MEMS 411 Senior Design 2015 Moped 3 Final Report

Megan Rupp  
*Washington University in St Louis*

Luke Duschl  
*Washington University in St Louis*

Ben Lake  
*Washington University in St Louis*

Brandon Staffeil  
*Washington University in St Louis*

Follow this and additional works at: [https://openscholarship.wustl.edu/mems411](https://openscholarship.wustl.edu/mems411)

Part of the Mechanical Engineering Commons

**Recommended Citation**
[https://openscholarship.wustl.edu/mems411/35](https://openscholarship.wustl.edu/mems411/35)

This Final Report is brought to you for free and open access by the Mechanical Engineering & Materials Science at Washington University Open Scholarship. It has been accepted for inclusion in Mechanical Engineering Design Project Class by an authorized administrator of Washington University Open Scholarship. For more information, please contact digital@wumail.wustl.edu.
The goal of this project was to design and build a motor scooter/moped that can replace the target user’s second vehicle for his commute to work. The moped needed to be easily to roll around when not being driven, similar to rolling luggage. The target user wanted it to be comfortable, street legal, and able to get him to and from his place of work twenty minutes from his house.
Table of Contents

List of Figures ........................................ 4
List of Tables .......................................... 5

1 Introduction ........................................ 6
  1.1 Project problem statement .................. 6
  1.2 List of team members ......................... 6

2 Background Information Study .................. 6
  2.1 A short design brief description that defines and describes the design problem 6
  2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL’s, et cetera) 6

3 Concept Design and Specification .............. 7
  3.1 User needs, metrics, and quantified needs equations. 7
     3.1.1 Record of the a user needs interview 7
     3.1.2 List of identified metrics ................. 8
     3.1.3 Table/list of quantified needs equations 9
  3.2 Four (4) concept drawings ...................... 10
  3.3 A concept selection process ................... 13
     3.3.1 Concept scoring .......................... 13
     3.3.2 Preliminary analysis of each concept’s physical feasibility 15
     3.3.3 Final summary ............................ 16
  3.4 Proposed performance measures for the design 16
  3.5 Design constraints (include at least one example of each of the following) 16
     3.5.1 Safety .................................... 16
     3.5.2 Quality ................................... 17
     3.5.3 Manufacturing ............................ 17
     3.5.4 Timing .................................... 17
     3.5.5 Economic ................................ 17
     3.5.6 Ergonomic ................................. 17
     3.5.7 Ecological ................................ 17
     3.5.8 Aesthetic ................................ 17
     3.5.9 Life cycle ................................ 17
     3.5.10 Legal .................................... 17

4 Embodiment and fabrication plan ............... 18
  4.1 Embodiment drawing ............................ 18
  4.2 Parts and Materials Lists ..................... 19
  4.3 Draft detail drawings for each manufactured part 21
  4.4 Description of the design rationale for the choice/size/shape of each part 26
  4.5 Gantt chart ..................................... 28

5 Engineering analysis ............................... 29
5.1 Engineering analysis proposal

5.2 Engineering analysis results
   5.2.1 Motivation.
   5.2.2 Summary statement of analysis done.
   5.2.3 Methodology.
   5.2.4 Results.
   5.2.5 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.
   5.2.6 Summary of code and standards and their influence.

5.3 Risk Assessment
   5.3.1 Risk Identification
   5.3.2 Risk Analysis
   5.3.3 Risk Prioritization

6 Working prototype
   6.1 A preliminary demonstration of the working prototype
   6.2 A final demonstration of the working prototype

7 Design documentation
   7.1 Final Drawings and Documentation
      7.1.1 A set of engineering drawings (See Appendix C for CAD model files)
      7.1.2 Sourcing instructions
   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
   7.3 Teardown

8 Discussion
   8.1 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.
   8.2 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?
   8.3 Discuss the overall experience:
      8.3.1 Was the project more or less difficult than you had expected?
      8.3.2 Does your final project result align with the project description?
      8.3.3 Did your team function well as a group?
      8.3.4 Were your team member’s skills complementary?
      8.3.5 Did your team share the workload equally?
      8.3.6 Was any needed skill missing from the group?
      8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?
8.3.8 Did the design brief (as provided by the customer) seem to change during the process? 50
8.3.9 Has the project enhanced your design skills? 50
8.3.10 Would you now feel more comfortable accepting a design project assignment at a job? 50
8.3.11 Are there projects that you would attempt now that you would not attempt before? 50

9 Appendix A - Parts List 51
10 Appendix B - Bill of Materials 51
11 Appendix C - CAD Models 51
12 Annotated Bibliography (limited to 150 words per entry) 51
List of Figures
Figure 1: List of team names .............................................................. 6
Figure 2: Concept 1 - Motor in front .................................................. 10
Figure 3: Concept 3 - Tricycle-based ................................................. 11
Figure 4: Concept 3 - Dual-hinged .................................................... 12
Figure 5: Concept 4 - Holding handlebars ........................................ 13
Figure 6: Embodiment drawing ........................................................... 18
Figure 7: Front fork assembly embodiment drawing ............................ 21
Figure 8: Handle and steering column embodiment drawings ................ 22
Figure 9: Front Tubing and 2” Tubing Embodiment Drawings ............... 23
Figure 11: Front Axle Embodiment Drawing ......................................... 24
Figure 10: Wheel Spacers and 2” Tubing Embodiment Drawing .............. 24
Figure 13: Seat embodiment drawing .................................................. 25
Figure 12: Hitch Embodiment Drawing .............................................. 25
Figure 14: Base Frame Embodiment Drawing ....................................... 26
Figure 15: Gantt chart ........................................................................ 28
Figure 16: Engineering Analysis Proposal Form .................................... 29
Figure 17: FEA analysis results ............................................................ 31
Figure 18: Missouri motor scooter requirements [1] ................................. 31
Figure 16: Luke on the completed frame ............................................. 33
Figure 18: Photo of final prototype ...................................................... 33
Figure 17: Videoclip of Final Prototype ................................................ 33
Figure 19: Video clip of final prototype ................................................ 34
Figure 21: Completed frame with seat .................................................. 34
Figure 20: Welded frame ..................................................................... 34
Figure 26: Completed frame with axles and tire/wheel assemblies ............ 35
Figure 23: Motor and power train ........................................................ 35
Figure 26: Full assembly drawing ........................................................ 36
Figure 27: Vertical handlebar rod drawing ............................................. 37
Figure 27: Handlebar assembly drawing .............................................. 37
Figure 29: Neck tube drawing ............................................................. 38
Figure 29: Horizontal handlebar rod drawing ....................................... 38
Figure 31: Front axle drawing ............................................................. 39
Figure 31: Pin block drawing ............................................................... 39
Figure 33: Rear assembly drawing ...................................................... 40
Figure 33: Handlebar spacer drawing .................................................. 40
Figure 35: Engine plate drawing .......................................................... 41
Figure 35: Seat plate drawing .............................................................. 41
Figure 37: Rear frame drawing ............................................................ 42
Figure 37: Back platform drawing ....................................................... 42
Figure 39: Back axle drawing ............................................................. 43
Figure 39: Back wheel spacer drawing ............................................... 43
Figure 41: 14” tube drawing ............................................................... 44
Figure 41: 18” tube drawing ............................................................... 44
Figure 43: 12” tube drawing ............................................................... 45
Figure 43: 13” tube drawing ............................................................... 45
Figure 45: 10” tube with hole drawing ................................................ 46
Figure 45: 10” tube drawing ............................................................... 46
Figure 47: 6” tube drawing ................................................................. 47
List of Tables
Table 1: User needs interview .......................................................................................... 7
Table 2: List of identified metrics.......................................................................................... 8
Table 3: List of quantified needs equations............................................................................ 9
Table 4: Happiness equation template ................................................................................. 10
Table 5: Concept 1 scoring................................................................................................. 13
Table 6: Concept 2 scoring................................................................................................. 14
Table 7: Concept 3 scoring................................................................................................. 14
Table 8: Concept 4 scoring................................................................................................. 14
Table 9: Parts List ............................................................................................................. 19
Table 10: Bill of Materials .................................................................................................. 19
Table 11: Scoring for final prototype .................................................................................. 49
1 Introduction

1.1 Project problem statement
The user wants to replace a second car as a vehicle for his commute to work. He wants to legally drive a motor scooter comfortably for the twenty-minute commute. He also wants to be able to collapse and roll the scooter around like a piece of luggage while not driving it.

1.2 List of team members

Figure 1: List of team names

Moped 3
Luke Duschl
Ben Lake
Megan Rupp
Brandon Staffeil

2 Background Information Study

2.1 A short design brief description that defines and describes the design problem
The collapsible, rollable motor scooter is a platform base with a large seat so the driver can sit recumbently. We decided aluminum tubing would be a good option for the moped frame for lightweight strength. The motor is much larger than the legal limit of 50cc, but it was in the MEMS storage area and used for cost reasons.

2.2 Summary of relevant background information (such as similar existing devices or patents, patent numbers, URL’s, et cetera)
There are many designs of motor scooters and moped on the market. No patents were relevant to our design process.
# Concept Design and Specification

## 3.1 User needs, metrics, and quantified needs equations.

### 3.1.1 Record of the a user needs interview

**Table 1: User needs interview**

<table>
<thead>
<tr>
<th>Question</th>
<th>Customer Statement</th>
<th>Interpreted Need</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you want this to replace a full-sized vehicle?</td>
<td>Yes.</td>
<td>Needs to be powerful and comfortable</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs to carry at least one person</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs to function in the rain.</td>
<td>4</td>
</tr>
<tr>
<td>Do you want this to be licensed?</td>
<td>No</td>
<td>Needs to fulfill street-legal requirements for moped in MO.</td>
<td>5</td>
</tr>
<tr>
<td>Do you want to carry cargo?</td>
<td>Yes, two paper shopping bags.</td>
<td>Needs to hold two paper shopping bags while under power.</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs to hold 30 lbs. of cargo.</td>
<td>2</td>
</tr>
<tr>
<td>How heavy is the driver?</td>
<td>Less than 250 lbs.</td>
<td>Needs to hold a 250 lb. driver.</td>
<td>5</td>
</tr>
<tr>
<td>Do you want an alternate to motor power?</td>
<td>Yes, but only in case of breakdown.</td>
<td>Needs to have a human-power option.</td>
<td>4</td>
</tr>
<tr>
<td>Do you have a dimension in mind for the collapsed moped?</td>
<td>I want to fit it inside the trunk of my Honda CRV.</td>
<td>Needs to fit in the trunk of a Honda CRV.</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs a footprint similar to a small shopping cart.</td>
<td>4</td>
</tr>
<tr>
<td>How long do you want it to take to collapse and set up?</td>
<td>No longer than 90 seconds and five steps.</td>
<td>Needs to take no longer than 90 seconds.</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Needs to take five steps or fewer to set up and collapse.</td>
<td>4</td>
</tr>
</tbody>
</table>
### 3.1.2 List of identified metrics

**Table 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>M can carry one person</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>M is waterproof</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Seat of M is recumbent and comfortable</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>M is street legal as a moped in MO.</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>M holds two paper shopping bags without falling out under power.</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>M holds 30 lbs. of cargo</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>M holds a 250 lb. driver</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>M has a human-power option</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>M has 2’ x 2.5’ footprint</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>M takes 90 seconds and fewer than 5 steps to set up and collapse.</td>
<td>4</td>
</tr>
<tr>
<td>11</td>
<td>M is less than 50 lbs.</td>
<td>5</td>
</tr>
<tr>
<td>12</td>
<td>M runs for 40 minutes</td>
<td>5</td>
</tr>
</tbody>
</table>
3.1.3 Table/list of quantified needs equations

Table 3: List of quantified needs equations

<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</td>
<td>Holds 1 Rider</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Waterproof</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Recumbent Seat</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Motor Size</td>
<td>Cm^3</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>Number of Wheels</td>
<td>Integer</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>Gross BHP</td>
<td>HP</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>4,13</td>
<td>Speed</td>
<td>MPH</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>Holds 2 Shopping Bags</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>Weight of cargo</td>
<td>Lbs</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>Weight of rider</td>
<td>Lbs</td>
<td>0</td>
<td>250</td>
</tr>
<tr>
<td>11</td>
<td>8</td>
<td>Human Powered option</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>9</td>
<td>Collapsed footprint area</td>
<td>Ft^2</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>Time to set up</td>
<td>Sec.</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>Steps to set up</td>
<td>Integer</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>11</td>
<td>Weight of M</td>
<td>Lbs</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>16</td>
<td>12</td>
<td>Operation Time</td>
<td>Min</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>17</td>
<td>14</td>
<td>Rolls as Collapsed</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>15</td>
<td>Hand Controlled</td>
<td>Binary</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
### 3.2 Four (4) concept drawings

**Figure 2: Concept 1 - Motor in front**

![Figure 2: Concept 1 - Motor in front](image-url)
PORTABLE ROLLING MOPED CONCEPT:
TRICYCLE-BASED

Figure 3: Concept 3 - Tricycle-based
Figure 4: Concept 3 - Dual-hinged
3.3 A concept selection process

3.3.1 Concept scoring

Table 5: Concept 1 scoring

<table>
<thead>
<tr>
<th>Metric</th>
<th>Need</th>
<th>Actual Value</th>
<th>Best Value</th>
<th>Weighted Value</th>
<th>Normalized Metric Happiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holds one rider</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Waterproof</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Recumbent Seat</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Motor Size</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Number of Wheels</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Gross BHP</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Speed</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Number of Bags</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Weight of Cargo</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Weight of Rider</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Human Powered</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Collapsed Footprint Area</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Time to Set Up</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Rolls As Collapsed</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Hand Controlled</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Weight of Moped</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
<tr>
<td>Operation Time</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.666667</td>
</tr>
</tbody>
</table>

Total Happiness: 1

Note: Importance weights (all entries should add up to 1)
### Table 8: Concept 2 scoring

<table>
<thead>
<tr>
<th>Metric</th>
<th>Overall</th>
<th>Weighted</th>
<th>Space</th>
<th>Battery Life</th>
<th>Ease of Use</th>
<th>Noise</th>
<th>Speed</th>
<th>Handling</th>
<th>Damage Resistance</th>
<th>Cost</th>
<th>Installation</th>
<th>Overall Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>5</td>
<td>0.85</td>
<td>3</td>
<td>3.5</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

| Total Happiness | 100 |

| Normalized Metric Happiness | 1 |

### Table 7: Concept 3 scoring

<table>
<thead>
<tr>
<th>Metric</th>
<th>Overall</th>
<th>Weighted</th>
<th>Space</th>
<th>Battery Life</th>
<th>Ease of Use</th>
<th>Noise</th>
<th>Speed</th>
<th>Handling</th>
<th>Damage Resistance</th>
<th>Cost</th>
<th>Installation</th>
<th>Overall Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>4</td>
<td>0.65</td>
<td>2</td>
<td>3</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3</td>
<td>16</td>
</tr>
</tbody>
</table>

| Total Happiness | 70 |

| Normalized Metric Happiness | 1 |

### Table 6: Concept 4 scoring

<table>
<thead>
<tr>
<th>Metric</th>
<th>Overall</th>
<th>Weighted</th>
<th>Space</th>
<th>Battery Life</th>
<th>Ease of Use</th>
<th>Noise</th>
<th>Speed</th>
<th>Handling</th>
<th>Damage Resistance</th>
<th>Cost</th>
<th>Installation</th>
<th>Overall Scoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>5</td>
<td>0.75</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>30</td>
</tr>
</tbody>
</table>

| Total Happiness | 100 |

| Normalized Metric Happiness | 1 |

---

**Page 14 of 51**
3.3.2 Preliminary analysis of each concept's physical feasibility

Concept 1: Motor in Front Moped

The design of concept one will be fairly hard to create. The frame will be constructed out of aluminum, and considering that no one in our group has ever TIG welded before, could pose a problem. By giving the moped the ability to turn on a single shaft in the front forks of the bike, while also hinging the bottom part of the connection, puts all the compressive stress of riding in the telescopic supporting arm. This means that the arm will have to be sufficiently strong not to break. The idea of having two wheels on the front axle should make the ride more comfortable and easier to balance under the user need of carrying a load of two shopping bags. Having the motor only turn one wheel takes out the aspect of the two wheels fighting each other while attempting turns. By using the back of the moped as a handle bar, the user will be able to roll the moped around when not in use like a golf bag, or dolly. The weight of the motor directly over top and slightly in front of the front axle will create a kind of counter weight to assist in the lifting of the overall weight of the moped.

Concept 2: Tricycle-based Moped

The tricycle-based design of concept two is pretty basic, but poses some physical challenges. The shape of the frame while in working position may not have enough support under the crossbeam to hold up against a rider leaning on the handlebars. Another big challenge is the sliding mechanism to collapse the moped. The design requires the handlebars and front wheel to slide back towards the pedals and also to rotate to tuck the wheel under. I believe a channel in the crossbeam and a round feature on the handlebar beam will achieve this. The locking mechanisms to hold the positions will have to be very strong but easy to release and lock. This is another challenge in itself. Like all of our concepts, we will have to tweak the balance and structure to create a comfortable and safe ride and also easy roll-around.

Concept 3: Dual-hinged Moped

This collapsing moped design is centered on the idea of a folding frame. In order to achieve this folding action, two hinges will need to be installed in the center of the frame. These two hinges will be responsible for not only the folding of the scooter, but will also bear the entire weight of the scooter, rider, and any stored items. This combined weight puts a lot of stress on the hinges and will require very strong hinges and hinge attachments. The hinges will likely need to be welded to the frame, which also complicates the design because similar metals will need to be found for the hinges and the frame. In addition, attaching the hinge will be a complicated welding process that will likely require the aid of an outside welder. Overall, the design of this folding scooter is simple, and the hinges will be the factor of the design that will complicate its creation.
Concept 4: Folding Handlebars Moped

The folding handlebars concept is fairly simple in design, relying on one large platform, but will have some complexities regarding the hardware at the front wheel. Because the platform connects to the front wheel at the same position the handlebars and the foot pedals do, the supports will need to turn with the wheel, allowing the rider to turn the moped and pedal in the event of a breakdown. Another issue that may arise is difficulty keeping the moped under 50 pounds while maintaining the structural integrity. Strong and lightweight materials will be necessary to meet the design goal. Once folded, the foot pegs will allow the rider to push the moped like a dolly, although only having one wheel may cause some balance issues. If proper materials can be found in our budget range, concept 4 is a viable option.

### 3.3.3 Final summary

**WINNER: Concept 4 – Folding Handlebars Moped**

Concept 4 did not have the highest happiness score; however, it has several advantages over the other concepts. We think having the base of the moped as a platform rather than a series of beams will be simpler to make strong enough to support the driver and moped components. It also provides a storage area without having to attach a basket like in the other concepts. Concept 4 also allows a big, comfortable seat that addresses the customer’s desire for the moped to replace a second car to make his commute. This concept also collapses very easily using two simple hinges rather than more complicated rotations and sliding used in the other concepts.

We eliminated Concept 3 due to its lack of recumbent seating and the complicated sliding mechanism to collapse. We thought creating the slot for the handlebar beam to slide along the crossbeam and lock into place would be too difficult for us to build. We eliminated Concept 1 due to its complexity of the front axle folding and turning. Additionally, we eliminated Concept 3 because we thought the steps to fold the moped might be too difficult to make smooth and easy.

#### 3.4 Proposed performance measures for the design

1. The moped adheres to all laws for motor scooter in Missouri.
2. The moped can be collapsed or opened in less than 90 seconds.
3. The moped has fewer than 5 steps to collapse or open.
4. The moped weighs less than 50 pounds.
5. The moped can be easily rolled after collapsing.

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

##### 3.5.1 Safety

The moped needs to accelerate and brake smoothly so the driver is not jerked. The welds must be strong enough to support the weight of the driver and motor. The driver should always wear a helmet.
3.5.2 Quality
The craftsmanship needs to be good enough to stand up to bumps in the road with the weight of the motor and driver.

3.5.3 Manufacturing
Most of the assembly will be done with welding. This is limited to what is available in the shop.

3.5.4 Timing
The old motor will take a significant amount of time to diagnose and get running.

3.5.5 Economic
The large motor must be used because there is not enough in the budget to buy a new motor. This constrains the power train design.

3.5.6 Ergonomic
The seat must be large and soft enough to be comfortable while riding on a bumpy road.

3.5.7 Ecological
We must not waste argon or weld tips unnecessarily while maintaining good craftsmanship.

3.5.8 Aesthetic
The seat needs to be covered neatly and the welds need to be done well to look aesthetically pleasing.

3.5.9 Life cycle
The power train needs to be balanced and aligned to minimize wear on the clutch, brakes, and tires.

3.5.10 Legal
The motor would have to be replaced with a 50 cc one to be legal.
4 Embodiment and fabrication plan

4.1 Embodiment drawing

Figure 6: Embodiment drawing
## 4.2 Parts and Materials Lists

### Table 9: Parts List

<table>
<thead>
<tr>
<th>Part #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Base Frame</td>
</tr>
<tr>
<td>2</td>
<td>Handle Bar Hitch</td>
</tr>
<tr>
<td>3</td>
<td>Front Fork Assembly</td>
</tr>
<tr>
<td>3-1</td>
<td>Grips Set</td>
</tr>
<tr>
<td>3-2</td>
<td>Hand Brake/Throttle</td>
</tr>
<tr>
<td>3-3</td>
<td>Handle</td>
</tr>
<tr>
<td>3-4</td>
<td>Cables</td>
</tr>
<tr>
<td>3-5</td>
<td>Steering Column</td>
</tr>
<tr>
<td>3-6</td>
<td>Bushing</td>
</tr>
<tr>
<td>3-7</td>
<td>Hitch Pin</td>
</tr>
<tr>
<td>3-8</td>
<td>Front Tubing</td>
</tr>
<tr>
<td>3-9</td>
<td>2” Tubing – 12” Long</td>
</tr>
<tr>
<td>3-10</td>
<td>Wheel Spacers</td>
</tr>
<tr>
<td>3-11</td>
<td>Front Tire/Wheel</td>
</tr>
<tr>
<td>3-12</td>
<td>2” Tubing – 10” Long</td>
</tr>
<tr>
<td>3-13</td>
<td>Front Axle</td>
</tr>
<tr>
<td>3-14</td>
<td>Front Axle Nut</td>
</tr>
<tr>
<td>4</td>
<td>Seat</td>
</tr>
<tr>
<td>4-1</td>
<td>Plywood</td>
</tr>
<tr>
<td>4-2</td>
<td>Foam</td>
</tr>
<tr>
<td>4-3</td>
<td>Vinyl Fabric</td>
</tr>
<tr>
<td>5</td>
<td>Main Platform</td>
</tr>
<tr>
<td>6</td>
<td>Motor Platform</td>
</tr>
<tr>
<td>7</td>
<td>Motor</td>
</tr>
<tr>
<td>8</td>
<td>Clutch</td>
</tr>
<tr>
<td>9</td>
<td>Brake</td>
</tr>
<tr>
<td>10</td>
<td>Sprocket</td>
</tr>
<tr>
<td>11</td>
<td>Chain</td>
</tr>
<tr>
<td>12</td>
<td>Rear Tire/Wheel</td>
</tr>
<tr>
<td>13</td>
<td>Seat Hinge</td>
</tr>
</tbody>
</table>

### Table 10: Bill of Materials

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Source</th>
<th>Model #</th>
<th>Quantity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>2” x 2” x .120 (11-Ga) 6061 – 24” long</td>
<td>Shapiro Metal Supply</td>
<td>4</td>
<td>$40.00</td>
<td></td>
</tr>
<tr>
<td>2” x 2” x .120 (11-Ga) 6061 – 36” long</td>
<td>Shapiro Metal Supply</td>
<td>6</td>
<td>$90.00</td>
<td></td>
</tr>
<tr>
<td>6061-T6 Sheet .125&quot;x2’x4’</td>
<td>Shapiro Metal Supply</td>
<td>1</td>
<td>$53.85</td>
<td></td>
</tr>
<tr>
<td>6061-T6511 Solid Round 1&quot;x 72&quot;</td>
<td>Shapiro Metal Supply</td>
<td>1</td>
<td>$22.16</td>
<td></td>
</tr>
<tr>
<td>6061-Multi Purpose 1” x .125”</td>
<td>McMaster-Carr (MC)</td>
<td>9056K36</td>
<td>1</td>
<td>$13.61</td>
</tr>
<tr>
<td>6061-Multi Purpose .75&quot; x .125”</td>
<td>McMaster-Carr (MC)</td>
<td>9056K33</td>
<td>1</td>
<td>$10.45</td>
</tr>
<tr>
<td>Hand Brake/Throttle</td>
<td>ScooterParts4Less.com</td>
<td>N/A</td>
<td>1</td>
<td>$21.00</td>
</tr>
<tr>
<td>Cables</td>
<td>ScooterParts4Less.com</td>
<td>N/A</td>
<td>1</td>
<td>$24.00</td>
</tr>
<tr>
<td>Item</td>
<td>Supplier</td>
<td>Part</td>
<td>Qty</td>
<td>Price</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>Bushing</td>
<td>MC</td>
<td>7815K68</td>
<td>2</td>
<td>$12.36</td>
</tr>
<tr>
<td>Hitch Pin</td>
<td>Home Depot (HD)</td>
<td>7010500</td>
<td>2</td>
<td>$9.96</td>
</tr>
<tr>
<td>Tire/Wheels</td>
<td>ScooterCatalog.com</td>
<td>SC-153-6</td>
<td>2</td>
<td>$89.90</td>
</tr>
<tr>
<td>Front Axle Nut</td>
<td>MC</td>
<td>90371A065</td>
<td>2</td>
<td>$7.20</td>
</tr>
<tr>
<td>2” Bulk Foam</td>
<td>HD</td>
<td>10030BULK2</td>
<td>1</td>
<td>$5.97</td>
</tr>
<tr>
<td>Vinyl Fabric</td>
<td>JoAnn Fabric</td>
<td>9131368</td>
<td>2/3 yard</td>
<td>$8.02</td>
</tr>
<tr>
<td>Motor</td>
<td>Ben Lake</td>
<td>N/A</td>
<td>1</td>
<td>$0.00</td>
</tr>
<tr>
<td>Clutch</td>
<td>Ben Lake</td>
<td>N/A</td>
<td>1</td>
<td>$0.00</td>
</tr>
<tr>
<td>Brake</td>
<td>OMB Warehouse</td>
<td>AZ2255b</td>
<td>1</td>
<td>$14.45</td>
</tr>
<tr>
<td>Sprocket</td>
<td>MC</td>
<td>6793K163</td>
<td>1</td>
<td>$57.09</td>
</tr>
<tr>
<td>Chain</td>
<td>MC</td>
<td>6261K174</td>
<td>1</td>
<td>$13.20</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$493.22</strong></td>
</tr>
</tbody>
</table>
4.3 Draft detail drawings for each manufactured part

Figure 7: Front fork assembly embodiment drawing
Figure 8: Handle and steering column embodiment drawings
Figure 9: Front Tubing and 2" Tubing Embodiment Drawings
Figure 11: Wheel Spacers and 2" Tubing Embodiment Drawing

Figure 10: Front Axle Embodiment Drawing
Figure 12: Seat embodiment drawing

Figure 13: Hitch Embodiment Drawing
4.4 Description of the design rationale for the choice/size/shape of each part

1. Base Frame. An early estimate on forces that will be applied to the base frame suggested that we use 2” by 2” aluminum square tubing with a 1/8th inch thickness. McMaster Carr has sections of this tubing of 3’ and 6’ sections (as well as smaller sections but we will cut to size). Part number 6546K23, $32.30, and $55.69 (3’ and 6’, respectively). Because many parts on the moped will be made of this material we will be buying 2 or 3, 6’ tubes and cutting them to the necessary length.

2. Handle Bar Hitch. The handle bar hitch’s function is to hold the handle bars in place once they are removed and the moped is being rolled. Because we are buying extra 2” by 2” aluminum, square tubing with 1/8th thickness from McMaster Carr, we will make the hitch out of this material as well. Part number, 6546K23, $55.69. The ID of the hitch will be slightly larger than the handle bars OD allowing the handle bars to slide into the hitch and be pinned for stability.

3. Front Fork Assembly. The front fork assembly needs to be simple enough for us to produce, light enough to allow it to be manipulated easily, and strong enough to prevent buckling. We decided to use 2” by 2” by 1/8” thick aluminum square tubing for the same rational as the frame. The handle bars and the steering column are the same material 1/8” thick to
create consistency and allow for ease of TIG welding. The steering column will go through
the hitch by way of two pressed bushings to allow for turning. The steering column will be
prevented from falling out of the hitch by way of a trailer hitch pin inserted into a 5/16”
hole in the steering column. The axle will be a 1” aluminum bar threaded at both ends and
will remain stationary, allowing the wheel to rotate around it. To prevent the wheel from
having play along the axle, tubing with a 1” ID and 1/8” thickness will be used. The grips will
be regular slip on grips 3/4” ID and the brake handle will be a cam system on a worm clamp
to attach it to the bar.

4. Seat. The seat needs to be comfortable for a full-sized man rider. We decided a 12” x 18”
foam-padded seat would work well. Since we are purchasing a piece of plywood from The
Home Depot for the platforms, we are using this for the seat base. Two-inch thick all-
purpose foam seems thick enough for the cushion. This is also from THD. We chose basic
black vinyl fabric from JoAnn Fabrics to cover the plywood and foam. We will staple the
fabric to the base.

5. Main Platform. We chose ¾” thick plywood for the main platform. We will do further
analysis of the strength of this size of wood, but we thought that this standard thickness will
suffice. We found this at the Home Depot.

6. Motor Platform. We decided to use the same plywood as the main platform to save costs.

7. Motor. We are using a motor that our group member, Ben, already owns to stay within
budget.

8. Clutch. Our group member also owns the clutch.

9. Brake. The brake and throttle system is needed to control the moped’s speed. Our user
need of having the moped controlled with hand controls dictated the design of this system.
It required squeezing handles for the handlebars, one throttle, and one brake. It also
required throttle and brake cable which was specified to reach the full length of the bike so
that it may be wired properly along the frame. For simplicity and costs sake, a band brake
was selected to wrap around the outside of the moped’s clutch. The brake and throttle will
operate smoothly with squeeze handles and cable systems to provide the user with a simple
operation of the moped.

10. Sprocket. The powertrain system is needed for the moped to move without the assistance
of human power. The powertrain was designed with cost being the most important factor,
and performance being second most important. A team member already owned an engine
and clutch as indicated above, and so those parts were immediately included in the design
to save money. The clutch and engine are compatible with one another in terms of
operating speeds of around 3000 RPM with about 500 RPM of room for error in tuning the
engine’s operation speed and the clutch’s engagement speed. To complete the system, a
rear sprocket and chain were needed. These were both selected based on the clutch’s
specifications. The rear sprocket was designed with a 6:1 gear ratio on the clutch to effectively transfer the engine’s maximum torque to the ground without making the clutch slip.

11. Chain. To connect the wheel and motor, a 40 or 41 ANSI Chain is used to fit both the sprocket and the clutch.

12. Rear wheel/tire. The wheel selection process was dictated by price as well as functionality. 12-inch wheels were selected to fit the frame and to create a larger torque ratio for the wheels. This will increase the moped’s speed while decreasing the likelihood of the wheel slipping when compared to smaller wheels. The wheels come pre-assembled and will only require an alteration of the rear sprocket to satisfy our design.

13. Seat Hinge. The seat needs to flip up to fit the front fork assembly underneath during storage. We found the cheapest, but reasonably sized hinges at The Home Depot. We chose a 2.5” long basic door hinge.

4.5 Gantt chart
5 Engineering analysis

5.1 Engineering analysis proposal

Figure 16: Engineering Analysis Proposal Form

**ANALYSIS TASKS AGREEMENT**

PROJECT: Moped 3 NAMES: Luke Duschl, Instrutor: Mallory Lakota
Ben Lake
Megan Rupp
Brandon Staff

The following engineering analysis tasks will be performed:

- Weight capacity:
  - The theoretical weight capacity will be solved using a factor of safety, while identifying all the potential weak spots/points of failure in the frame. This theoretical work will be supplemented and verified with FEA on SolidWorks.

- Top speed calculations with and without rider:
  - The theoretical top speed will be found using a conservation of energy method at the most efficient RPM of the motor (including the weight of the rider, but excluding the air drag on the moped and rider). This speed will be checked post build with trial runs.

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


Megan/Brandon: Top speed calculations

Team: Post build trials

Instructor signature: _______________ Print: instructor name: _______________

(Group members should initial near their name above.)
5.2 Engineering analysis results

5.2.1 Motivation.
The frame must be strong enough to hold the weight of the motor and driver. This is essential to safety and quality of the scooter. We would need to redesign before ordering parts and beginning fabrication.

5.2.2 Summary statement of analysis done.
We did FEA analysis on the frame on CAD software. The axles were fixed with a 300-pound distributed force on the seat, representing the driver.

We also used the conservation of energy method to find the theoretical top speed of the scooter based on the RPMs of the motor.

\[
\frac{0.00595 \omega r}{R} = \frac{0.00595 \cdot 3800 \text{ RPM} \cdot 12 \text{ in}}{6} = 45.2 \text{ MPH}
\]

where \( \omega = \text{engine speed in RPM, } r=\text{tire radius} \)

5.2.3 Methodology.
For the FEA analysis, we used CAD software to load our frame design with a 300-pound distributed force on the seat with the axles fixed.

5.2.4 Results.
The theoretical top speed we calculated is 45.2 MPH. This is obviously a very high estimate because we neglected any friction or air drag occurring on the moped. This was also using the maximum engine RPM, which will likely not always be achievable.

The result of the FEA analysis was a deflection of about a millimeter. This tiny deflection makes sense. This relies on the weld strength being sufficient because our CAD model was a single-piece frame.
5.2.5 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 FEA analysis results confirmed our design strength, but we knew we needed to have sufficiently strong welds for the analysis to be applicable. The top speed calculations were higher than the street legal specifications, but we decided the result was acceptable because of the assumptions of neglecting friction and air drag.

5.2.6 Summary of code and standards and their influence.

The only code that affected our design is the list of requirements for street legality in the state of Missouri. Our theoretical top speed was over this limit, but we decided the actual top speed would be much lower due to friction and air drag and a lower-than-maximum engine RPM.

Figure 17: FEA analysis results

Figure 18: Missouri motor scooter requirements [1]

MO Motor Scooter Requirements

- 2 or 3 wheels
- Automatic transmission
- Motor under 50cc capacity
- Under 3 gross brake HP
- Max. speed under 30 MPH
5.3 Risk Assessment

5.3.1 Risk Identification
The major risk when working on this project is the structural stability and the prevention of buckling at high speeds under different road conditions. The welds could be weak points.

5.3.2 Risk Analysis
This risk is very important because safety is our ultimate concern. We will have to perform FEA on our CAD design prior to building to re-affirm that it should work, in combination with slow speed tests of the moped.

5.3.3 Risk Prioritization
As previously mentioned, safety is our ultimate concern. We must include a factor of safety in our final design to account for unplanned incidents and prevent injuries at high speeds. We will make the best welds we can.
6 Working prototype

6.1 A preliminary demonstration of the working prototype
The moped was built frame-first. The seat was covered and attached next. We then added the power train, axles, and tire/wheel assemblies.

6.2 A final demonstration of the working prototype

Figure 20: Photo of final prototype
Figure 22: Video clip of final prototype

Figure 23: Completed frame with seat

Figure 24: Welded frame
Figure 25: Completed frame with axles and tire/wheel assemblies

Figure 26: Motor and power train
7 Design documentation

7.1 Final Drawings and Documentation

7.1.1 A set of engineering drawings (See Appendix C for CAD model files)
All units are inches.
Figure 28: Vertical handlebar bar rod drawing

Figure 29: Handlebar assembly drawing
Figure 30: Neck tube drawing

Figure 31: Horizontal handlebar rod drawing
Figure 33: Pin block drawing

Figure 32: Front axle drawing
Figure 35: Handlebar spacer drawing

Figure 34: Rear assembly drawing
Figure 37: Seat plate drawing

Figure 36: Engine plate drawing
Figure 39: Back platform drawing

Figure 38: Rear frame drawing
Figure 41: Back wheel spacer drawing

Figure 40: Back axle drawing
Figure 43: 18" tube drawing

Figure 42: 14" tube drawing
Figure 45: 13” tube drawing

Figure 44: 12” tube drawing
Figure 47: 10" tube drawing

Figure 46: 10" tube with hole drawing
7.1.2 Sourcing instructions
All parts are easily sourced using part numbers on the bill of materials or from a stock metal supplier. The motor could be found online.

7.2 Final Presentation

7.2.1 A live presentation in front of the entire class and the instructors
This occurred on Friday December 14, 2015.

7.2.2 A link to a video clip version of 1
https://youtu.be/CLNItJy2pyM

7.3 Teardown
Teardown was discussed with the instructors.
Figure 50: Tear down form front

Figure 49: Tear down form back
8 Discussion

8.1 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 11: Scoring for final prototype

We scored the final prototype as if it had a legal, 50cc motor. The result is 0.675 for the quantified needs equation. This is lower than the concept chosen mostly due to weight and the lessened storage space because we moved the motor to under the seat. The happiness equation value could go up by mounting a basket on the back platform.

8.2 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 needed to scrounge the motor because a new motor would be significantly over budget. The issue with this is that the only motor available to us was four times the size of the legal limit in Missouri. It was also much heavier, causing the moped to be much less portable.

We used part of the MEMS 405 project in building the chain tensioner. We suggest a sprocket for future prototypes.

Purchased parts were all stock items and came in a few days after ordering. This would be easily repeated in the future.

8.3 Discuss the overall experience:

8.3.1 Was the project more or less difficult than you had expected?

The time in the shop was a little more extensive than we expected mostly to get the motor cleaned up and running. The welding took time to figure out, but Ben caught on pretty easily.
8.3.2 Does your final project result align with the project description?
Other than the larger, scrounged motor being over the legal limit, the project definitely aligns with the project description.

8.3.3 Did your team function well as a group?
We were all willing to help and willing to put in time for whatever the group needed. The team functioned well.

8.3.4 Were your team member’s skills complementary?
Ben and Luke had more skills in the shop than Brandon and Megan. We balanced this by having Brandon and Megan contribute their organizational skills to do the documentation and assignments while keeping in constant communication as a group.

8.3.5 Did your team share the workload equally?
Ben and Luke put in more time in the shop to get the motor running and all the welding and power train work done.

8.3.6 Was any needed skill missing from the group?
It would have been less work for Ben and Luke if someone had already been able to weld. Ben taught himself during the semester.

8.3.7 Did you have to consult with your customer during the process, or did you work to the original design brief?
We used the original design brief.

8.3.8 Did the design brief (as provided by the customer) seem to change during the process?
The design brief stayed the same during the process.

8.3.9 Has the project enhanced your design skills?
The project enhanced our design skills because we needed to change the design as the prototype was being built. We ran into challenges and had to make decisions as the semester progressed.

8.3.10 Would you now feel more comfortable accepting a design project assignment at a job?
The more experience we have, the more comfortable we feel with these kinds of projects.

8.3.11 Are there projects that you would attempt now that you would not attempt before?
We could tackle another vehicle-building projects now that we’ve done this one.
9 Appendix A - Parts List
The parts list is included in Section 4.2 in Table 9.

10 Appendix B - Bill of Materials
The bill of materials is included in Section 4.2 in Table 10.

11 Appendix C - CAD Models
All CAD models are in the group’s file exchange on Blackboard. The file is called “CAD Models” and will download as a zipped folder.

12 Annotated Bibliography (limited to 150 words per entry)

1. DMV.org “Scooters, Mopeds Etc. in Missouri” [http://www.dmv.org/mo-missouri/other-types.php](http://www.dmv.org/mo-missouri/other-types.php)
   We used this source for the list of requirements to make a motor scooter street legal in Missouri.

2. Shelquist Engineering “Speed versus RPM Calculator” [https://wahiduddin.net/calc/calc_speed_rpm.htm](https://wahiduddin.net/calc/calc_speed_rpm.htm)
   We used this source to get an equation for the theoretical top speed equation and verify our calculation.