Team TARP

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The Grid²
Mission Statement:

The Grid² is a durable, lightweight tarp that allows for the accurate placement of the main support beams in a greenhouse. The Grid² will increase the speed and accuracy of the setup of the greenhouses and will allow for more to be built. This product will be used in developing countries, such as Kenya, and it will be mass-produced making the final product price under $50, with our 15% gross income. The Grid² has an intuitive design, quick setup, water and weather proof, and is easily folded up and transported. Designed as a simple 6mx6m square, The Grid² will work to eradicate food poverty by providing Kenyan farmers with a greenhouse to plant and grow vegetables as a source of income and of food. The primary stakeholders in The Grid² include us, the producers of the greenhouse grid, the users of the grid (the farmers in Kenya), and the manufacturers of the grid. The overall design of this product has the customer’s welfare placed first.

Concept Development Summary:

To collect the ideas and information about the region of the world that the greenhouse is to be used, we researched the Internet. From our research on the culture, economy, and climate of Kenya, we learned how valuable knowledge about the location is. Amongst other things we learned that our projects ability to maintain it’s durability under extreme weather conditions was very important. The location we researched experienced times of intense humidity and monsoon winds throughout the year. This played a key role into our prototype’s design. If our design was unable to withstand the water or high winds, then it would ultimately fail as a design.
For prototype #1, we desired features such as, durable, waterproof/weatherproof, lightweight, and transportable. Early sketches of our design looked like a large rectangle tarp or smaller square sections of a tarp.

**Test Report Summary for Prototype #1:**

**Test Results Summary For Prototype #1:**

<table>
<thead>
<tr>
<th>User Need/ Feature/ Requirement</th>
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<th>Pass/Fail</th>
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<tbody>
<tr>
<td>Water and weather proof</td>
<td>We will pour water on top of the tarp and shake it around to see if the tarp repels the moisture. We will also shake the tarp around mimicking high winds.</td>
<td>One side of the tarp (the plastic side) repelled the moisture. The other side of the tarp absorbed the moisture causing it to rip more easily. The tarp was able to be whipped around in the high winds and did not rip or tear.</td>
<td>Fail and Pass</td>
<td>The tarp was not able to withstand different weather conditions because it was not water proof on both sides, however; it was able to withstand high winds by remaining in-tact.</td>
</tr>
<tr>
<td>Sturdy</td>
<td>We will hold the tarp a few feet above the ground at all four corners and gradually add weights to the center of the tarp to see how much</td>
<td>The tarp was able to withstand 12.8 pounds before breaking.</td>
<td>Pass</td>
<td>The tarp was able to support 12.8 pounds before ripping which was more weight than we anticipated.</td>
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weight it can hold before it breaks.

Heat resistant

We will hold the tarp in front of a hair dryer that will heat the tarp to about 160-165 degrees to see if it will be able to withstand and not stretch due to the high temperatures.

The tarp was able to withstand the heat from the blow dryer and the heat did not alter the shape of the tarp.

Pass

The tarp was not affected by the high heat and it did not stretch out. Also, the tarp did not absorb much of the heat because upon inspection of the heated area, it was not hot to the touch.

Durability

We will lie the tarp on the ground and walk all over it with shoes to see if it rips.

The tarp was able to withstand four people with shoes on walking on it for about five minutes and did not stretch or rip.

Pass

The tarp was able to maintain its shape and not stretch or rip after several pairs of shoes walked all over it.

Transportability

We will weigh the tarp to see if it is light enough to be able to be carried long distances. We will also fold the tarp up to see if it is small enough to transport easily.

The tarp weighed 0.5 pounds, and was able to be folded small enough to fit inside a purse.

Pass

The tarp is very light and folds up to a small size making it very easy to transport and carry.
Observation Summary For Prototype #1:

While observing and performing the tests on our first prototype, we learned multiple lessons about our design. Firstly, our prototype proved to be too thin and unreliable for the task requirements. The material our tarp was made out of was not sturdy enough for the type of conditions that it would need to endure to be used in the developing nations. The grid needs to be able to withstand the various weather conditions, rough handling, and to be used multiple times without losing its accuracy. As seen in Figure 1, the tarp had multiple rips in it. Secondly, our first prototype, although it was able to support 12.8 pounds, still tore rather easily during handling and testing due to the fragile nature of the thin plastic material (as seen in Figure 2). The tests proved that the material our grid is made out of is not sturdy enough because tears and rips in the material will ruin the effectiveness and accuracy of the grid. Thirdly, the tarp needs to be water proof on both sides, which we observed was not the case of our first prototype. As seen in Figure 3, water damage occurred on the side of the material that was made of paper which failed to be water resistant. This test revealed the necessity for the grid to be plastic on both sides to be weather proof. Next, our observations revealed that the size and reinforcement of the holes for the rebars were inefficient. The tape around the holes was inconsistent and left pieces of the circles’ edge exposed and susceptible to rips and tears, which is shown in Figure 4. Additionally, the diameter of the holes was too large for the rebars and could be reduced to increase accuracy.

One of the only surprises we experienced during the testing of our first prototype was the strength of the material. We expected the material to be unable to support much weight considering how easily it ripped when we unfolded it from its original packaging. Ironically, the
tarp supported over ten pounds of mass before ripping. This surprise confirmed our choice of material because plastic can be more supportive and durable than one anticipates.

Re-Design Ideas/Thoughts for Prototype #2:

The most beneficial improvements for our second prototype will stem the shortcomings of our first prototype. For example, our first prototype was only plastic on one side of the material while the other side was a paper material. The paper side caused the grid to be susceptible to water damage as observed in our water test. Therefore, we have elected to improve upon this by requesting a material that is plastic on both sides to construct the grid. Additional improvements we will implement for our second prototype include smaller holes (from 1” to ¾”), reinforcement around the grid border, thicker material (or bilayered), tape to mark the grid lines, and a different method of reinforcing the edges of the holes. All of the improvements mentioned above result from our experiences during the testing process. Smaller holes will increase the accuracy as opposed to the larger holes that were less accurate and increased tears in the grid. Because the material for our first prototype was too thin and too delicate, the grid material for our second prototype would be improved with a thicker, more durable material. With the edges of the grid taped, the material will be stronger and lay flatter as opposed to our first prototype which tended to wrinkle up. The tape to mark the grid lines is an improvement on the previous grid lines drawn in marker on our first prototype that rubbed off. Lastly, on our first prototype we cut out the holes and then attempted to tape the edges for reinforcement. That process resulted in inconsistent holes and a sloppy appearance. To improve that, we have elected to stick squares of tape on both sides of the grid at the location of the holes and then cut the holes
out. In this way the edges of the holes will be reinforced consistently and result with a clean appearance.

For our second prototype, we will add an “ease of use” test and remove the folding test because it did not seem to prove or reveal any important information about the quality or capability of the grid to function properly. As we noticed in the creation of our prototype the hallway is a prime location to test this experiment. To perform our “ease of use” test we will ask people passing by if they could spare a few minutes to see if they would know how to use our design with no prior knowledge about this project. We will give them the tarp folded up and a few wooden stakes to represent the rebar place holders the consumers in undeveloped locations will be using. We will ask them to place the wooden stakes in the correct locations while only using the tarp as a guide. This experiment will show how intuitive our design is to users who, before that day, had no knowledge about how the grid layout is used. This test can also be used to test the accuracy of the grid. We will be able to see if the rebar poles are placed at the correct distances from each other. This test is important because it will not only reveal how intuitive our design is, but it will also reveal what needs to be emphasized or explained in the directions we will compose for the users of this product.

From our set of tests that we performed, we did not obtain information about the accuracy of our tarp. In all of our testing, we did not actually test using the tarp to see if wooden sticks (representing the rebar) would be evenly spaced correctly for the greenhouse support layout. Moreover, we did not obtain information about the ability for the average person to use our device. This is important to know because our design needs to be simple enough for the locals in
developing nations to be able to use without reading directions written in a language they may not be able to read. This is the reason we added the “ease of use” test to our second prototype.

The HESE student gave us both positive and negative feedback about our prototype. She told us that the light weight and flexibility of our grid was very beneficial for transportation in a bag or carried in hand. It is important for the grid to be easily transported to meet the needs of the users who may have to travel a long distance to arrive at the greenhouse site. Moreover, the HESE student provided feedback on the size of our holes for the support beams of the greenhouse by informing us that they appeared to be too large. Because of her feedback, we decided to change the hole diameter from 1.5” to ¾” for our second prototype. This is an important alteration to increase accuracy of the holes for the greenhouse supports.

**Concept Refinement Summary:**

We used the development and testing of prototype #1 to guide the development of prototype #2 in many ways. Firstly, prototype #1 was too large to work with and took too much time to prepare for testing. To improve that, we decreased the size tarp we used for prototype #2. Next, we observed the poor quality of the tape folded around the hole edges to reinforce the material and we determined this had to be improved upon for prototype #2. We decided to place duct tape over where the holes should be and then cut out the holes. During our waterproof test for prototype #1 we observed that although the grid repelled water on one side, on the other non-plastic side it did not which could lead to grid damage. To improve upon this, we specified a material for prototype #2 be plastic on both sides of the material to ensure it would be completely waterproof. All of our improvements to develop a better prototype #2 than prototype #1 came from observations of the shortcomings of prototype #1 during testing.
There were a couple features we did change from prototype #1 to prototype #2. One change was the size of the holes from 1.5” to ¾” because of the HESE student’s feedback. Another change was the method in which we cut and reinforced the holes of the grid. Instead of cutting the holes and attempting to fold tape over the edges, we decided to lay duct tape at the hole location and then use an X-ACTO knife to cut the holes. Additionally, our prototype #2 was made both smaller (5”x5”) than prototype #1 (7”x7”) and also made of a different material. The material for prototype #1 was paper on one side and plastic on another while the material for prototype #2 was plastic on both sides. Our prototype design sketch remained the same as a simple rectangle from prototype #1.

Test Report Summary for Prototype #2:

Test Result Summary for Prototype #2:

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<tr>
<td>Water and weather proof</td>
<td>We will pour water on top of the tarp and shake it around to see if the tarp repels the moisture. We will also shake the tarp around mimicking high winds.</td>
<td>The tarp repelled the water on both sides not causing any damage to the material. The tarp was able to be whipped around in the high winds and did not rip or tear.</td>
<td>Pass</td>
<td>The tarp as able to withstand the different weather conditions because it was waterproof and was able to withstand high winds.</td>
</tr>
<tr>
<td>Sturdy</td>
<td>We will hold the tarp a few feet above the ground at all four corners and gradually add weights to the center of the tarp to see how much weight it can hold before it breaks.</td>
<td>The tarp was able to withstand more than ten pounds before breaking.</td>
<td>Pass</td>
<td>The tarp was able to support more than 10 pounds before ripping which was more weight than we anticipated.</td>
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<td>Heat Resistant</td>
<td>We will hold the tarp in front of a hair dryer that will heat the tarp to about 160-165 degrees to see if it will be able to withstand and not stretch due to the high temperatures.</td>
<td>The tarp was able to withstand the heat from the blow dryer and the heat did not alter the shape of the tarp.</td>
<td>Pass</td>
<td>The high heat did not affect the tarp and it did not stretch it out. Also, the tarp did not absorb much of the heat because upon inspection of the heated area, it was not hot to the touch.</td>
</tr>
<tr>
<td>Durability</td>
<td>We will lay the tarp on the ground</td>
<td>The tarp was able to withstand</td>
<td>Pass</td>
<td>The tarp was able to maintain</td>
</tr>
<tr>
<td>Transportability</td>
<td>We will weigh the tarp to see if it is light enough to be able to be carried long distances. We will also fold the tarp up to see if it is small enough to transport easily.</td>
<td>The tarp weighed 0.6 pounds, and was able to be folded small enough to be easily carried.</td>
<td>Pass</td>
<td>The tarp is very light and folds up to a small size making it very easy to transport and carry.</td>
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<td>Ease of use</td>
<td>We will give people, who have no prior knowledge of our project, the tarp and wooden rebar poles, and see if they are able to figure out how it works.</td>
<td>Out of the five people that we surveyed all of them were able to correctly set up the tarp and place the rebar poles.</td>
<td>Pass</td>
<td>People were able to use our product without any direction showing that it is easy to use and does not require much prior knowledge.</td>
</tr>
<tr>
<td>Time of Set up/Accuracy</td>
<td>We had each group member unfold the tarp, lay it out on the ground and mark where they rebar poles would be placed all while being timed. We then measured the placement markings of the rebar poles to check the accuracy.</td>
<td>Each group member was able to lie out the grid and mark the holes in under one minute. With each group member we also measured the accuracy of the points and they were all even spaced with the correct measurements.</td>
<td>Pass</td>
<td>The grid was proven easy to set up and time efficient. The grid was also proven to have consistent accuracy.</td>
</tr>
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</table>

Observation Summary For Prototype #2:

While observing and performing the tests on prototype #2, we learned many lessons about our design. Firstly, prototype #2 performed better during our tests than prototype #1 did, due to the design changes. In our first design, we experienced many setbacks with how fragile the material was because it would continually tear. After adding more than 12.8 pounds to our first design the material ripped and the prototype was ruined, but prototype #2 was able to hold 12.8 pounds without showing signs of ripping. Secondly, this tarp proved to be more successful in the weather and water resistance testing then the first prototype had been. Prototype #2 was
made out plastic on both sides which proved to be water resistant. Prototype #1, on the other hand, failed the water test because it was paper on one side of the material. Thirdly, the new test we added was the “ease of use” test, which tested to see how intuitively people were able to take our design and use it without any instructions or prior knowledge of the greenhouse grid project. During this test, five different people were able to take our grid design and the wooden stakes we used as our rebar poles to properly use them without any problems. This test and the success of the “ease of use” test proves our design is intuitive and does not require complicated instructions.

Next, through some observations on how people were using our prototype, we found that an improvement on prototype #2 would be to create four corner holes to properly anchor the grid to the ground. This observation was recognized when the grid would shift positions while in use and impede the accuracy of the grid.

Cost Analysis:

Our prototype #2 grid design could be made to full size while keeping the cost under the required price of $50. The estimated cost of our final prototype is $38.75 after using ratios of the area over the price of prototype #2 compared to the area of the full scale. For our final product we estimate that the price would be much closer to $50 because of many factors. In the final product, there would be more material required for one grid, the plastic rings around the holes will be more expensive than the duct tape previously used, the cost of manufacturing the grids would impact the price per grid, and the choice of locally available material would increase the price per greenhouse grid. Given all of those factors, the estimated price for the final product for the goal of 250 greenhouses manufactured per year is $46.
User Guide:

1. Unfold the Grid

2. Place the Grid over the desired location.

3. Hammer the rebar poles inside of the holes in the grid. Then remove the grid by lifting at the edges, up and over the rebar poles.

Re-design Ideas/ Thoughts:
During the showcase we received a lot of feedback on our design for the greenhouse grid. One of the HESE students who reviewed our prototype liked the idea of how easy to use our prototype is. We mentioned to the HESE student that one test for our second prototype was to ask random people to use our design without any instructions they were able to use the prototype correctly, thus proving our design is intuitive. Additional feedback from our showcase included positive comments on the size of our grid folded up and the cost effectiveness of our estimated price of $38.75 for the final, full scale design. Lastly, we received feedback about our choice of material and how available plastic would be in Kenya to produce and/or repair the grid. Although this was somewhat of a negative comment, this feedback proves useful and constructive for redesign ideas for prototype #3. For a future prototype, we would take into consideration a new choice of material because of our showcase feedback.

For redesign our “dream” prototype #3 would be made to full scale (6mx6m) of a plastic-like material available in Kenya. It would have four corner holes to pin down the grid before the rebars are inserted. Our prototype #3 would also have the holes reinforced with a plastic ring to prevent tearing instead of duct tape.