease of repair. An ideal prototype 3 would be one that is more spacious, specifically taller. It would also incorporate materials other than wood. This could be done by using a plastic or metal roof. This would ultimately lead to life longevity of the shelters, but would increase the initial cost. In order to change the current design for the better, windows and more living comforts need to be added, such as tables, chairs etc. The prototype can also be improved by painting it, which may lengthen the life of the wood and protect it from rotting. In all a multitude of factors went into designing the prototypes. The design process began with proper research about the disaster, culture and location of the displaced people. From there a secondary customer was chosen, in this case the Red Cross and Crescent Foundation was the secondary customer. Once the customers were chosen, the initial design process included sketches alone, then collaboration. Needs and specifications were
discussed in order to evaluate the preliminary sketches. Ideas were then tested against each other via a scoring matrix to determine the “best” possible prototype. Once the winner was chosen, it was built and tested against the previously determined specifications. The data was evaluated and then improvements were made in order to make a better prototype 2. In all, the design process is a multi-step procedure that consists of brainstorming, testing and improving. This was made evident through the conceptualization, building and testing of the first prototype.
Works Cited


