Fall 2015

Moped II - Frankenbike

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This moped concept combines a motorized pedal assist bicycle with a collapsible rain shielding pod. Focused on optimizing the commuter experience, the design features personal storage for the user as well as for the collapsible pod. A “street legal” electric rear wheel hub motor allows the user to travel long distances and hilly terrain or function as a traditional bicycle. Frankenbike may be ridden on the roads, bicycle paths or sidewalks around campus, rain or shine.
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1 Introduction

1.1 Project problem statement

The proposed project problem was an ultra-light collapsible moped. Through user need interviews and customer inquiries, however, the design concept was altered to address the primary needs of a commuter. In particular, a motorized pedal assist component was desired. The project was expected to have both motorized components, and traditional bicycling capabilities. The initial ultra-light project stipulation was dropped in favor of rider weather protection and storage components. A rear wheel electric hub motor, equipped with a throttle, cruise control and electric braking on the handlebars was chosen to aid riders over long commutes and up steep hills. The design features a rain protecting pod, which can be stored elegantly in the frame and rear storage components. The waterproofed rear storage component also has an internal separated cushioned compartment to keep the motor battery safe. The pod assembly was designed with collapsibility as a priority, but collapsibility in the main moped body was non-prioritized in order to address more pertinent user needs. A budget of $500 dollars was allocated to produce a working prototype of our design project within a semester, utilizing basic manufacturing skills and both purchased and scrapped parts.

1.2 List of team members

<table>
<thead>
<tr>
<th>Table 1: List of Team Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sade Odumuye</td>
</tr>
<tr>
<td>Jake Gaskill</td>
</tr>
<tr>
<td>Nkiru Udenze</td>
</tr>
</tbody>
</table>
2 Background Information Study

2.1 A short design brief description that defines and describes the design problem

A “street legal” traditional moped (functions with both motorized and pedal components) was set forth as the basis of our design problem. Additional commuter needs of rain protection and storage capabilities were chosen for our design niche. Some collapsible components were maintained and the initial “ultra-light” stipulation was de-prioritized.

2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL’s, et cetera)

In preparation of building the weather resistant moped we looked at current rain protection gear and bike attachments. Some of the ideas pulled from this research in terms of rain protection were pod shapes that went around or overtop the rider. Others had hard shelled windshields that secure to mounting frames put on the bike, but couldn’t necessarily collapse and be stored. Overall we tried to look into the market for rain protection for bikers. The following link shows the concerns and actions taken to offer a more comfortable ride in the rain.

http://www.cyclingweekly.co.uk/news/latest-news/cycling-in-the-rain-how-to-survive-it-19050

We also had to research what motor worked best in rain and that could easily be used with pedal assist. Friction drive was one concept we thought about, but required an involved mounting device and doesn’t work well with wet. Overall we were looking for motors that could work well in rain, operate with existing pedals, and easily be mounted on the bike. Therefore we researched a lot into hub motors and the pros and cons of having front wheel drive or back wheel drive. Back wheel drive offers better handling and gives a better weight distribution. Front wheel drive can be harder to steer when the motor is being powered. FWD is also harder to work in unison with the user pedaling. Being street and campus legal was also a big concern and we had to make sure we fit the legal definition of a motorized bicycle/ moped. The following link explains one state’s classification of different cycles.

https://www.dmv.ca.gov/portal/dmv/detail/motorcycles/motorcycles

In summary, a moped can’t exceed 30 mph, can have pedals or no pedals, automatic transmission and in the case of an electric motor – no more than 1000 W. A moped doesn’t have to be licensed in the same way a motorcycle is, but some states may require a small (~ $20) unique registration fee.
3 Concept Design and Specification

3.1 User needs, metrics, and quantified needs equations.

3.1.1 Record of the user needs interview
### Table 2: Customer Data

**Customer Data: Pedal Assisted Commuter Bicycle (PACB)**  
**Customer:** Professor Jakiela  
**Address:** Washington University Mechanical Engineering Department  
**Date:** 14 September 2015

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>What aspects of your current commute require aid?</td>
<td>Weather protection, interaction with cars, physical fatigue, wind resistance.</td>
<td>PACB protects from rain.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PACB has brake lighting &amp; reflector systems.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PACB has motorized component to reduce effort exerted by rider.</td>
<td>5</td>
</tr>
<tr>
<td>What distance and encountered inclines does your usual commute encounter?</td>
<td>About 10 miles, and up about 200 ft elevation over a ½ mile distance.</td>
<td>PACB motor must support 20+ miles of travel.</td>
<td>4</td>
</tr>
<tr>
<td>Will this bicycle primarily be used on the sidewalk or street?</td>
<td>Definitely street, almost never sidewalk. The bicycle will be ridden on the side of the street in a space about ½ the width of a car.</td>
<td>PACB is street legal: &lt; 30 mph on flat ground, &lt; 50 cc cylinder capacity motor, &lt; 3 gross brake horsepower PACB is slim in width.</td>
<td>5 3</td>
</tr>
<tr>
<td>How heavy should the bike be, do you need to be able to pick it up?</td>
<td>While ultra-light is not the design focus, it should be able to be lifted if necessary.</td>
<td>PACB weighs less than 60 lbs.</td>
<td>3</td>
</tr>
<tr>
<td>How fast do you expect the bike to go?</td>
<td>20 mph is sufficient, I fully expect to be passed by cars on the street.</td>
<td>PACB reaches 20 mph</td>
<td>4</td>
</tr>
<tr>
<td>Do you have a preference for the motor type?</td>
<td>About 60% favored towards electric.</td>
<td>Electric motor should be used.</td>
<td>2</td>
</tr>
</tbody>
</table>
### Table 3: Importance

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PACB protects from rain.</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>PACB has brake lighting &amp; reflector systems.</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>PACB has motorized component to reduce effort exerted by rider.</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>PACB is street legal: &lt; 30 mph on flat ground, &lt; 50 cc cylinder capacity motor</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>PACB is slim in width</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>PACB weighs less than 60 lbs.</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>PACB reaches 20 mph</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>PACB supports a 250 lb. total load.</td>
<td>4</td>
</tr>
</tbody>
</table>
9. PACB motor must support 20+ miles of travel.
10. PACB has (waterproof) load storage.
11. PACB motor is electric.

### 3.1.1 List of identified metrics

<table>
<thead>
<tr>
<th>Metric Number</th>
<th>Associated Needs</th>
<th>Metric</th>
<th>Units</th>
<th>Min Value</th>
<th>Max Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,10</td>
<td>Dryness</td>
<td>Percentage</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Visibility to cars</td>
<td>Percentage</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>4, 7</td>
<td>Speed</td>
<td>mph</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>Width</td>
<td>ft.</td>
<td>2</td>
<td>3.5</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
<td>Weight</td>
<td>lbs.</td>
<td>45</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>Supported Load/Strength</td>
<td>lbs.</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>Storage Volume</td>
<td>ft³</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>Distance per full charge/tank</td>
<td>miles</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>Cylinder capacity</td>
<td>binary (cubic cm)</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>11</td>
<td>Electric Motor</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>11</td>
<td>3</td>
<td>Motor</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
### 3.1.2 Table/list of quantified needs equations

**Table 5: Quantified Need Equations Template**

| Pedal Assisted Commuter Bicycle (PACB) | Metric | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Need/Importance of Weight (all entries should add up to 1) | Total Happiness Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pedal Assisted Commuter Bicycle (PACB) | | | | | | | | | | | | | | | | | |
| Need | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | | | |
| PACB Protects from Rain | 1 | | | | | | | | | | | | | | | | 0.0952381 |
| PACB Has Brake | 1 | | | | | | | | | | | | | | | | 0.0952381 |
| PACB Has Motorized Component | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| PACB is Taller Legal | 0.3 | 0.3 | | | | | | | | | | | | | | | 0.1106496 |
| PACB is Taller Legal | 1 | | | | | | | | | | | | | | | | 0.1106496 |
| PACB is Taller Legal | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| PACB Speed Reaches 20 mph | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| PACB Supports at least 250 lbs | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| PACB Supports at least 20 miles of Travel | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| PACB Has Water Proof | 0.4 | 1 | | | | | | | | | | | | | | | 0.0714267 |
| PACB Motor is Electric | 1 | | | | | | | | | | | | | | | | 0.0714267 |
| Units | | | | | | | | | | | | | | | | | |
| % | % | MPH | ft | lbs | lbs | in | Miles | Binary | Binary | Binary | unit 12 | unit 13 | Total Happiness | 0.0 |
| Best Value | 100 | 100 | 20 | 45 | 100 | 2 | 15 | 1 | 2 | 1 | 1 | 1 | 0.0 |
| Worst Value | 0 | 0 | 10 | 35 | 90 | 2 | 20 | 0 | 2 | 0 | 1 | 1 | 0.0 |
| Normalized Metric Happiness | | | | | | | | | | | | | | | | | |
3.2 Four (4) concept drawings

![Concept 1 Drawing](image)

**CONCEPT 1: COMPACT, MINIMALISTIC DESIGN**

**FEATURES:** PEDAL ASSIST, FOLDABLE STORAGE BASKET, COLLAPSIBLE PEDALS & HANDLES, WEATHER PROTECTION, REGENERATIVE BRAKING, MIRRORS

Figure 1: Concept 1 Drawing
Figure 2: Concept 2 Drawing
Figure 3: Concept 3 Drawing
Figure 4: Concept 4 Drawing

CONCEPT 4 - "Car" Bike frame with gas/pedal motor

Features: Windshield, protective boot pedals, strobe headlight, lock storage, high performance
3.3 A concept selection process. This will have three parts:

3.3.1 Concept scoring (not screening)

<table>
<thead>
<tr>
<th>PACB Compact Assessorized Bike</th>
<th>Metric</th>
<th>Need</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>Need Importance</th>
<th>Weight</th>
<th>Total Happiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACB Protects from Rain</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.40</td>
<td>0.095238</td>
<td>0.095238</td>
</tr>
<tr>
<td>PACB Has Brake</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
<td>0.095238</td>
<td>0.095238</td>
</tr>
<tr>
<td>PACB Has Motorized Component</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
<td>0.095238</td>
<td>0.095238</td>
</tr>
<tr>
<td>PACB Has Visible</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
<td>0.374295</td>
<td>0.374295</td>
<td>0.374295</td>
</tr>
<tr>
<td>PACB Has Weight Less than 60 lbs</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.079388</td>
<td>0.079388</td>
<td>0.079388</td>
</tr>
<tr>
<td>PACB Supports at least 250lb</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.005238</td>
<td>0.005238</td>
<td>0.005238</td>
</tr>
<tr>
<td>PACB Has (Water Proof)</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.083109</td>
<td>0.083109</td>
<td>0.083109</td>
</tr>
<tr>
<td>PACB Motor is Electric</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td>0.079388</td>
<td>0.079388</td>
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</tbody>
</table>

Table 6: Concept 1 Happiness Calculations

<table>
<thead>
<tr>
<th>PACB Canopy Concept</th>
<th>Metric</th>
<th>Need</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>Need Importance</th>
<th>Weight</th>
<th>Total Happiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PACB Protects from Rain</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>0.75</td>
<td>0.095238</td>
<td>0.095238</td>
</tr>
<tr>
<td>PACB Has Brake</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.75</td>
<td>0.095238</td>
<td>0.095238</td>
</tr>
<tr>
<td>PACB Has Motorized Component</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>0.095238</td>
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<tr>
<td>PACB Has Visible</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
<td>0.079388</td>
<td>0.079388</td>
<td>0.079388</td>
</tr>
<tr>
<td>PACB Supports at least 250lb</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.005238</td>
<td>0.005238</td>
<td>0.005238</td>
</tr>
<tr>
<td>PACB Has (Water Proof)</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.083109</td>
<td>0.083109</td>
<td>0.083109</td>
</tr>
<tr>
<td>PACB Motor is Electric</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.079388</td>
<td>0.079388</td>
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Table 7: Concept 2 Happiness Calculations
### Table 8: Concept 3 Happiness Calculations

<table>
<thead>
<tr>
<th>PACB Leisure and Comfort Rider</th>
<th>Metric</th>
<th>Need/Happiness</th>
<th>Total Happiness Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Needs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Prepects from Rain</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Has Brake</td>
<td>1</td>
<td>0.4</td>
<td>0.0904760 0.038750</td>
</tr>
<tr>
<td>Lighting/Reflective System</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Has Motorized Component</td>
<td>0</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>To Reduce Effort Exerted</td>
<td>2</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Has Seat Legal</td>
<td>1</td>
<td>0.8</td>
<td>0.6059200 0.479250</td>
</tr>
<tr>
<td>PACB Weights Less than 80 lbs</td>
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<td>0.8</td>
<td>0.6059200 0.479250</td>
</tr>
<tr>
<td>PACB Speed Reaches 20 mph</td>
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<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Supports at least 250 lb</td>
<td>1</td>
<td>0.4</td>
<td>0.0904760 0.038750</td>
</tr>
<tr>
<td>PACB Supports at least 30 miles</td>
<td>0</td>
<td>0.6</td>
<td>0.3666000 0.2911250</td>
</tr>
<tr>
<td>PACB Has (Water Proof) Load</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Motor is Electric</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
</tbody>
</table>

### Table 9: Concept 4 Happiness Calculations

<table>
<thead>
<tr>
<th>PACB High Performance Commuter</th>
<th>Metric</th>
<th>Need/Happiness</th>
<th>Total Happiness Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Needs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Precepts from Rain</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Has Brake</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>PACB Has (Water Proof) Load</td>
<td>0.4</td>
<td>0.6</td>
<td>0.2026000 0.1553750</td>
</tr>
<tr>
<td>PACB Motor is Electric</td>
<td>1</td>
<td>0.5</td>
<td>0.0052360 0.0479250</td>
</tr>
</tbody>
</table>

### Table 8: Concept 3 Happiness Calculations

<table>
<thead>
<tr>
<th>Units</th>
<th>% MPH</th>
<th>% FT</th>
<th>% Lbs</th>
<th>% Lbs</th>
<th>% P/5</th>
<th>% Miles</th>
<th>% Binary</th>
<th>% Binary</th>
<th>% Binary</th>
<th>% Unit 12</th>
<th>% Unit 13</th>
<th>Total Happiness Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Value</td>
<td>100</td>
<td>100</td>
<td>20</td>
<td>2</td>
<td>45</td>
<td>100</td>
<td>2</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>Worst Value</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
</tr>
<tr>
<td>Normalized Metric Happiness</td>
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<td>0.4</td>
<td>0.5</td>
<td>0.3</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.0052360 0.0479250</td>
</tr>
</tbody>
</table>

### Table 9: Concept 4 Happiness Calculations

<table>
<thead>
<tr>
<th>Units</th>
<th>% MPH</th>
<th>% FT</th>
<th>% Lbs</th>
<th>% Lbs</th>
<th>% P/5</th>
<th>% Miles</th>
<th>% Binary</th>
<th>% Binary</th>
<th>% Binary</th>
<th>% Unit 12</th>
<th>% Unit 13</th>
<th>Total Happiness Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best Value</td>
<td>100</td>
<td>100</td>
<td>20</td>
<td>2</td>
<td>45</td>
<td>100</td>
<td>2</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>Actual Value</td>
<td>20</td>
<td>10</td>
<td>77</td>
<td>45</td>
<td>100</td>
<td>2</td>
<td>15</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0.0052360 0.0479250</td>
</tr>
<tr>
<td>Normalized Metric Happiness</td>
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<td>0.3</td>
<td>0.6</td>
<td>0.3</td>
<td>1</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.0052360 0.0479250</td>
</tr>
</tbody>
</table>
3.3.2 Preliminary analysis of each concept’s physical feasibility

Concept 1: Compact Accessorized Bike

This concept most closely resembles a traditional bicycle while attempting to achieve the greatest amount of functionality and meeting of user needs through a compacting and minimalist design. Playing on various current features of different bicycle styles or accessories in combination with newer design ideas makes this concept a sort of “Swiss army knife of bikes.” Anticipated difficulties with this concept include stylistic matching between components to ensure it doesn’t appear as a hodgepodge mismatch of parts. Furthermore, an appropriate material that is waterproof and rigid, yet can be formed into the desired shaped will be necessary for the foot and handle covers. Investigations towards methods of heating and molding plastic, for instance, may need to be pursued if this concept were chosen. Other more complex aspects of this design in particular as compared to concepts 2-4 are the collapsible/adjustable features which would involve mechanisms such as telescoping rods and hinges.

Concept 2: Canopy Concept

The Canopy Concept primarily focuses on the weather protection user needs. Inspired by ideas of baby strollers, this design takes a more aggressive approach to protecting the rider from rainfall. Disadvantages of this design include loss of speed capabilities due to the wide surface created from the canopy. Also, width and overall design sleekness are arguably lesser than other concepts. Ideally the canopy pod should be clear so that maximum user safety and visibility is achieved, thus an appropriate material would be necessary and may be somewhat difficult to acquire. Furthermore proper design and support rods that are easy to assemble and disassemble are desirable; enabling the canopy should not be a difficult complex process. The rear storage space. Other than the main identifying canopy feature, this concept is fairly mechanically simple and should be easier to manufacture. Therefore, more time can be focuses on the fabrication component of the project to truly perfecting its design, perhaps even allowing multiple prototype and testing phases.

Concept 3: Leisure & Comfort Rider

Concept 3 is significantly lesser of a bicycle base and is more similar to a typical moped scooter/Vespa concept. This design is meant to appeal to users that almost never ride bicycles and would not place high emphasis on the pedaling functionality. This concept allows for a more comfortable ride due to its upright sitting position and because of the backrest incorporated into the seat. A more powerful motor could be used with this design as it could be better mounted to the frame. This design is not very weatherproof, however. Although a collapsible umbrella feature is added, it
would be more for shade cover in hot and sunny environments or maybe to protect against a light drizzle. Difficulties encountered with this design will be creating the body of the vehicle (other concepts can be built up from traditional bike frames). The folding component between the handle bars and body will add some complexity compared to other designs. The lock incorporated into the seat will also be a difficult component of this concept, but it would add a high level of convenience for the user.

Concept 4: High Performance Commuter

The high performance commuter moped is stemmed from the concept of a dirt bike or motorcycle. The contiguous body is aimed to create more of a vehicle like appearance while maintaining the pedaling component. With more strength in the body, this concept would be able to support a higher load and be meant for riding at higher speeds and longer distances than the more bicycle related designs. A windshield is added for protection from debris or head on weather, but top falling weather protection is limited. Differing from other concepts, the storage unit on the performance commuter is similar to a car trunk and could be locked against theft. This concept would provide a sturdier ride for the user. Downsides of this concept are that it will probably be heavier and thus more difficult to pedal. Major difficulties with this concept would be manufacturing the highly contoured body, seat and “trunk” components.

3.3.3 Final summary

Winner:

Concept number 1, the compact accessorized moped design was chosen as the best concept design due to its overall advantages compared to the others. According to the happiness equation calculations documented in section 3.3.1 above, this concept satisfies the widest range and best meets the most important user needs. Compared to designs 2 and 4, the compact accessorized moped will have the thinnest and sleekest body. Although it may not support as heavy a load and probably reach a lower maximum speed than designs 3 and 4, it should reasonably satisfice the performance goals. There is no risk associated with not being the fastest or strongest concept, thus in assessing the designs number 1 is still a reasonable option. Additionally, while the weather protection is lesser than design 2’s convertible rain pod, added components and accessories such as the pedal and handle bar rain covers, the fender and seat rain protector allow decent weather protection. At this point in the design process, the collapsible storage bin isn’t as water proof as other concepts and therefore has a small associated risk, but this can be adjusted and improved upon as we move forward. As foreseen, more research is necessary for hashing out the details of the motor and electrical lighting components. There is also risk associated with moving forward under these specification uncertainties, however this was expected no matter which design concept was chosen. Proper time management and budgeting will be used.
Overall, concept number 1 provides the most aesthetically pleasing, industrial design while meeting the maximum number of user needs. This design is special because it incorporates many different components to achieve the perfect commuting experience for the user.

3.4 Proposed performance measures for the design

1. PACB provides user at least 50% increase in weather protection.
2. PACB lighting & reflective systems allow visibility of rider from 30 ft. distance away.
3. PACB operates between 20 and 30 mph maximum speed.
4. PACB motor has less than 50 cc motor capacity.
5. PACB width is less than 3.5 ft.
6. PACB weighs less than 60 lbs.
7. PACB supports minimum of 250 lb. total load.
8. PACB can travel minimum distance of 20 miles per trip.
9. PACB has at least 1ft³ of load storage capability.

3.5 Design constraints (include at least one example of each of the following)

3.5.1 Functional
Bike width needed to be able to fit into bike lanes when rain pod was setup. Motor needed sufficient weather durability. Ideally all material (storage box, motor, frame, etc.) would either be water resistant or have sufficient protection from the rain.

3.5.2 Safety
Moped needs to be able to stand out to and ride along with cars. User must be able to see out of pod windshield when raining. User can’t be too constrained while pod is setup. In the event of the crash, the user shouldn’t be trapped by the rain shield.
3.5.3 Quality
Moped should be as well maintained as a normal bicycle in terms of keeping brake pads, chain and other basic functions in working order. The flexible rain shield would ideally be able to last a significant number of user commutes before any potential ripping occurs.

3.5.4 Manufacturing
The main parts that need to be manufactured are the handlebar pod supports that keep the pod framework upright and secured to the handlebar. Other manufacturing needs (wire frame storage, storage box, breaks) depend on the existing geometry of the original bicycle. Therefore future versions may not have the same measurements and geometry of the prototype, but will follow the basic nature in terms of how different parts fit together.

3.5.5 Timing
Production time can be decreased once a uniform bike model is chosen to be the basis of the moped. Any additional parts and fittings can be easily retrofitted to a new frame and the design schedule should be unhindered.

3.5.6 Economic
The number of people that rely on cycling as their primary commute is very considerable, especially in densely populated cities with high car traffic. Thus this identifies our primary market. We address two major problems for our cycling market base: strenuous commute and weather protection. This gives us a clear advantage in this market. Our prototype cost was very comparable to a standard bicycle (~$500), but this may increase with design improvements.

3.5.7 Ergonomic
All of the motor controls and breaks must be able to fit on the handlebars and easy to use. This puts considerable design constraints on our layout since the racing style we are using has an already narrow horizontal section. The handlebars, breaks, and controls need to be integrated in way that will not cause confusion, discomfort, or failure.

3.5.8 Ecological
Our moped gives off no carbon emissions and will provide a nice, easy alternative to automotive traffic. Frankenbike uses no harmful materials. It also lasts a long time with minimal upkeep.
3.5.9 Aesthetic
Moped should effectively hide and protect all electrical wiring and pod framework. The pod storage secured to the frame can also be colored differently and complemented with the bike frame color.

3.5.10 Life cycle
Our product is designed to last sufficiently long given it is meant to operate in non-ideal weather conditions. If disposal of the main pod structure and motor is necessitated by the user, then the moped can be converted to a normal bicycle once again, and either used or disposed as such.

3.5.11 Legal
Frankenbike is designed to fit into the legal definition of a “motorized bicycle/moped”. The exact terms of this classification may vary from state to state, but in general our product must not exceed 30 mph or have to high of an engine rating (cc or wattage).
4 Embodiment and fabrication plan

4.1 Embodiment drawing

Figure 5: Embodiment Final Assembly Drawing
Figure 6: Embodiment Front View
## 4.2 Parts List

### Table 10: Parts List

<table>
<thead>
<tr>
<th>Balloon Number</th>
<th>Use</th>
<th>Part (Model)</th>
<th>Cost</th>
<th>Quantity</th>
<th>Parts Source/Supplier (URL, Catalog etc.)</th>
<th>Image (if applicable)</th>
</tr>
</thead>
</table>
| 1              | Rear Hub Motor kit | 36V/800W 26" Rear Wheel Electric Bicycle Motor Kit PAS Cycling Hub Conversion Kit  
1.a) Hub motor  
1.b) Controller  
1.c) Rear rack  
1.d) Throttle  
| 2              | Pod Frame | Thin Aluminum Rods (4ft, 1/8 in. diameter) | n/a (already in possession) | 2 | MEMS Basement | n/a |
| 3              | Canvas Straps for Pod Rear | 2” width canvas straps | n/a (already in possession) | 2 | MEMS Basement | n/a |
| 4              | Carabiners for Pod Rear Attachments | n/a | n/a (already in possession) | 4 | MEMS Basement | n/a |
| 5              | Pod Windshield Material | Mildew-Resistant Antibacterial Heavy-Duty Shower Curtain Liner – 72” x 72” | $13.95 | 2 | http://www.amazon.com/Mildew-Resistant-Antibacterial-Heavy-Duty-Shower-Curtain/dp/B00DH2H5KG/ref=sr_1_7?ie=UTF8&qid=1443501708&sr=8-7&keywords=clear+curtain | ![Image](image2.jpg) |
| 6              | Pod Front Attachment/Hold | Masterkleer PVC Tubing – McMaster Carr 5233K52 (1/8 in. inner diameter, ¼ in. outer diameter, 1/16 in. wall) | ($0.24/ft.)  
(2ft) = $0.48 | 2ft | http://www.mcmaster.com/#standard-plastic-tubing/ez5000at | ![Image](image3.jpg) |
<p>| 7              | Bike Frame | AMF Vintage 10 Speed Bike | $55 | 1 | Craigslist | n/a |
| 8              | Storage Box | 3D Print Collapsible Box w/ Holes for Pod Attachment | n/a (3D printing costs negligible) | 1 | n/a | n/a |
| 9              | Storage Box Hinges | 10 Pcs Silver Tone Metal Butt Hinge for Window Cupboard | $6.04 | 1 | <a href="http://www.amazon.com/Silver-Metal-Hinge-Window-Cupboard/dp/B006Z6YWIO/ref=sr_1_1?ie=UTF8&amp;qid=1443502334&amp;sr=8-1&amp;keywords=hinge">http://www.amazon.com/Silver-Metal-Hinge-Window-Cupboard/dp/B006Z6YWIO/ref=sr_1_1?ie=UTF8&amp;qid=1443502334&amp;sr=8-1&amp;keywords=hinge</a> | <img src="image4.jpg" alt="Image" /> |
| 10             | Pod Frame connectors | Aluminum rod. Drilled holes: 1/8 in ID, ¼ in OD | n/a | 4 | Machine shop | n/a |</p>
<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Model</th>
<th>Quantity</th>
<th>Unit Price</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Handle Bar Tape</td>
<td>SRAM Supercork Bicycle Bar Tape</td>
<td>$13.01</td>
<td>1</td>
<td></td>
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<tr>
<td>12</td>
<td>Hub Motor Battery (36V Total)</td>
<td>Turnigy (37 V, 4.5 Ah, 35 – 70 Discharge) - 11.5 x 1.75 x 1.375 in</td>
<td>$30</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Zip Ties</td>
<td>100 PCS 8” inch 40 lbs. Black Zip Cable Hose Plastic Nylon Ties Zap-Strap</td>
<td>$3.99</td>
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<td></td>
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<tr>
<td>14</td>
<td>Anti-Rust Paint for Frame</td>
<td>Spray Paint, Black Night, 11 oz.</td>
<td>$4.58</td>
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<td></td>
</tr>
<tr>
<td>15</td>
<td>Clamping U-Bolts</td>
<td>Zinc Plated Steel - McMaster Carr 3042T84 (1 5/8 in. thread size)</td>
<td>$1.71</td>
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<tr>
<td>16</td>
<td>Pod Frame Holster</td>
<td>PVC (ID 1 in, Length 3.5 ft.)</td>
<td>n/a</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**TOTAL COST:** $347.90
4.3 Draft detail drawings for each manufactured part

Figure 7: Collapsible Hub Detailed Drawing
Figure 8: Pod Frame Connector Detailed Drawing
Figure 9: Storage Container Detailed Drawing
4.4 Description of the design rationale for the choice/size/shape of each part

During this stage in the design process, the largest questions remaining pertain to the detailed components of the hub motor kit. Extensive research has been conducted regarding the sizing, capability and parts included in the kit by reading instruction manuals and information sites however certain design decisions are unable to be confirmed until the physical parts are acquired.

Specifications for the exact size of the motor controller are undetermined; therefore estimated dimensions for its encasing will be adjusted accordingly. Additionally, we are considering removing the gears attached to the hub motor in order to have a single speed bicycle with a simpler design. This decision, however, will be made further into the fabrication process as the feasibility is assessed once the physical motor assembly is obtained.

Taking into account these uncertainties, the design decisions for crucial parts were chosen considering the following rational and analysis:

1. Rear Hub Motor Kit

Motor Assembly-DIY Motorize Bike 36v 800W 26in Rear Wheel Electric Bicycle Motor Conversion Kit. Considerations were taken between a friction drive, mid-drive and hub motor. Electric motors were favored over gas by the user. This hub motor kit was chosen due to its economic advantage and inclusion of necessary parts. Designs for both the mid drive and friction systems required acquisition of separate throttles, wiring, brake systems etc. and total costs were estimated at similar or greater prices than the hub motor. Additionally, our user niche includes functionality and comfort in wet/rainy environments. We found that the friction drive motor would not perform ideally in this situation, and compared to the mid drive motor, the hub motor has fewer external moving parts and would not require extra mounting or an addition of a second chain. Measurements of the wheels of the bicycle currently in possession are 26 in. therefore this motor kit fits with other parts accordingly. 1000W is the electric bicycle wattage limit in many U.S. states (including MO), yet international countries only allow 250W, therefore our 800W power capability is reasonable. A rear hub motor was chosen over a front wheel because it’s better for traction and driving control.

2. Pod Frame

1/8” Aluminum rods 4 ft. in length are chosen to create the frame structure for our pod. Aluminum is chosen for its light weight. At this diameter it allows sufficient bending to create the curved features envisioned. The curved shape was desired so that any rain hitting the surface will easily drip off and to minimize drag/resistance to wind. We made an assumption based on experimenting with the aluminum rods that a deflection of less than 1 ft. should be reasonable enough to not break the rods. Using this, an estimate for allowable tension in the straps was calculated at 144 lbs.
3. Canvas Straps for Pod Rear

Canvas trap material found in the MEMS basements seems suitable for our needs. We will test/further research this material to ensure that it can withhold the specified tension. Initial assessments imply that a light weighted (about 150lb) individual could hang from this material without it failing.

5. Pod Material

Clear plastic shower curtains are chosen to create the fabric component of the weatherproof pod because it is transparent, water resistant, form fitting and sew-able. This material allows the incorporation of seams and locations for the rods to slide through into the design. While somewhat unconventional, this material will serve our prototyping needs.

7. Bike

A simple road bike was chosen to create the basis of our bike because it included necessary components such as functioning front caliper brakes, good conditioned tires, reflectors and a comfortable seat for a reasonable price. Although we were initially interested in the disk brake installed on the rear wheel because it functions better than caliper brakes in the rain, however this wheel be removed upon installation of the hub motor. If there is sufficient time during the fabrication phase, we may consider installing the disk brakes on the front wheel but this would add extra weight in comparison to the calipers. This decision will be made further along in the process. The wheels provided with the bike are 26” and are compatible with the hub motor conversion kit. We considered manufacturing hybrid handlebars to attach the throttle and motor brake system to. We decided, however to keep the drop handlebars originally included because they provide a convenient location to add the curved tube fittings for holding the aluminum rods. This requires a more central placement of the brakes and throttle closer to the handlebar stem, and eliminates the furthest most leaned forward riding position. Shown below, the sitting angle of the rider in the upright position is still comfortable and reasonable for our commuting (non-racing) user needs. The comfort/cruiser position seats the rider too vertical for reasonable pod fabrication.
8. Storage Box

We have chosen to 3D print this part because it allows us to create the exact dimensions we’d like and to include an extra internal closed compartment with sliding lid for holding the battery safely. The plastic printing material is waterproof, thus meeting our user need of keeping the stored goods dry. This material can be easily drilled through to allow wiring to the battery, zip tie connections to the rear rack, side connections to the pod and hinges for the lid.

10. Pod Frame Connectors

Small Aluminum pieces will be acquired in the shop and machined into necessary dimensions according to the part drawing. In particular, 1/4” diameter with 1/8” drilled holes on either side to allow the Aluminum rods to fit in. 3” length connections are chosen to allow significant overlap between the connector and rods so that the parts remain together when bent.

12. Hub Motor Battery

Turnigy 37 V 4.5 Ah Li Polymer battery and charger was chosen because it is light weight (< 2.5 lbs.), smaller than competitor SLA batteries (11 ½ x 1 ¾ x 1 3/8 in) and meets the required voltage for the hub motor. This battery was also chosen because it won’t give off too much external heat.
4.5 Gantt chart

![Gantt Chart]

Figure 11: Gantt Chart
5 Engineering analysis

5.1 Engineering analysis proposal

5.1.1 A form, signed by your section instructor

The following engineering analysis tasks will be performed:

Table 11: Engineering Analysis Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Description</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hub Motor power</td>
<td>Find the nominal power and torque output of the hub motor, given the selected battery with its nominal voltage of 37V, 4.5Ah and 35-70c discharge rating</td>
<td>before building</td>
</tr>
<tr>
<td>2. Pod structure</td>
<td>Determine the best position of the pod (supports and connections) by analyzing max deflection, and forces acting on structure. Rider position may also influence pod shape</td>
<td>before and during building</td>
</tr>
<tr>
<td>3. Storage unit</td>
<td>Analyze strength of PLA to determine thickness. Determine placement of battery compartment and how cover slides on. How do the sides of the unit hold together (screws or mating parts)</td>
<td>before building</td>
</tr>
<tr>
<td>4. Aerodynamics</td>
<td>Study aerodynamic characteristics of pod (i.e. how much drag) and relate to how much rain protection it gives the rider. Excessive drag may alter final pod design</td>
<td>during and after building</td>
</tr>
<tr>
<td>5. Weight effects</td>
<td>Looking at product as a whole, analyze the effect that the total weight (motor, rider, storage, pod, etc.) has on the rider.</td>
<td>during and after building</td>
</tr>
</tbody>
</table>

The work will be divided among the group members in the following way:

Nkiru Udenze – Tasks 3

Sade Odumuye – Tasks 5 and 2

Jake Gaskill – Tasks 1 and 4

**Met with Professor Jakiela on October 1st, 2015**

Instructor signature: ________________; Print instructor name: Mark Jakiela
5.2 Engineering analysis results

5.2.1 Motivation
The before analysis is essential in determining key components of our project such as pod orientation, battery selection and motor performance capabilities. This analysis facilitates the carrying forward of the project as these various design decisions are essential components.

5.2.2 Summary of Analysis
The main feature and part we had to analyze was the external pod framework. Mainly measuring the deflection and how it holds its shape. We also had to look at motor durability, strength, and speed. The way the weight is distributed across the bike frame and how the different components are secured to the frame will also play a crucial role to how the moped will handle.

5.2.3 Methodology
Most of our analysis was done by building and testing out by hand. For testing purposes of the motor we suspended the bicycle and ran the controls to make sure we got sufficient torque and speed given our battery. We also had to disassemble the bike and fix any mechanics such as the brake wires and chain tension. For the pod framework the only way to get a good representation of its natural deflection was to secure it to the handlebars and secure it given our initial design plans. From there we added more stiffeners to the pod framework. We also had to test the durability of the transparent pod material and how it integrated with the framework.

5.2.4 Results
We found it easier to assess the motor power under different strain conditions. It was able to reach a 20 mph cruising speed. The motor tested to work well in the rain and the wiring was easily controlled and mounted to the bike frame. After initially stating we would use PLA for the bike, budget and manufacturing constraints forced us to use wood for the storage box material. The wood was ½ in. thickness which was the best available and most sturdy option. In terms of the pod framework the analysis has shown that the initial 1/8 in. pod frame was too structurally unsound to use by itself. The arching pod frame is too thin to hold its rigidity while riding and turning. We determined that we need more support towards the front end of the pod frame, especially near the handlebars.

5.2.5 Significance
The analysis results influenced our final prototype in multiple ways. From our determination of stability issue with the pod, our design was adjusted to include a horizontal stabilizing rod for extra support and
adjust the clipping locations of the side attachments. Furthermore, our use of wood added more weight to the rear end of the bike than initially intended, however the motor performance under this weight was still satisfactory. The motor performance had the significance of assuring our street legal classification while reaching reasonably fast cruising speeds for commuter needs.

5.2.6 Codes and Standards Summary
Missouri state law specifies that for a non-registered motorized vehicle it must not have operating capability over 30mph.

5.3 Risk Assessment

5.3.1 Risk Identification

Table 12: Risk Identification

<table>
<thead>
<tr>
<th>Risk No.</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Visibility</td>
</tr>
<tr>
<td>2</td>
<td>Agility</td>
</tr>
<tr>
<td>3</td>
<td>Balance</td>
</tr>
<tr>
<td>4</td>
<td>Traffic Integration</td>
</tr>
<tr>
<td>5</td>
<td>Rider Safety</td>
</tr>
<tr>
<td>6</td>
<td>Motor Malfunction</td>
</tr>
</tbody>
</table>

5.3.2 Risk Analysis

Table 13: Risk Analysis

<table>
<thead>
<tr>
<th>Risk</th>
<th>Risk Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>When controlling or maneuvering any vehicle, it is important for the user to maintain a consistent sightline with his or her surroundings. When in object, such as a rain protecting pod, is placed in front of the user, it is important to evaluate how that object effects the user’s sight. Front, rear, and peripheral vision are important for crash prevention.</td>
</tr>
<tr>
<td>Agility</td>
<td>Design specifications call for several features such as the pod and storage box to be added to a bicycle frame. When coupled, these features alter typical mounting procedures for the bicycle. Consequently, it can become more difficult to demount from the bicycle as well. Although this is not a risk as the user begins and completes his or her commute, it is cause for concern during the</td>
</tr>
</tbody>
</table>
commute. When faced with oncoming hazard, it is not uncommon for a user to quickly dismount from a bicycle to avoid collision. The constraints of the design may limit this instinctive reaction and force the user to be bound to the bike, resulting in a safety hazard.

### Balance
A key component of a bicycle is balance. When riding a bike, the user is not only pedaling forward but also maintaining a weight balance with the bike to keep it upright. This same principle applies to our moped because it uses a bicycle frame. Unfortunately, added components in our design including the pod, rear wheel motor, and storage box not only will make the structure heavier than a typical bike, but may also throw off the weight balance between the front and back of the bike. It will be important to pay attention to how this affects the ease of riding, because there could be an added safety risk.

### Traffic Integration
In our society, bikes and cars are common transportation vehicles. Bikes can be ridden on the street, but are most commonly seen on sidewalks, due to the speed difference between cars and bikes. There is risk with integrating the moped design because it does not exactly fit with current infrastructure. When the motor is in use, it will be operating at a speed too fast for the sidewalk due to pedestrian traffic. On the other hand, the speed of cars may make it difficult to safely ride the moped on the street permanently.

### Motor Malfunction
It is important to evaluate the risk associated with the motor being exposed to the elements over time.

#### 5.3.3 Risk Prioritization

<table>
<thead>
<tr>
<th>Risk</th>
<th>Priority (1 is highest, 5 is lowest)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility</td>
<td>2</td>
</tr>
<tr>
<td>Agility</td>
<td>1</td>
</tr>
<tr>
<td>Balance</td>
<td>3</td>
</tr>
<tr>
<td>Traffic Integration</td>
<td>4</td>
</tr>
<tr>
<td>Motor Malfunction</td>
<td>5</td>
</tr>
</tbody>
</table>
6 Working prototype

6.1 A preliminary demonstration of the working prototype (this section may be left blank).

6.2 A final demonstration of the working prototype (this section may be left blank).

6.3 At least two digital photographs showing the prototype

![Working Prototype Photo](image1)

*Figure 12: Working Prototype Photo*

![Working Prototype Rear Photo](image2)

*Figure 13: Working Prototype Rear Photo*
6.4  A short video clip that shows the final prototype performing

https://www.youtube.com/watch?v=OEJeRM6uDsY

6.5  At least four (4) additional digital photographs and their explanations

![Image of Handlebar Assembly]

Figure 14: Handlebar Assembly (Throttle, Cruise Control, Electric & Cantilever Brakes)
Figure 15: Handlebar Pod Support Sub Assembly (Pre Handlebar Tape Wrapping)
Figure 16: Inside Pod View - Post Rain

Figure 17: Profile View Complete Frankenbike Assembly
7 Design documentation

7.1 Final Drawings and Documentation

7.1.1 A set of engineering drawings that includes all CAD model files and all drawings derived from CAD models.

All units are in inches.

Figure 18: Box Subassembly
Figure 19: Box Lid
Figure 20: Box Base
Figure 21: Battery Compartment Lid
Figure 22: Handlebar Pod Stabilize Subassembly
Figure 23: Pod Stabilizer, "Brookings"
Figure 24: Rod Support
Figure 25: Pod Assembly
Figure 26: Pod Cover
Figure 27: Final Assembly
### 7.1.2 Sourcing instructions

**Table 15: Part Sourcing**

<table>
<thead>
<tr>
<th>Balloon Number</th>
<th>Use (Purpose)</th>
<th>Part (Model)</th>
<th>Cost</th>
<th>Quantity</th>
<th>Parts Source/Supplier (URL, Catalog etc.)</th>
<th>Image (if applicable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Storage Box Assembly – stores battery as well as the user’s miscellaneous goods</td>
<td>$20</td>
<td>1</td>
<td>(Scrounged) – This part was constructed in the Machine shop using wood purchased from the Home Depot</td>
<td>See Frankenbike Box Parts I, II, III, and subassembly CAD Drawings</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Handlebar Pod Stabilizer – this part functions as a base and holder for the pod assembly and holds the pod rods upright and in place for a stable pod</td>
<td>Est. $5</td>
<td>2</td>
<td>(Scrounged) – This part was constructed in the Machine Shop using thin pvc, wood, a metal bolt clamp, and plastic tubing from an ink pin</td>
<td>See Pod Stabilizer“Brookings” and Handlebar Pod Stabilizer Subassembly CAD Drawings</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Rod Support – this part supports the pod structure as well as provides a link for connecting the collapsible pod wiring</td>
<td>Est. $5</td>
<td>2</td>
<td>(Scrounged) – This part was constructed by merging a thin steel rods with a hollow steel rod</td>
<td>See Rod Support CAD Drawing</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Pod - This part provides a weather proof covering to protect the rider from getting wet if it is raining</td>
<td>$5</td>
<td>1</td>
<td>(Scrounged) - This part was constructed by manipulating and sewing clear shower curtain material</td>
<td>See Pod Cover Drawing and Pod Assembly Drawing</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Bike Frame – Fundamental system for biking</td>
<td>AMF Vintage 10 Speed Bike</td>
<td>$55</td>
<td>1</td>
<td>Craigslist</td>
<td>n/a</td>
</tr>
</tbody>
</table>
7.2 Final Presentation

7.2.1 A live presentation in front of the entire class and the instructors

7.2.2 A link to a video clip version of 1

https://www.youtube.com/watch?v=vuWT7iqQQxU&feature=youtu.be

7.3 Teardown

The following teardown/cleanup tasks will be performed:

Our senior design project has already been cleaned out of the Machine Shop and taken off school campus. This includes our bike frame, motor, rain pod and all other attachments. It is currently being stored in one of our group members’ (Sade’s) residence.
Instructor comments on completion of teardown/cleanup tasks:

Instructor signature:  

Print instructor name:  Mary Malast

Date:  12/7/15
8 Discussion

8.1 Final Prototype Quantified Needs

Table 16: Quantified Needs Equation Final Prototype

Overall, the final prototype successfully met the identified needs. Moped “Weight” was the only area where the need was not explicitly met. Due to budget, time, and material constraints, the moped was significantly heavier than anticipated or desired. In the future, it will be important to pay close attention to material selection and placement of additional features (such as the motor and storage box) to facilitate a more balanced load.

8.2 Part Sourcing and Material Scrounging

Some issues were encountered finding appropriate materials that had been envisioned during our product development phases. This required some creative thinking to find reasonable alternatives. Additionally, some desired materials were too expensive for our budget so less ideal alternatives were used for prototyping purposes. Scrounging parts, such as our bicycle frame and brakes, was extremely helpful for our project to stay within budget. Some difficulties were encountered with scrounging of...
parts, however. For example a material that we preferred for our pod rods was found, but there was not enough of it to create a large enough, uniform, assembly, so we were forced to find alternatives.

8.3  Discuss the overall experience:

8.3.1  Was the project more or less difficult than you had expected?
We initially expected the project to be extremely difficult because we had little experience with bikes or motors. While the project was definitely time intensive, it ended up being a reasonable level of difficult, slightly lesser than we’d expected.

8.3.2  Does your final project result align with the project description?
While our final project does not completely align with the initial project description of an “Ultra-light Collapsible Moped,” it does reflect the specific niche and design plan set forth by our team. We were extremely satisfied with our execution of our project.

8.3.3  Did your team function well as a group?
Our team functioned very well as a group. Friendship amongst members made communication easy and allowed for greater understanding of each other’s skills, schedules and preferred work environments.

8.3.4  Were your team member’s skills complementary?
Our team member’s skills were very complimentary in that some members were better at working with word/excel, making quality drawings or using programs such as iMovie to complete assignments, whereas others were better with hands on aspects pertaining more to the prototype building stages of the project.

8.3.5  Did your team share the workload equally?
At times the workload would be carried unequally by certain individuals at different times in the semester, but overall it evened out.
8.3.6 Was any needed skill missing from the group?
None of our group members had any significant experience with working on bikes, so there were many skills learned throughout the process regarding the assembly. Additionally, we learned about the electronics etc. for the motor and battery.

8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?
Yes, after receiving the initial design brief multiple user interviews and consultations with our customer were necessary in order to specify and adjust the original design brief for a more feasible and unique product design.

8.3.8 Did the design brief (as provided by the customer) seem to change during the process?
Yes, the original design brief of an “Ultra-light Collapsible Moped” was changed during the process to become a commuter pedal assisted bicycle, with weather protecting and storage capabilities.

8.3.9 Has the project enhanced your design skills?
The project has enhanced our design skill by requiring multiple phases of concept development. Necessary adjustments were made as various difficulties were encountered, which helped us learn how to work through design problems.

8.3.10 Would you now feel more comfortable accepting a design project assignment at a job?
We feel that while this project did provide some necessary introduction and baseline exposure to design projects, we are unsure that we would feel comfortable soliciting these skills or accepting an official design project assignment/design role.

8.3.11 Are there projects that you would attempt now that you would not attempt before?
After this experience, we are more likely to attempt DIY type projects. We feel more comfortable working with bicycles, sewing machines, machine shop equipment and now understand the necessity of documenting and the iterative nature of the design process.
9 Annotated Bibliography

"Advantages of Electric Bike Mid-Drive Motor Vs. Hub Motor." EVELO Advantages of MidDrive Motor Comments. N.p., n.d. Web. 10 Dec. 2015. This source served as a means to gather useful information regarding various motor options available for motorized bicycles. We used this source to decide upon our final selection of a hub motor.

"Cycling in the Rain: How to Survive It - Cycling Weekly." Cycling Weekly. N.p., 30 Aug. 2015. Web. 10 Dec. 2015. Our group used this article to learn more about practices of biking in the rain and potential methods to stay dry. This source helped us become more of our main user need: weather protection.


"Installing and Adjusting Caliper Brakes." Installing and Adjusting Caliper Brakes. N.p., n.d. Web. 10 Dec. 2015. This source was frequently visited for learning about various braking options, and to gain knowledge on the installation of different parts of our bicycle.

"Patent US4045077 - Convertra-bike Top." Google Books. N.p., n.d. Web. 10 Dec. 2015. This patent was one of the main competing design concepts that was viewed and analyzed in order to determine what adjustments could be made to create the best rain protection for a bicycle.

"Registering Scooters & Mopeds in Missouri | DMV.org." DMV.org. N.p., n.d. Web. 10 Dec. 2015. This official DMV site was used to educate ourselves about regulations and the definition of “street legal.” Valuable knowledge was gained regarding the classification and usage of mopeds in Missouri.