Team 4: 4TW

EDSGN 100, Section 25, Fall 2015

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4TWristband
Mission Statement

The mission of 4TW is to provide low income families with affordable, efficient, and reliable cell phone chargers. Our key business goals are to keep costs under ten dollars and to make our product readily accessible to families in Rwanda. This technology will ideally save our families and their communities money, which can then be spent on other necessities, as well as benefit travellers who may not have access to traditional power sources. Assuming the necessity of this product, our primary and secondary markets will thus have an optimal way to charge their cellphones.

Concept Development Summary

Our chosen market was low income families in Mayange, Rwanda. Through internet research, we found that Mayange, not unlike the rest of Rwanda, has an extremely dense population. Approximately 90% of the labor force are farmers; however, drought has led to decreased harvest and increased hardship in recent years [15]. In fact, approximately 45% of Rwandans live under the poverty line, and the average daily income is $1.90 [12].

Approximately 63% of all Rwandans own a cell phone, and almost 100% of Rwandans have access to a cell phone [15]. However, only 50% of these people have access to electricity [5]. Those who don’t must walk to charging kiosks where they pay $0.14 every time they wish to charge their phone [14]. This may not seem like a lot, but it is a considerable fraction of their daily income, which is why it is so imperative to find alternative ways to power cell phones.
Customer Needs

Based on our research on our primary market, we identified six user needs to keep in mind throughout our design process. The first and most important is safety, and our goal was that our product would impose no risk on the user.

The second is that the device could charge a phone within one day. Our team based this on the fact that we each charge our phones once per day. Although we do not know exactly how Rwandan cell phone usage compares to our own, we deemed this sufficient as the majority of Rwandans use their cell phones for business and government [15], and not additionally for recreation as we do.

The third user need is that the device can charge a cell phone without any additional input from the user. This includes time, as many Rwandans must currently take several hours out of their day to walk to and from charging kiosks [14]. This also includes physical input, as Rwanda is a food-insecure nation [9], and we do not want our product to push people to overexert themselves.

Our fourth user need is that the cost of our product can not exceed $10. While this is much larger than an average Rwandan daily income, we are certain that in time our product will save Rwandan families time and money, as they will no longer need to use charging kiosks.

Our fifth user need is durability; that is, our product must be able to withstand daily use for long periods of time. This is necessary because although our goal is to create a simple design from cheap, common parts, Rwandans may not have the optimal resources to repair our product.
Our last user need is that our product must be aesthetically pleasing. If it is not we run the risk of our target market being unwilling to use our product, in which case it will not meet any of the other user needs. Our goal was for 75% of a surveyed group to agree to use our product.

**Early Concept Ideas:**

![Figure 1: Early Concept Idea 1](image)

Our first early concept idea was a hydroelectric powered device to be placed in the Murais Murago river, which is located approximately one mile from the village of Mayange [8]. Some pros of this design were that it is environmentally benign and could perhaps be used by multiple families. Some cons of this design were that it only applied to this specific village, as not all Rwandan villages have such proximity to a body of water, and that it posed a risk of injury or drowning to users.
A second early concept idea was a similarly hydroelectric powered device; however, this design would be used in the home. The user would fill the provided container with water from the same river. The user would then stir the water manually, which would move small turbines in the container, generating electricity. Additionally, we thought that by placing a filter in the bottom of the container, this action could generate clean water as well. An obvious pro to this design was that it would provide a solution to two problems. Some cons were that, again, it only applied to this specific village, it posed a risk of injury to the user, and it also required physical exertion by the user, in order to carry the water back from the river and to continuously stir it.
A third early concept idea was a wristband that would harness both solar and kinetic energy. The band would be made of two flexible magnets, within which copper beads would rotate whenever the user moved, generating electricity. Additionally, the wristband would have an outer shell made of solar panels, so that whenever the user was outside, there would be an additional power source. A pro to this design was that it would be incorporated into the daily life of the user and would not require any additional input. A con to this design was that it would be expensive and complicated.
## Selection Matrix

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Safety</th>
<th>Durability</th>
<th>Aesthetic</th>
<th>Cost</th>
<th>Time</th>
<th>Input</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Idea 1</td>
<td>3*6</td>
<td>1*2</td>
<td>2*1</td>
<td>4*3</td>
<td>3*5</td>
<td>3*4</td>
<td>61</td>
</tr>
<tr>
<td>Idea 2</td>
<td>3*6</td>
<td>5*2</td>
<td>3*1</td>
<td>4*3</td>
<td>2*5</td>
<td>1*4</td>
<td>57</td>
</tr>
<tr>
<td>Idea 3</td>
<td>5*6</td>
<td>4*2</td>
<td>3*1</td>
<td>2*3</td>
<td>4*5</td>
<td>5*4</td>
<td>87</td>
</tr>
</tbody>
</table>

**Figure 4: Concept Scoring Matrix**

To decide between the three ideas discussed above, our team weighted each of the user needs according to their importance. We decided that safety was the most important, followed by time to charge, input required by user, cost, durability, and finally aesthetic. We assigned point values accordingly. Then we gave each of the concept ideas a score in each category, with five being the best and one being the worst, and multiplied this score by its weight. We added all of these values and found that the solar and kinetic powered wristband had the highest score, and so we moved forward with this design.
Test Report Summary for Prototype One

Figures 5 and 6: First Prototype

Our first prototype consisted of two flexible magnets arranged in a circle, with small copper beads arranged in several small circuits between the two magnets. A capacitor, to store the energy, and an adapter, to connect the capacitor to the cell phone charger, were also located between the two magnets. The entire band was covered in flexible solar panels.

We ran numerous tests on our first prototype to discover whether or not our design would meet our defined user needs.
Aesthetic

Aesthetic Test for Team 4TW

* Required

Would you be willing to wear a black wristband approximately one inch wide and one quarter to one half of an inch thick, knowing that it could charge your phone on-the-go and could save you 20% of your daily income?

- No
- Yes
- No, but maybe if it were smaller
- No, but maybe if it were a different color
- Unsure
- Other: 

Submit

Figure 7: Aesthetic Test Survey [6]

<table>
<thead>
<tr>
<th>Answer</th>
<th>Yes</th>
<th>Unsure</th>
<th>Maybe if it were smaller</th>
<th>Maybe if it were a different color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Votes</td>
<td>23</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Percentage</td>
<td>85%</td>
<td>4%</td>
<td>7%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Figure 8: Aesthetic Test Survey Results

The first test we ran was the aesthetic test. We surveyed the class to determine whether or not people would be willing to wear a wristband with the size, shape, and color of our design. A pass was defined as 75% of the surveyed group being willing to wear the wristband. We found that 85% of our surveyed group was willing to wear the 4TWristband, so this test passed.
Durability

<table>
<thead>
<tr>
<th>Height</th>
<th>3 Feet</th>
<th>6 Feet</th>
<th>9 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage?</td>
<td>No</td>
<td>No</td>
<td>Not to the inside, but the outer shell is slightly damaged</td>
</tr>
</tbody>
</table>

Figure 9: Durability Test Results

To test the durability of our product we dropped the 4TWristband from heights of three feet, six feet, and nine feet. We did five drops on each height and after all of the drops the wristband had sustained minimal damage, passing the durability test.

Costs

Figure 10: Magnetic Tape, Home Depot, $1.50 [7]
Time to Charge

Figure 11: Copper Wire, Fusion Beads, $2.99 [13]

Figure 12: Capacitor, Global Industrial, $2.89 [1]
### Figure 13: Solar Panel, Sundance Solar, $3.95 [11]

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown Bolt .5 x 30 in Magnetic Tape Roll</td>
<td>Home Depot</td>
<td>$1.50</td>
</tr>
<tr>
<td>20 Gauge Bare Copper Artistic Wire</td>
<td>Fusion Beads</td>
<td>$2.99</td>
</tr>
<tr>
<td>110-125V Start Capacitor</td>
<td>Global Industrial</td>
<td>$2.89</td>
</tr>
<tr>
<td>Ring Terminal .880 in (x2)</td>
<td>Grangier</td>
<td>$0.70</td>
</tr>
<tr>
<td>PowerFilm 3V 25mA Flexible Solar Panel</td>
<td>Sundance Solar</td>
<td>$3.95</td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
<td>$12.03</td>
</tr>
</tbody>
</table>

### Figure 14: Cost Summary

We also ran a preliminary cost analysis to determine whether or not we could produce and sell the 4TWrapband for under $10. To do this we determined all of the required materials,
chose suppliers, and added all of the costs. Our total cost, $12.03, exceeded our goal of less than or equal to $10.00, so this test failed. However, this was the expected cost to produce a single wristband, and would decrease significantly if we purchased the materials in bulk.

Time to Charge

<table>
<thead>
<tr>
<th>Type of Energy</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Power</th>
<th>Time to Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>3</td>
<td>0.025</td>
<td>0.075</td>
<td>50.4 hours</td>
</tr>
<tr>
<td>Kinetic</td>
<td>5</td>
<td>0.11</td>
<td>0.573</td>
<td>6.6 hours</td>
</tr>
<tr>
<td>Combined</td>
<td></td>
<td></td>
<td>0.648</td>
<td>5.8 hours</td>
</tr>
</tbody>
</table>

Figure 15: Time to Charge Test Calculations

Figure 16: Time to Charge Test Results
To figure out how long it would take to charge the 4TWristband, we did a series of calculations using data from our chosen set of solar panels and AMPY, a product that similarly measures and stores kinetic energy. All of the data on the AMPY was derived from an iPhone 5C, so we had to obtain information about that battery to understand how that data would apply to the phone we are charging [3] [4]. Above is some of the information we found and some of our calculations.

We saw that the total time to charge would be 5.8 hours, which is far less than our goal of one day. We also found that power from the kinetic portion of our wristband contributed much more significantly to charging, which became a major consideration later in the design process.

Additional User Input

Because our time to charge calculations were based on a light activity level and they still showed that the band would charge well within our goal of one day, we determined that the user would not have to go out of their way at all in order to charge the band, thereby meeting the additional user input goal.

Safety

To insure that the 4TWristband was safe for anyone to use in their everyday life we made sure that the outer shell, of solar panels, was waterproof. But we do advise that our product be taken off whenever the user will be submerged in water to prolong the life of our product.
Concept Refinement Summary

Our biggest takeaway from the testing of prototype one was to eliminate the solar panels from our design. They accounted for approximately one-third of our cost ($4.00 of $12.03), but only one-tenth of the power (0.075 of 0.648 watts). We would then cover the wristband with a plastic shell rather than a solar panel shell. We also decided to replace the capacitor with a battery, as we did not have any need for the quick energy release provided by a capacitor, and we found a much cheaper and smaller battery.

In making these changes, we hoped to bring our cost within the pass range, and improve in other areas of our design, such as durability and aesthetic, where our results technically passed but were not perfect.

Test Report Summary for Prototype Two

Figure 17: Second Prototype
Our second prototype, much like the first, consisted of two flexible magnets arranged in a circle, with small copper beads arranged in several small circuits between the two magnets. Rather than a capacitor, we used a battery, which is located between the two magnets, along with an adapter to transfer the energy from the battery to our phone’s battery. Rather than a solar panel shell, we eliminated the solar panels entirely and covered the band a 3D printed hard plastic shell. (This is not shown in the prototype so that the reader can see the more important inside of the band.)

**Aesthetic**

We again ran extensive tests to ensure that our second prototype not only met all of our user needs but also improved upon the first prototype. We did not conduct a second aesthetic test; however, we can reasonably assume the results. By eliminating the solar panels, our design is thinner and will have a cleaner-looking outside. We may also be able to offer our design in a variety of colors or even customized designs due to the flexible nature of 3D printing. As these were are our only two complaints from the first aesthetic test, we expect that 100% of our surveyed group would be willing to use the 4TWristband, constituting not only a pass but also a large improvement over our first prototype.

**Durability**

<table>
<thead>
<tr>
<th>Height</th>
<th>3 Feet</th>
<th>6 Feet</th>
<th>9 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage?</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*Figure 18: Durability Test Results*
We conducted the same durability test, however we dropped the second prototype rather than the first. We saw improvement in our durability results, which can be attributed to replacing the solar panels with a hard plastic. While the solar panels adequately protected the inside of the wristband, they suffered minimal damage themselves. Since the plastic shell is a lot stronger than the solar panel shell we predict that our second prototype will last longer than our first prototype. We believe this because during testing our product sustained no damage. We conclude that the durability test on prototype two passed and improved upon prototype one.

**Time to Charge**

To test how long it would take to charge the second prototype, we used the same calculations as before, but factored out the power from the solar panels. Using only kinetic energy, our band would charge in 6.6 hours. While this is longer than our first prototype’s 5.8 hours, it is still well within our goal of one day, and so was defined as a pass.

**Additional User Input**

Although the time to charge is slightly longer in our second prototype, it is still well within one day, and therefore the user would not have to go out of their way to charge the band, again passing the user input test.

**Safety**

Since our band no longer has a solar panel outer shell but a plastic covering our band is now completely submersible.
Cost Analysis

Figure 19: 3D Printer Filament, Hatchbox 3D Printer, $0.65 [2]

Figure 20: 3D Desktop Printer, HICTOP, $0.36 [2]
Figure 21: 3.7V Battery, Shenzhen Grand Powersource Co., $0.10 [10]

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crown Bolt .5 x 30 in</td>
<td>Home Depot</td>
<td>$1.50</td>
</tr>
<tr>
<td>Magnetic Tape Roll</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 Gauge Bare Copper</td>
<td>Fusion Beads</td>
<td>$2.99</td>
</tr>
<tr>
<td>Artistic Wire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.7 V Battery</td>
<td>Shenzhen Grand Powersource Co.</td>
<td>$0.10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring Terminal .880 in (x2)</td>
<td>Grangier</td>
<td>$0.70</td>
</tr>
<tr>
<td>Black PLA 3D Printer</td>
<td>Hatchbox</td>
<td>$0.65</td>
</tr>
</tbody>
</table>
The majority of our materials remained the same in our second prototype. We did, however, replace the capacitor with a battery and the solar panels with a plastic, 3D printed shell. We determined the cost of the necessary filament by assuming the shell to weigh one ounce, and dividing the price of our chosen material ($22.98) by the weight of our chosen material (35.2 ounces), to get $0.65. We determined the cost of the 3D printer by taking its list price and dividing it by 1000, as this is the number of bands we are analyzing.

We found that our total cost would be $6.30 to produce one 4TWristband, which is well within our goal of less than or equal to $10.00 and a significant improvement from prototype one’s cost of $12.03. This is due to eliminating the solar panel and capacitor, which were our two most expensive components, and replacing them with much cheaper parts. Also, all of our materials would be imported as many are not produced in Rwanda. Despite this, we are well within our budget which leaves room to deal with any unforeseen circumstances which may arise as we continue the testing and implementation of our solution.
Redesign Thoughts

One of the biggest takeaways from the DEM Showcase and from HESE students was that, despite what our class had voted, our product may not be aesthetically pleasing enough. With the decision to use 3D printing to create the plastic outer shell, there are many options available to customize the color and even design of the bracelets, which may improve upon this. In our third prototype we would be sure to explore these options more thoroughly. We would also work to optimize the efficiency of our wristband, with the goal of reducing our charging time to under four hours, while also making the band thinner.

To improve the project as a whole, we would wish to be able to build and test working prototypes. Although we recognize that funding is limited, we feel as though students could
adequately cover the costs. The design must cost less than $10.00 to produce. If we make two prototypes, we would be spending $20.00 total, which divided by four group members would only be $5.00 per person!). Considering there is no cost for a textbook or lab materials for this class, students would still be spending far less on materials for this class than others. Even without this, we gained an enormous amount of valuable knowledge about the design process through this project.
Works Cited


Oct. 2015.
