Fall 2015

Commuting Moped for MEMS411

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Our project is to design and build a moped that can be used to commute from home to the Washington University campus, and then be used as a pedal powered transport for travel on the campus grounds.
# Table of Contents

List of Figures ........................................................................................................................................ 5
List of Tables ......................................................................................................................................... 6

1 Introduction ........................................................................................................................................ 7
1.1 Project problem statement ............................................................................................................. 7
1.2 List of team members ..................................................................................................................... 7

2 Background Information Study ......................................................................................................... 7
2.1 A short design brief description that defines and describes the design problem ....................... 7
2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL’s, et cetera) ......................................................................................... 7

3 Concept Design and Specification .................................................................................................... 8
3.1 User needs, metrics, and quantified needs equations. This will include three main parts: ........ 8
   3.1.1 Record of the user needs interview ....................................................................................... 8
   3.1.2 List of identified metrics ....................................................................................................... 9
   3.1.3 Table/list of quantified needs equations .............................................................................. 11
3.2 Four (4) concept drawings .......................................................................................................... 12
3.3 A concept selection process. This will have three parts: ........................................................ 16
   3.3.1 Concept scoring (not screening) ......................................................................................... 16
   3.3.2 Preliminary analysis of each concept’s physical feasibility ................................................. 19
   3.3.3 Final summary .................................................................................................................. 20
3.4 Proposed performance measures for the design ......................................................................... 20

3.5 Design constraints (include at least one example of each of the following) .............................. 21
   3.5.1 Functional ......................................................................................................................... 21
   3.5.2 Safety ............................................................................................................................... 21
   3.5.3 Quality ............................................................................................................................ 21
   3.5.4 Manufacturing .................................................................................................................. 21
   3.5.5 Timing ............................................................................................................................. 21
   3.5.6 Economic ........................................................................................................................ 21
   3.5.7 Ergonomic ....................................................................................................................... 21
   3.5.8 Ecological ........................................................................................................................ 21
   3.5.9 Aesthetic .......................................................................................................................... 21
3.5.10 Life cycle ................................................. 21
3.5.11 Legal ....................................................... 21

4 Embodiment and fabrication plan .................................................. 22
4.1 Embodiment drawing .......................................................... 22
4.2 Parts List ........................................................................... 23

5 ......................................................................................... 24
5.1 Draft detail drawings for each manufactured part ............................ 24
5.2 Description of the design rationale for the choice/size/shape of each part 28
5.3 Gantt chart ........................................................................ 30

6 Engineering analysis ..................................................................... 31
6.1 Engineering analysis proposal .................................................. 31
6.1.1 A form, signed by your section instructor (insert your form here) ........ 31
6.2 Engineering analysis results .................................................... 31
6.2.1 Motivation. Describe why/how the before analysis is the most important thing to study at this time. How does it facilitate carrying the project forward? ................................. 31
6.2.2 Summary statement of analysis done. Summarize, with some type of readable graphic, the engineering analysis done and the relevant engineering equations ................................. 31
6.2.3 Methodology. How, exactly, did you get the analysis done? Was any experimentation required? Did you have to build any type of test rig? Was computation used? ................................. 33
6.2.4 Results. What are the results of your analysis study? Do the results make sense? ....... 34
6.2.5 Significance. How will the results influence the final prototype? What dimensions and material choices will be affected? This should be shown with some type of revised embodiment drawing. Ideally, you would show a “before/after” analysis pair of embodiment drawings. .... 34
6.2.6 Summary of code and standards and their influence. Similarly, summarize the relevant codes and standards identified and how they influence revision of the design. ....................... 35

6.3 Risk Assessment .................................................................... 35
6.3.1 Risk Identification ............................................................. 35
6.3.2 Risk Analysis .................................................................. 35
6.3.3 Risk Prioritization ............................................................. 35

7 Working prototype ........................................................................ 36
7.1 A preliminary demonstration of the working prototype (this section may be left blank). ...... 36
7.2 A final demonstration of the working prototype (this section may be left blank). ............... 36
7.3 At least two digital photographs showing the prototype ............................................. 36
7.4 A short videoclip that shows the final prototype performing ............................................. 37
7.5 At least four (4) additional digital photographs and their explanations .......................... 37

8 Design documentation ......................................................................................................... 42

8.1 Final Drawings and Documentation .................................................................................. 42
  8.1.1 A set of engineering drawings that includes all CAD model files and all drawings derived from CAD models. Include units on all CAD drawings. See Appendix C for the CAD models. .......... 42
  8.1.2 Sourcing instructions .................................................................................................. 46

8.2 Final Presentation .............................................................................................................. 47
  8.2.1 A live presentation in front of the entire class and the instructors (this section may be left blank) 47
  8.2.2 A link to a video clip version of 1 ................................................................................ 47

8.3 Teardown ............................................................................................................................ 47

9 Discussion ............................................................................................................................ 47

9.1 Using the final prototype produced to obtain values for metrics, evaluate the quantified needs equations for the design. How well were the needs met? Discuss the result ........................................ 47

9.2 Discuss any significant parts sourcing issues? Did it make sense to scrounge parts? Did any vendor have an unreasonably long part delivery time? What would be your recommendations for future projects? .................................................................................. 48

9.3 Discuss the overall experience: ....................................................................................... 48
  9.3.1 Was the project more of less difficult than you had expected? .................................. 48
  9.3.2 Does your final project result align with the project description? .............................. 49
  9.3.3 Did your team function well as a group? ...................................................................... 49
  9.3.4 Were your team member’s skills complementary? ...................................................... 49
  9.3.5 Did your team share the workload equally? ................................................................. 49
  9.3.6 Was any needed skill missing from the group? ............................................................ 49
  9.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief? .................................................................................. 49

Once we had completed the customer needs interview we did not need any more customer input to complete our project .................................................................................. 49

9.3.8 Did the design brief (as provided by the customer) seem to change during the process? 49

9.3.9 Has the project enhanced your design skills? ............................................................... 49

9.3.10 Would you now feel more comfortable accepting a design project assignment at a job? 49

9.3.11 Are there projects that you would attempt now that you would not attempt before? .... 49
10  Appendix A - Parts List ............................................................................................................ 50
11  Appendix B - Bill of Materials ................................................................................................. 51
12  Appendix C - CAD Models ....................................................................................................... 51
List of Figures

Figure 1: 2-wheeled design ................................................................. 12
Figure 2: 4-wheeled Design ............................................................... 13
Figure 3: The Big Wheel ................................................................. 14
Figure 4: The Reverse Tricycle .......................................................... 15
Figure 5: Embodiment Drawing ....................................................... 23
Figure 6: Rear Axle Support ............................................................. 25
Figure 7: Rear Axle ................................................................. 26
Figure 8: Wheel to Axle adaptor ............................................................ 27
Figure 9: Chainring spider ............................................................. 28
Figure 10: Gantt chart ................................................................. 30
Figure 11: Overall view of the prototype ........................................ 36
Figure 12: High polish demonstrated on cap of novelty gas tank ............. 37
Figure 13: A view from the rear of the moped, showing the connected human-powered drivetrain and disconnected motorized drivetrain ................................................................. 38
Figure 14: Side view of the rear of the moped during deflection measurements .... 39
Figure 15: Top-down view of the rear axle area during deflection tests ......... 40
Figure 16: CNC’ed axle adaptor connects the driveshaft to the 6-bolt disc brake connection on the rear drive wheels ................................................................. 41
Figure 17: Final Assembly drawing ...................................................... 42
Figure 18: Rear axle support final ..................................................... 43
Figure 19: Axle final ..................................................................... 43
Figure 20: Hub adaptor final ............................................................ 44
Figure 21: Spider final ................................................................... 45
Figure 22: Roll hoop section ............................................................. 46
List of Tables
Table 1: Customer interview .............................................................................................................. 8
Table 2: Identified Metrics ..................................................................................................................... 9
Table 3: Design Metrics .......................................................................................................................... 10
Table 4: Needs Table .............................................................................................................................. 11
Table 5: Concept 1 Happiness Metrics .................................................................................................. 16
Table 6: Concept 2 Happiness Metrics .................................................................................................. 17
Table 7: Concept 3 Happiness Metrics .................................................................................................. 18
Table 8: Concept 4 Happiness Metrics .................................................................................................. 19
Table 9: Purchased Parts ......................................................................................................................... 23
Table 10: Fabricated Parts - Metal stock from machine shop ................................................................. 24
Table 11: Sourcing instructions ............................................................................................................... 46
Table 12: Happiness equations ............................................................................................................... 48
Table 13: Parts List .................................................................................................................................. 50
1 Introduction

1.1 Project problem statement

Design and manufacture an ultralight, street-legal, collapsible moped.

1.2 List of team members

- Charlie Mellinger
- Jon Okenfuss
- Ethan Bermudez

2 Background Information Study

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

Design a moped for less than $500 that can be used as a replacement for a car and/or bicycle. The moped needs to comply with state and local regulations regarding street- legality. The design should also be as safe as possible to prevent injury during operation.

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

www.popularmechanics.com/cars/how-to/a181/1276826

www.dmv.org/other-types.php

www.bikeengines.com/
3 Concept Design and Specification

3.1 User needs, metrics, and quantified needs equations. This will include three main parts:

3.1.1 Record of the user needs interview

Conducted with potential customer Jakiela
11 September 2015

Table 1: Customer interview

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>What do you envision out of this product?</td>
<td>Like a trolling motor on rec boat</td>
<td>Needs to be powered</td>
<td>5</td>
</tr>
<tr>
<td>What sort of propulsion does that entail?</td>
<td>Externally powered until reach campus, then pedaled</td>
<td>needs engine and pedals</td>
<td>5</td>
</tr>
<tr>
<td>What sort of distance do you need to travel?</td>
<td>Jakiela lives 8 miles away.</td>
<td>Required range of 20 miles</td>
<td>5</td>
</tr>
<tr>
<td>Is there a noise constraint?</td>
<td>Less of an issue than you might think – no noisier than a motorcycle or push lawnmower</td>
<td>less than 90 dB</td>
<td>2</td>
</tr>
<tr>
<td>How large an engine?</td>
<td>Jakiela suggests 4 stroke engine so it can accelerate well</td>
<td>Accelerates to 35 mph in 5 seconds</td>
<td>3</td>
</tr>
<tr>
<td>Why not just get a powered bicycle?</td>
<td>wants what a car does</td>
<td>clarified below</td>
<td></td>
</tr>
<tr>
<td>What does a car do that you want?</td>
<td>weather protection</td>
<td>enclosed cockpit</td>
<td>4</td>
</tr>
<tr>
<td>What does a car do that you want?</td>
<td>doesn’t want to have to change clothes</td>
<td>clothing protected from chain and other grease sources</td>
<td>5</td>
</tr>
<tr>
<td>What does a car do that you want?</td>
<td>trunk instead of pannier</td>
<td>has trunkspace</td>
<td>4</td>
</tr>
<tr>
<td>Would you be ok plugging parts in?</td>
<td>could recharge lights or such daily</td>
<td>Lights for safety- at least 700 lumens forwards</td>
<td>3</td>
</tr>
</tbody>
</table>
How large a vehicle would you want? | Smaller than a car, but similar to having a motorcycle | Garage floor footprint of 1m x 2m | 4
---|---|---|---
Do you care how many wheels it has? | Doesn’t care how many wheels it has | Has two wheels | 1
How heavy can it be? | Light enough to lift and move, but not necessarily easily | under 100 lbs | 2

### 3.1.2 List of identified metrics

<table>
<thead>
<tr>
<th>Need Number</th>
<th>Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Has engine</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Has pedals</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>range of 20 mi</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>less than 90dB output</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>accelerates to cruising speed in 5 seconds</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>user is protected from rain</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>user’s clothing protected from grease</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>Trunkspace of 0.25m³</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Lights total 700 lumens</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>footprint of 2m²</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>has only 2 wheels</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>under 100 lbs</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 3: Design 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>
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<tbody>
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<td>1</td>
<td>1</td>
<td>Engine Powered</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Pedal Powered</td>
<td>Binary</td>
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<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Range</td>
<td>Miles</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Sound</td>
<td>dB</td>
<td>70</td>
<td>110</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Acceleration to 25 mph</td>
<td>Seconds</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Weather Protection</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Grease Protected</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Trunkspace</td>
<td>m^3</td>
<td>0</td>
<td>0.5</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Light Illumination</td>
<td>Lumens</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Footprint</td>
<td>m^2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>11</td>
<td># of wheels</td>
<td>Integer</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>Weight</td>
<td>lbs</td>
<td>40</td>
<td>100</td>
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</table>
### 3.1.3 Table/list of quantified needs equations

#### Table 4: Needs Table

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<th>Need</th>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
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<tbody>
<tr>
<td>1</td>
<td>Max Engine</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2</td>
<td>No Pedals</td>
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<td></td>
<td></td>
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<td>.116</td>
<td>.116</td>
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<td>3</td>
<td>Ranges of 12 Mils</td>
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<td></td>
<td></td>
<td></td>
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<td>.116</td>
<td></td>
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<tr>
<td>4</td>
<td>Less than 93 dB output</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>.007</td>
</tr>
<tr>
<td>5</td>
<td>Acceleration to cruising speed in 5s</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>.008</td>
</tr>
<tr>
<td>6</td>
<td>User is protected from rain</td>
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<td></td>
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<td></td>
<td></td>
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<td>.054</td>
</tr>
<tr>
<td>7</td>
<td>User's clothing is protected from grease</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>8</td>
<td>Total mass 0.25m3</td>
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<td></td>
<td></td>
<td></td>
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<td>.094</td>
</tr>
<tr>
<td>9</td>
<td>Light mass 700 Luminous</td>
<td></td>
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<td></td>
<td></td>
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<td>.023</td>
</tr>
<tr>
<td>12</td>
<td>Under 200 Lb</td>
<td></td>
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<table>
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<th>Binary</th>
<th>Miles</th>
<th>dB</th>
<th>Seconds</th>
<th>Binary</th>
<th>Binary</th>
<th>m³</th>
<th>Luminos</th>
<th>m²</th>
<th>Integer</th>
<th>lbs</th>
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<td>20</td>
<td>70</td>
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<td>1</td>
<td>0.1</td>
<td>5000</td>
<td>1</td>
<td>2</td>
<td>40</td>
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<tr>
<td>Worst Value</td>
<td>0</td>
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<td>10</td>
<td>110</td>
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<table>
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<tr>
<th>Importance Rating</th>
<th>Happiness Value</th>
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</tbody>
</table>

Page 11 of 51
3.2 Four (4) concept drawings

Figure 1: 2-wheeled design
Figure 2: 4-wheeled Design
Figure 3: The Big Wheel
Figure 4: The Reverse Tricycle
3.3 A concept selection process. This will have three parts:

3.3.1 Concept scoring (not screening)

Concept 1:

Table 5: Concept 1 Happiness Metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Score</th>
<th>Pedal Provided</th>
<th>Range</th>
<th>Speed Limit</th>
<th>Weather Protection</th>
<th>Gross Protection</th>
<th>Throttle</th>
<th>Brakes</th>
<th>Suspension</th>
<th>Exit</th>
<th>Safety</th>
<th>Total Happiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nudoll</td>
<td>Nudol</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<td>11</td>
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<td>~Engine</td>
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</tr>
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<td></td>
<td></td>
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<td>116</td>
</tr>
<tr>
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Concept 2:

Table 6: Concept 2 Happiness Metrics

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Units: Binary, Binary, Mils, dB, Seconds, Binary, Binary, m³, Lumen, m², Integer, lbs. Total Happiness: 0.895
## Concept 3:

### Table 7: Concept 3 Happiness Metrics

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<th>Overall Protection</th>
<th>Overall Noise</th>
<th>Wind Noise</th>
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Concept 4:

Table 8: Concept 4 Happiness Metrics

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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1: 2-wheeled design
The first concept has a number of advantages over the others. First of all, this design is much lighter than the others as it is essentially a bicycle with an attached small engine. This means that the vehicle could be easily moved around by the user. A smaller engine could also be used with a lighter design and still achieve the same performance on the road. This design is also much simpler to manufacture as it is based on a production bike frame meaning that we could focus entirely on the drivetrain and handling characteristics. However, this design limits the cargo capacity as well as protection from the elements which severely lowers its usefulness in many situations. This design also has no protection for the user from the grease in the components which means that clothes could be ruined during the ride.

Concept 2: 4-wheeled design
This second concept is a 4 wheeled vehicle that is somewhat closer to a car rather than a motorcycle. This design is much more weather proof than the others; as it fully
encloses the user under tent material which improves comfort immensely. Unfortunately this design would prove to be one of the most difficult to manufacture as it would need a fully custom frame as well as a full steering system for the front wheels. This design would also be the heaviest of the four which means that the acceleration and top speed would suffer a lot with a smaller engine. In addition, the four wheels may need some form of suspension to remain in contact with the road surface. Finally, the 4 wheeler would need a large area to park at the destination.

Concept 3: Big wheel
This third concept is a 3-wheeled standard tricycle. It has a few disadvantages: primarily the increased exposure to the elements compared to completely faired designs and the potential instability. The benefits are numerous: the big wheel has very good visibility due to the high driver position, so rider safety is promoted over the lower designs. Cargo space is large enough and the cargo storage could help serve as a firewall for driver protection. This design’s familiar form is easy to manufacture from standard parts, so costs will be kept relatively low.

Concept 4: Reverse Tricycle Design
This fourth concept is a 3 wheeled reverse trike, with two wheels up front and one wheel in the rear. This design is covered completely, giving it a similar weather resistance to the second design. The rider is seated in a comfortable, recumbent position. It is relatively ultralight compared to the second design. However, it has very limited cargo space and a complicated, difficult-to-manufacture steering mechanism. The friction drive system will reduce overall tire life as the knurled friction shaft wears heavily on the tire. The reliance of friction on the tire means reduced effectiveness in inclement conditions.

3.3.3 Final summary
Winner: Concept 3 - The Big Wheel

This concept has several key advantages over the other three designs. This design is simple to manufacture (unlike concepts 2 and 4) as well as weather proof (unlike concept 1). This design also contains a larger space than some of the others designated for cargo meaning it could be used in a variety of scenarios. The design is light enough to get decent performance, while also providing sufficient comfort and utility to the user. All in all, this design is the winner because it takes the best features of the other concepts and combines them into one machine that can do it all.

3.4 Proposed performance measures for the design
1. Moped can travel 15 miles on one tank of fuel
2. Moped can be stored in a space smaller than a parking spot
3. Moped can reach 30 mph
4. Moped can be used at all times of day
5. Moped can be used in all weather
6. Moped can carry more than a backpack
7. Moped can be used without engine

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

3.5.1 Functional
1. Must be able to hold weight of rider without excessive flex

3.5.2 Safety
2. Must be stable in turns and straights to avoid crashes

3.5.3 Quality
3. Moped must be durable enough to be usable for everyday commutes

3.5.4 Manufacturing
4. Parts must be simple enough to manufacture in house with high tolerances

3.5.5 Timing
5. Design should be easily designed and manufactured within 3 months

3.5.6 Economic
6. Budget cannot exceed $500

3.5.7 Ergonomic
7. Moped must be comfortable enough to make a 20 mile round trip commute

3.5.8 Ecological
8. Made out of recyclable materials to reduce environmental impact after products life

3.5.9 Aesthetic
9. Parts with high polish and loud colors to make sure the rider is seen in traffic

3.5.10 Life cycle
10. Must be usable for multiple years with nothing more than simple services

3.5.11 Legal
11. Must comply with all state and local regulations to be street legal
4 Embodiment and fabrication plan

4.1 Embodiment drawing
4.2 Parts List

Table 9: Purchased Parts

<table>
<thead>
<tr>
<th>#</th>
<th>Part</th>
<th>Use</th>
<th>Location</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bicycle frame and components</td>
<td>donor bike gives frame, fork, wheel, hub, brakes, handlebars, seat, seatpost, crankset, etc</td>
<td><a href="http://www.walmart.com/ip/700c-Kent-Thruster-Men-s-Fixie-Bike-Yellow-Blue/40519014">http://www.walmart.com/ip/700c-Kent-Thruster-Men-s-Fixie-Bike-Yellow-Blue/40519014</a></td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>Handlebar mount windscreen</td>
<td>Weather protection is provided by the windscreen attached to the handlebars</td>
<td><a href="http://www.discountramps.com/atv-windshield/p/ATV-WINDSHIELD/">http://www.discountramps.com/atv-windshield/p/ATV-WINDSHIELD/</a></td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>single speed sprocket (2)</td>
<td>transmit force from the chain</td>
<td><a href="http://www.amazon.com/Origin8-Single-Speed-Cog-16t/dp/B000BMT0RQ/">http://www.amazon.com/Origin8-Single-Speed-Cog-16t/dp/B000BMT0RQ/</a></td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>26inch, 6-bolt bicycle wheels (2)</td>
<td>Rear wheels for the tricycle are driven forwards by the disc brake flange, so these have to be 6-bolt front wheels</td>
<td><a href="http://www.niagaracycle.com/categories/weinmann-519-front-wheel-26-x-1-5-qr-6-bolt-disc-36h-silver">http://www.niagaracycle.com/categories/weinmann-519-front-wheel-26-x-1-5-qr-6-bolt-disc-36h-silver</a></td>
<td>90</td>
</tr>
</tbody>
</table>
8. Bearings (4) allow rotation of the drive shaft McMaster#6384k610 36
9. 94BCD 38T chainring drives axle forwards http://www.jensonusa.com/la13stfbU845WxXC5MDLOTg/Blackspire-Epic-DH-Chainring 30

Table 10: Fabricated Parts - Metal stock from machine shop

<table>
<thead>
<tr>
<th>#</th>
<th>Part</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>rear axle</td>
<td>½” steel rod</td>
</tr>
<tr>
<td>11</td>
<td>rear axle supports</td>
<td>0.1 steel plate and 1-¼ tube</td>
</tr>
<tr>
<td>12</td>
<td>6-bolt adaptor (2)</td>
<td>1-½” round aluminum stock</td>
</tr>
<tr>
<td>13</td>
<td>chainring adaptor</td>
<td>2.5” square or round aluminum stock</td>
</tr>
</tbody>
</table>

5

5.1 Draft detail drawings for each manufactured part
Rear Axle Support:
Figure 6: Rear Axle Support

Rear Axle:
Figure 7: Rear Axle

Wheel to Axle Mount:
Figure 8: Wheel to Axle adaptor

Chainring to Axle Mount:
Figure 9: Chainring spider

5.2 Description of the design rationale for the choice/size/shape of each part
Part 10: Rear Axle

The rear axle is 30 inches long and ½” diameter. The volume is around six cubic inches of steel, as calculated here:

Volume = 30in * *(0.5*12in)2=5.9in3

Six cubic inches of steel is around 1-¾ pounds, as calculated:

Mass=5.9in3*0.29 lbs1 in3=1.68 lbs

This weight is rotating, but the relatively small diameter means that this will not contribute significantly to rotating mass. The engine only puts out 2000W with low torque (not defined by the manufacturer) so it will not cause a significant amount of twisting in the rod.

Deflection of axle:
Each wheel is mounted roughly two inches from the end of the axle support, so only that two inch section will be in bending. Weight is about double the expected load to provide for factor of safety.

e=29.5*106
I=0.00306in4
P=250lbs
L=2 inches
Deflection=PL3/3EI=0.0346 inch

That deflection is negligible, so the rod is thick enough for this application.

Part 11: Rear Axle Support

The Rear axle support is the main component that will act as an interface between the rear wheels and the bicycle frame. This part is designed with 1.25” steel tubing and .1” steel plate. The size of the tube was chosen so that it could accommodate the axle as well as the bearings from McMaster which have an O.D. of 1.125”. The plate is welded to the ends to extend to the dropouts for the bicycle rear wheel. This allows us to utilise existing mounting points on the bike. The component is mounted using the axle of the bicycle’s rear hub. The supports are mirrored for the right and left side, making manufacturing much simpler and less prone to errors.

Part 12: 6 Bolt Adaptors
The 6 bolt adaptors are used to fix the rotation of each wheel to the rotation of the axle. The 6 bolt pattern is defined by published standards and the internal diameter is defined by the axle. The 6 bolt flange on the wheel’s hub is designed to take forces from sudden deceleration due to disc braking so it is strong enough to handle the drive forces. The adaptor is built up bulkier than the purchased part, so will not be close to failure.

Part 13: Chainring Adaptor

The chainring adaptor is used to fix a standard four bolt bicycle chainring to the rear axle. As the 2.5HP chainsaw motor produces torque similar to a strong cyclist, the chainring adaptor was designed to be more stout than the standard chainring spider (bit that attaches the chainring to the crank on a bicycle). This bulkier construction suggests that the chainring adaptor will withstand the rigors of driving.

5.3 Gantt chart

![Figure 10: Gantt chart]
6 Engineering analysis

6.1 Engineering analysis proposal

6.1.1 A form, signed by your section instructor (insert your form here)

Analysis Tasks Agreement

Moped 1

Ethan Bermudez, Charlie Mellinger, Jon Okenfuss

The following engineering analysis tasks will be performed:

1. Determine gear ratios
   a. Base on output of engine and average human output
2. Crash test
   a. Due to high cost and potential for injury, this will be done as a simple FEA of the frame.
3. Acceleration test
   a. 0-35 mph time should be low
4. Braking
   a. Should be able to stop safely

6.2 Engineering analysis results

6.2.1 Motivation. Describe why/how the before analysis is the most important thing to study at this time. How does it facilitate carrying the project forward?

Doing a basic engineering analysis before embarking on an engineering project is always important as to ascertain the necessary parameters for a successful project. Studying engineering analyses is important as to reduce wasted time as well as create a working prototype faster and earlier with fewer pitfalls, like broken parts.

6.2.2 Summary statement of analysis done. Summarize, with some type of readable graphic, the engineering analysis done and the relevant engineering equations

Engineering Analyses performed: Torsion of rear axle, bending analysis of rear axle, acceleration test, braking test, curved beam deflection, and gear ratio determination.

To start, we determined the gear ratio by first selecting a power plant and finding the appropriate gear ratio to suite it. Using the fixed torque output of the motor (1.6 ft-lb), we determined the gear ratio
required to propel the trike to operating speed (~30 mph) This was as simple as finding the wheel speed at operating speed and doing the basic algebra to reduce the engine speed to the wheel speed.

The acceleration test was fairly crude. We used a stop watch and some guesswork backed up by gut feeling in order to determine the time it took to reach 25 mph. We tried to use a cell phone app and a gps unit but these methods proved unreliable as the GPS takes time to figure out how fast it is going and it is just plain unsafe to use a mobile phone while operating a motor vehicle without a hands free device. Safety was a serious concern for us.

The braking test was done by applying the brakes. When they worked, we considered it passing. The trike slowed from 20 mph to a halt in 15 feet.

The torsion of the rear axle considered the torque of the pedals on the rear axle. As the torque of a human pedaling is greater than the motor (41.67 lb-ft vs 1.6 lb-ft), the analysis was done at 41.67 lb-ft or 500 in-lb. Utilizing both hand calculations and Solidworks FEA we found that the axle would strain at max load .00088 radians about its central axis. We decided that our axle would be more than strong enough to withstand the rigors of every day driving.
The curved beam deflection was done experimentally as the analysis proved to be too complicated. We used a dial indicator to measure the deflection of the beam under load.

6.2.3 Methodology. How, exactly, did you get the analysis done? Was any experimentation required? Did you have to build any type of test rig? Was computation used?

To start, we determined the gear ratio by first selecting a power plant and finding the appropriate gear ratio to suite it. Using the fixed torque output of the motor (1.6 ft-lb), we determined the gear ratio required to propel the trike to operating speed (~30 mph) This was as simple as finding the wheel speed at operating speed and doing the basic algebra to reduce the engine speed to the wheel speed.

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\[
\theta = \frac{L \cdot T}{(J \cdot G)}
\]

\[
J = \frac{\pi \cdot R^4}{2}
\]

\[
T_{\text{max}} = \frac{\tau_{\text{max}} \cdot J}{R}
\]

The bending analysis of the axle was done by assuming a simple loading case of two reaction forces at the wheels and four supports along the length of the axle. This was then applied to a Solidworks FEA model and the maximum deflection was found.

The curved beam deflection was done experimentally as the analysis proved to be too complicated. We used a dial indicator to measure the deflection of the beam under load.

6.2.4 Results. What are the results of your analysis study? Do the results make sense?

We found that in torsion, the rear axle only twists by .00088 radians, a negligible amount. The axle in bending deflects at a maximum of .0011 mm at full load times 1.5 (250lb*1.5=375lb). When we analysed the bending of the curved beam, we found that it deflected a maximum of .212 inches, at a load of 250 lb. These results make sense, as the trike is built slightly undersized to improve speed and reduce weight.

6.2.5 Significance. How will the results influence the final prototype? What dimensions and material choices will be affected? This should be shown with some type of revised embodiment drawing. Ideally, you would show a “before/after” analysis pair of embodiment drawings.

The results show that the trike needs more rear stiffness. In order to gain more stiffness without adding extra frame members, we plan to use the engine as a stressed member. In figure 5, the engine is simply bolted to a large fixture and the fixture is bolted to the frame. By using the engine as a stressed member, we can save weight and material in the final prototype.
6.2.6 Summary of code and standards and their influence. Similarly, summarize the relevant codes and standards identified and how they influence revision of the design.

The codes surrounding mopeds are concerned with the legality of mopeds in various municipalities. For instance, a moped in St. Louis must not have an engine larger than 49cc. This factored into our design as we chose a 49cc engine to power our vehicle.

6.3 Risk Assessment

6.3.1 Risk Identification

Welds could fail
You could get struck by a car
Rollover risk
Chain could snap
Fuel tank could be mis-identified as an actual fire extinguisher

6.3.2 Risk Analysis

Our welder was professionally trained, so risk was mitigated by his experience and training.
Cars will always be a danger, but the maximum speed is high enough to travel at or near the speed limit.
Rollover risk on cornering is substantial at high speeds, more work is needed to mitigate.
Chains are engineered to handle higher torque than we can output with this engine.
The fuel tank is zip tied, taped, and velcroed to the downtube, so removal will be difficult.

6.3.3 Risk Prioritization

The highest priority to address is rollover risk. Moving forward, we will stabilize steering with a tension spring to force steering towards remaining facing forwards. Another concept to explore would be independent rear suspension, which would allow the trike to lean through turns.
7  Working prototype

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

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

7.3  At least two digital photographs showing the prototype

Figure 11: Overall view of the prototype
Figure 12: High polish demonstrated on cap of novelty gas tank

7.4 A short videoclip that shows the final prototype performing

https://youtu.be/pV2c4NBwW5k

7.5 At least four (4) additional digital photographs and their explanations
Figure 13: A view from the rear of the moped, showing the connected human-powered drivetrain and disconnected motorized drivetrain.
Figure 14: Side view of the rear of the moped during deflection measurements
Figure 15: Top-down view of the rear axle area during deflection tests
Figure 16: CNC’ed axle adaptor connects the driveshaft to the 6-bolt disc brake connection on the rear drive wheels
8 Design documentation

8.1 Final Drawings and Documentation

8.1.1 A set of engineering drawings that includes all CAD model files and all drawings derived from CAD models. Include units on all CAD drawings. See Appendix C for the CAD models.

Figure 17: Final Assembly drawing
Figure 18: Rear axle support final

Figure 19: Axle final
Figure 20: Hub adaptor final
Figure 21: Spider final
Figure 22: Roll hoop section

### 8.1.2 Sourcing instructions

Table 11: Sourcing Instructions

<table>
<thead>
<tr>
<th>Part</th>
<th>Source</th>
<th>Supplier Part Number</th>
<th>Color, TPI, other part IDs</th>
<th>Unit price</th>
<th>Shipping</th>
<th>Quantity</th>
<th>Total price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kent Fixie Small</td>
<td>Walmart</td>
<td>553260313</td>
<td>yellow</td>
<td>$99.97</td>
<td>$0.00</td>
<td>1</td>
<td>$104.19</td>
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<tr>
<td>26&quot; front wheel</td>
<td>Niagara Cycle</td>
<td>12132</td>
<td>silver</td>
<td>$37.08</td>
<td>$9.50</td>
<td>2</td>
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<tr>
<td>Delta MegaRack</td>
<td>Amazon</td>
<td>B004OVYSUY</td>
<td>black</td>
<td>$17.25</td>
<td>$4.00</td>
<td>1</td>
<td>$21.25</td>
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<tr>
<td>SRAM SS Chain</td>
<td>Amazon</td>
<td>B0013FBE8I</td>
<td>silver</td>
<td>$10.78</td>
<td>$4.11</td>
<td>1</td>
<td>$14.89</td>
</tr>
</tbody>
</table>
The fixie can be any steel donor bike that has a working front brake, front wheel, and rear flipflop hub. 26 inch front disc brake wheels are used to drive the tricycle, with the axles blown out and fastened through the brake adaptor. Any bike rack will do for the cargo rack. Any single speed bike chain will do, the SRAM one supports an American company so we chose that. The ball bearings are needed for the axle unit. This chainsaw is needed for its engine; the blade to the chainsaw is thrown directly into the recycling bin. Rim strips and tires (scrounged) are needed for the wheels.

8.2 Final Presentation

8.2.1 A live presentation in front of the entire class and the instructors (this section may be left blank)

8.2.2 A link to a video clip version of 1

https://youtu.be/ODsUmQtI5lQ

8.3 Teardown
Completed

9 Discussion

9.1 Using the final prototype produced to obtain values for metrics, evaluate the quantified needs equations for the design. How well were the needs met? Discuss the result.
Table 12: Happiness equations

<table>
<thead>
<tr>
<th>need</th>
<th>engine</th>
<th>pedal</th>
<th>pox</th>
<th>range</th>
<th>sound level</th>
<th>acceleration to 25 mph</th>
<th>weather proof</th>
<th>grease protection</th>
<th>trunk space</th>
<th>light illumination</th>
<th>footprint</th>
<th># wheels</th>
<th>weight</th>
<th>Need has engine</th>
<th>happiness value</th>
</tr>
</thead>
<tbody>
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<td>0.739968</td>
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<td></td>
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<td>0.008155</td>
<td>0.01175</td>
<td>1</td>
<td>0.94936</td>
<td>0.0943</td>
<td>0.116</td>
<td>0.739968</td>
</tr>
<tr>
<td>less than 90dB out</td>
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<td>1</td>
<td>0.94936</td>
<td>0.0943</td>
<td>0.116</td>
<td>0.739968</td>
</tr>
<tr>
<td>accel 5s</td>
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<td>0.94936</td>
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<td>0.01175</td>
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<td>0.739968</td>
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<tr>
<td>under 100lbs</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.270667</td>
<td>0.008155</td>
<td>0.01175</td>
<td>1</td>
<td>0.94936</td>
<td>0.0943</td>
<td>0.116</td>
<td>0.739968</td>
</tr>
</tbody>
</table>

Based on these calculations, the total happiness is between the highest calculated happiness predicted and the second-highest predicted, verifying the original design choice as being the best of the possibilities. Needs could be better met with a more user-friendly design, including weatherproofing, grease protection, and an increase in trunk space.

9.2 Discuss any significant parts sourcing issues? Did it make sense to scrounge parts? Did any vendor have an unreasonably long part delivery time? What would be your recommendations for future projects?

We had a few issues with ordering parts. To start, our initial order was misread by the people placing the order which ended in us only receiving one of the two wheels that we needed. We were able to get the other just in time for the initial demo but definitely raised the stress level while during manufacturing. Then, the engine we ordered came from EBay and was shipped from China. Because of this, the shipping took a very long time which put us in another time crunch before the final demo. It would have been much better to order the chainsaw engine from a local vendor but budget constraints made that unrealistic. For future projects, teams should make sure to order all of their parts very early in order to ensure they leave enough time for manufacturing.

9.3 Discuss the overall experience:

9.3.1 Was the project more of less difficult than you had expected?

This project was definitely more difficult than expected, however most of the difficulties we ran into were making sure the prototype was of high quality. Had we solely been
worried about making a more barebones prototype there would have been significantly
less work.

9.3.2 Does your final project result align with the project description?
While our final project doesn’t exactly align with the initial design brief, it does fit very
closely to our customer needs interview and the design niche we chose.

9.3.3 Did your team function well as a group?
We functioned very well as a group, we each had our own specialties that meshed well
with each other to get the project done well and on time.

9.3.4 Were your team member’s skills complementary?
We are each good at different things; which helped immensely.

9.3.5 Did your team share the workload equally?
Most of our workload was shared equally while trying to make sure everyone could do
the work they were best at.

9.3.6 Was any needed skill missing from the group?
We weren’t missing any essential skills for this project.

9.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?
Once we had completed the customer needs interview we did not need any more
customer input to complete our project.

9.3.8 Did the design brief (as provided by the customer) seem to change
during the process?
The design brief changed to be more specific during the customer needs interview.

9.3.9 Has the project enhanced your design skills?
Yes, this project showed us what is needed to see a project through from design through
manufacturing.

9.3.10 Would you now feel more comfortable accepting a design project
assignment at a job?
We would definitely feel more comfortable accepting a design project assignment after
this class.

9.3.11 Are there projects that you would attempt now that you would not
attempt before?
Yes, there are a number of projects that seem much more realistic to complete now after
this invaluable experience.
### 10 Appendix A - Parts List

Table 13: Parts List

<table>
<thead>
<tr>
<th>#</th>
<th>Part</th>
<th>Use</th>
<th>Location</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Handlebar mount windscreen</td>
<td>Weather protection is provided by the windscreen attached to the handlebars</td>
<td><a href="http://www.discountramps.com/atv-windshield/p/ATV-WINDSHIELD/">http://www.discountramps.com/atv-windshield/p/ATV-WINDSHIELD/</a></td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>single speed sprocket (2)</td>
<td>transmit force from the chain</td>
<td><a href="http://www.amazon.com/Origin8-Single-Speed-Cog-16t/dp/B000BMT0RQ/">http://www.amazon.com/Origin8-Single-Speed-Cog-16t/dp/B000BMT0RQ/</a></td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>26inch, 6-bolt bicycle wheels (2)</td>
<td>Rear wheels for the tricycle are driven forwards by the disc brake flange, so these have to be 6-bolt front wheels</td>
<td><a href="http://www.niagaracycle.com/categories/weinmann-519-front-wheel-26-x-1-5-qr-6-bolt-disc-36h-silver">http://www.niagaracycle.com/categories/weinmann-519-front-wheel-26-x-1-5-qr-6-bolt-disc-36h-silver</a></td>
<td>90</td>
</tr>
<tr>
<td>6</td>
<td>Engine</td>
<td>Chainsaw engine will provide drive force for the moped</td>
<td><a href="http://www.ebay.com/itm/22-52CC-EPA-Cutting-Chainsaw-Wood-Gas-Aluminum-Gasoline-2-4-HP-Engine-Brake-HD-/351456193852?hash=item51d46bed3c">http://www.ebay.com/itm/22-52CC-EPA-Cutting-Chainsaw-Wood-Gas-Aluminum-Gasoline-2-4-HP-Engine-Brake-HD-/351456193852?hash=item51d46bed3c</a></td>
<td>100</td>
</tr>
</tbody>
</table>
8 | Bearings (4) | allow rotation of the drive shaft | McMaster#6384k610 | 36
---|---|---|---|---
9 | 94BCD 38T chainring | drives axle forwards | [http://www.jensonusa.com/la13st fbU845WxXC5MDLOTg//Blackspire-Epic-DH-Chainring](http://www.jensonusa.com/la13st fbU845WxXC5MDLOTg//Blackspire-Epic-DH-Chainring) | 30

11 **Appendix B - Bill of Materials**

12 **Appendix C - CAD Models**