Fall 2015

MEMS 411 Senior Design 2015 Moped 3 Final Report

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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.

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Moped 3

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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.

3 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

Customer Data: Portable Rolling Moped
Customer: Prof. Jakiela – Guy that might by the scooter

Address: Washington University Date: 14 September 2015

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

How heavy does it need to be?	I want it to be less than 50 lbs.	Needs to be under 50 lbs.	5
What is your average commute time?	20 minutes to work.	Needs to run for at least 40 minutes.	5
Do you want to sit down or stand up while driving?	I want it to be recumbent.	Needs to allow driver to sit recumbently.	5
How fast do you want it to go?	Speed is not important to me.	Needs to go 15-20 mph.	2
How do you want to transport the collapsed moped?	I want to roll it like a suitcase.	Needs to roll when collapsed.	5
Do you prefer hand controls or foot controls?	I want hand controls.	Needs to be controlled by hand.	5
How do you want to start the moped?	Kick start	Needs to kick start.	3

3.1.2 List of identified metrics

Table 2: List of identified metrics

Need Number	Need	Importance
1	M can carry one person	5
2	M is waterproof	4
3	Seat of M is recumbent and comfortable	5
4	M is street legal as a moped in MO.	5
5	M holds two paper shopping bags without falling out under power.	3
6	M holds 30 lbs. of cargo	2
7	M holds a 250 lb. driver	5
8	M has a human-power option	4
9	M has 2’ x 2.5’ footprint	5
10	M takes 90 seconds and fewer than 5 steps to set up and collapse.	4
11	M is less than 50 lbs.	5
12	M runs for 40 minutes	5

13	M runs at 15 mph.	2
14	M rolls while collapsed	5
15	M is controlled by hand	5
16	M is kick-started	3

3.1.3 Table/list of quantified needs equations

Table 3: List of quantified needs equations

Metric Number	Associated Needs	Metric	Units	Min Value	Max Value
1	1	Holds 1 Rider	Binary	0	1
2	2	Waterproof	Binary	0	1
3	3	Recumbent Seat	Binary	0	1
4	4	Motor Size	Cm^3	0	50
5	4	Number of Wheels	Integer	2	3
6	4	Gross BHP	HP	0	3
7	4,13	Speed	MPH	15	30
8	5	Holds 2 Shopping Bags	Binary	0	1
9	6	Weight of cargo	Lbs	0	50
10	7	Weight of rider	Lbs	0	250
11	8	Human Powered option	Binary	0	1
12	9	Collapsed footprint area	Ft^2	0	5
13	10	Time to set up	Sec.	0	90
14	10	Steps to set up	Integer	0	5
15	11	Weight of M	Lbs	0	50
16	12	Operation Time	Min	0	40
17	14	Rolls as Collapsed	Binary	0	1
18	15	Hand Controlled	Binary	0	1

Table 4: Happiness equation template

		Metric																				
Moped Example		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Area	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		0	0.078125	0
2	Waterproof		1																	0	0.0625	0
3	Seat recumbant and comfortable			1																0	0.078125	0
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												5.55E-17	0.078125	4.34E-18
5	Hold two paper shopping bags without falling under power								1											0	0.046875	0
6	Holds 30 lbs of cargo									1										0	0.03125	0
7	Hold 250 lbs driver										1									0	0.078125	0
8	Human power option											1								0	0.0625	0
9	Has 2' x 2.5' footprint												1							1	0.078125	0.078125
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					1	0.0625	0.0625
11	Vehicle less than 50 lbs.															1				1	0.078125	0.078125
12	Can run for 40 min.																1			0	0.078125	0
13	Runs at 15 mph							1												-1	0.03125	-0.03125
14	Rolls while collapsed																	1		0	0.078125	0
15	Controlled by hand																		1	0	0.078125	0
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.1875
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value																						
Normalized Metric Happiness		0	0	0	0	3	0	-1	0	0	0	0	1	1	1	1	0	0	0			

3.2 Four (4) concept drawings

Figure 2: Concept 1 - Motor in front

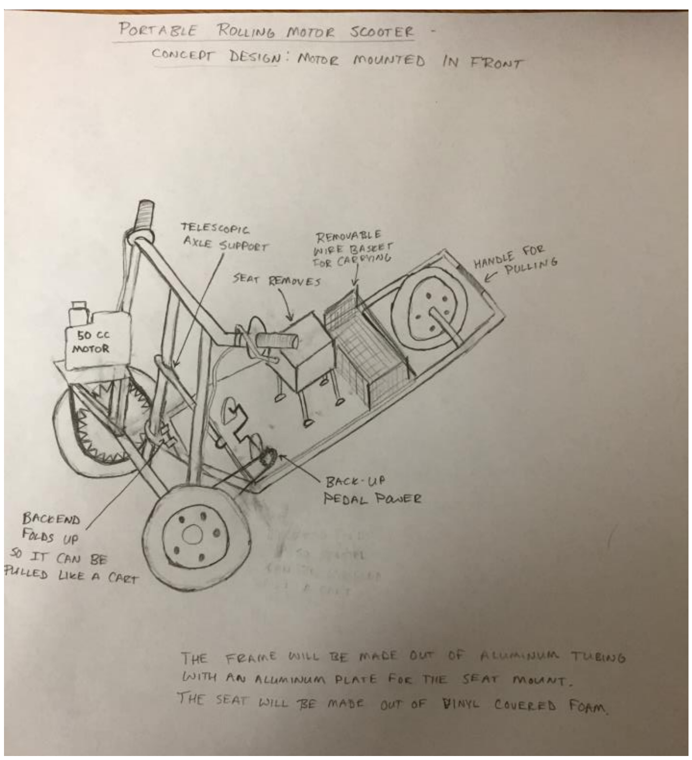


Figure 3: Concept 3 - Tricycle-based

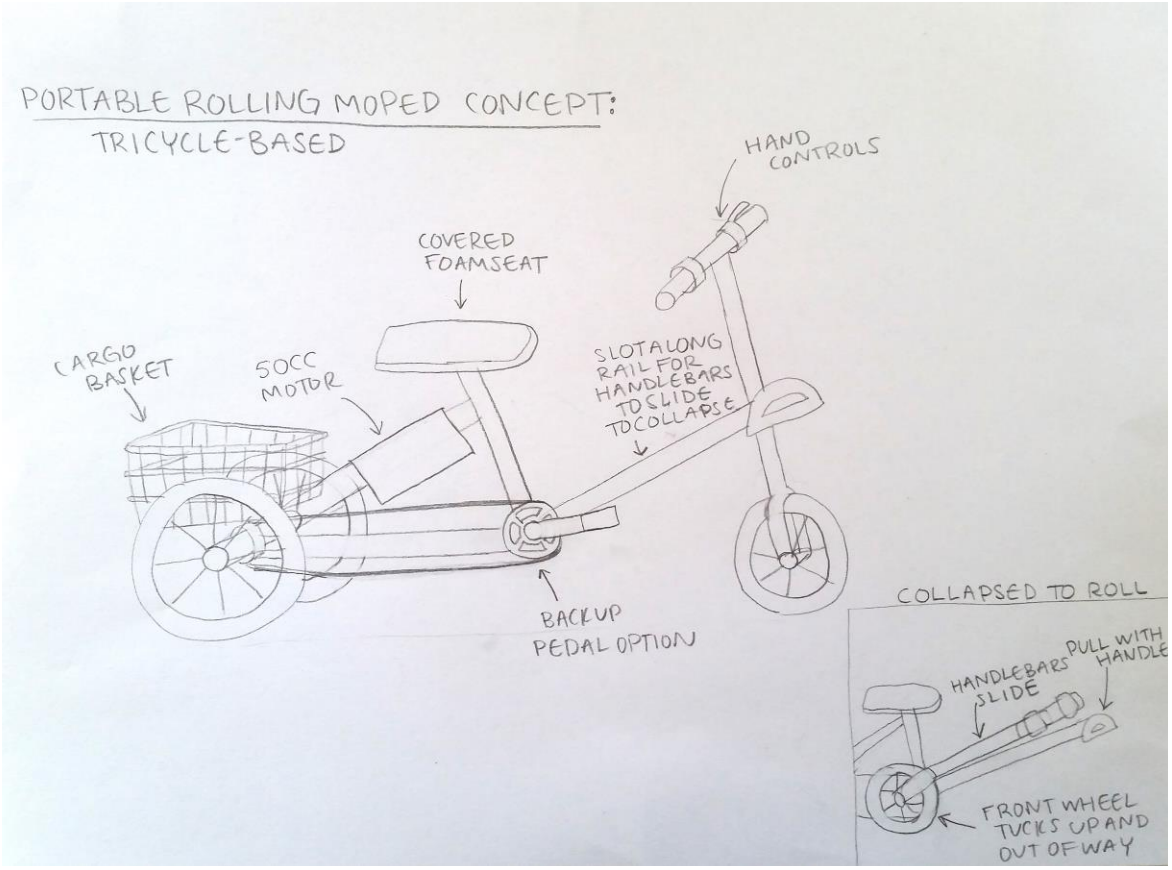


Figure 4: Concept 3 - Dual-hinged

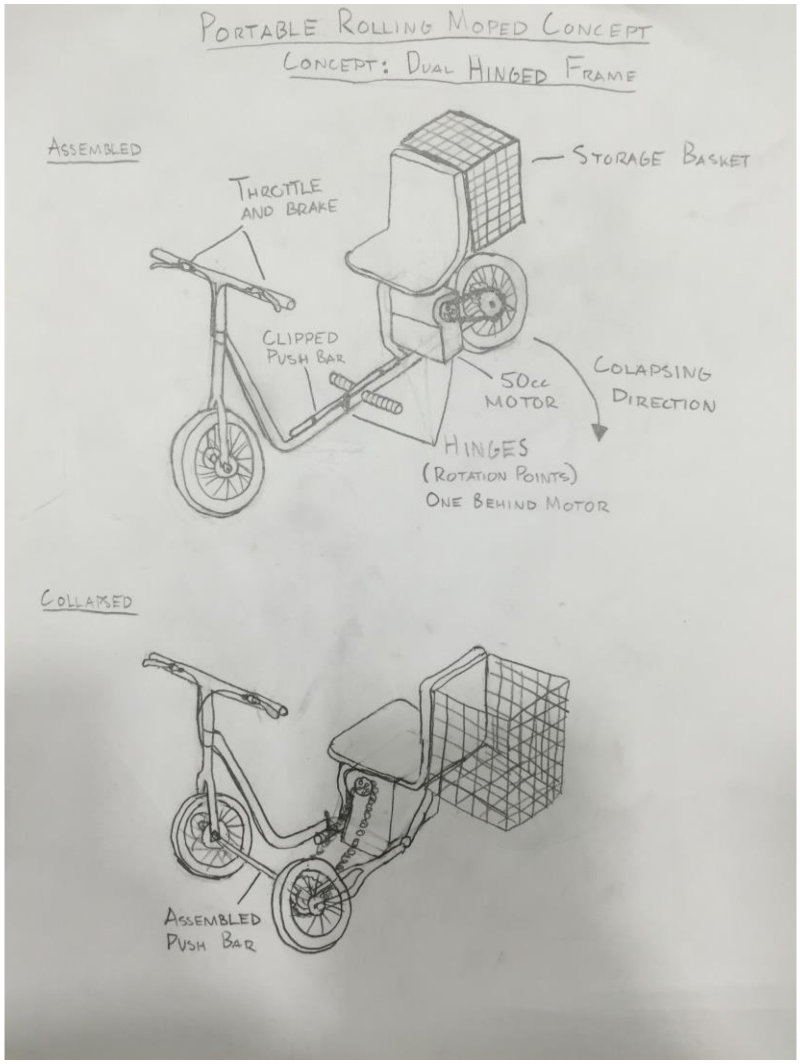
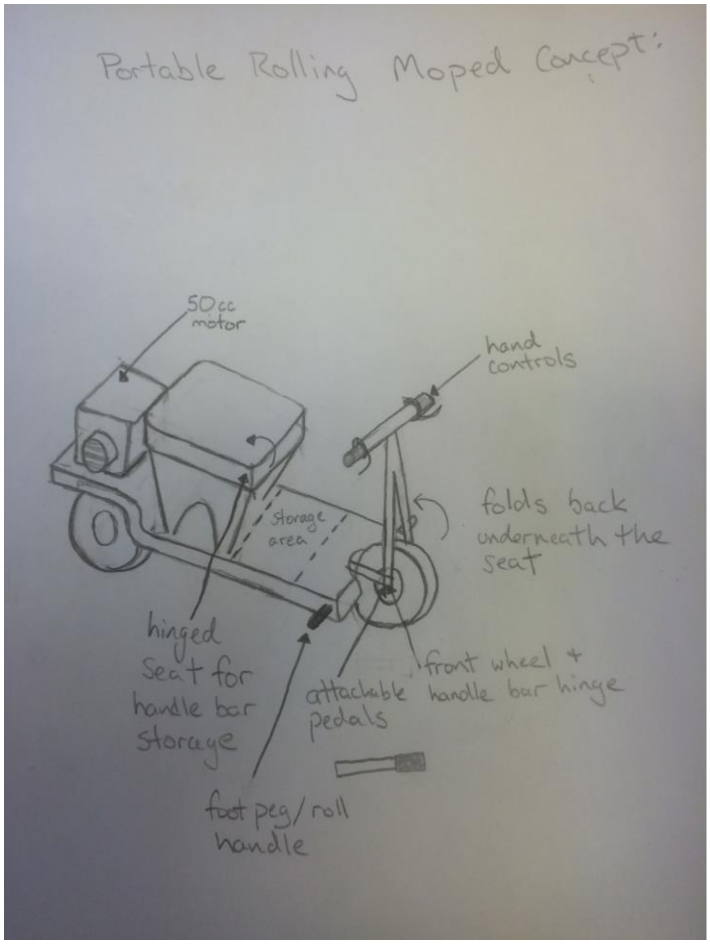


Figure 5: Concept 4 - Holding handlebars



3.3 A concept selection process

3.3.1 Concept scoring

Table 5: Concept 1 scoring

Portable Rolling Moped - Motor in Front		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Are:	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		1	0.078125	0.078125
2	Waterproof		1																	1	0.0625	0.0625
3	Seat recumbant and comfortable			1																1	0.078125	0.078125
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												0.8	0.078125	0.0625
5	Hold two paper shopping bags without falling under power								1											1	0.046875	0.046875
6	Holds 30 lbs of cargo									1										1	0.03125	0.03125
7	Hold 250 lbs driver										1									1	0.078125	0.078125
8	Human power option											1								1	0.0625	0.0625
9	Has 2' x 2.5' footprint												1							0	0.078125	0
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					0.724444	0.0625	0.045278
11	Vehicle less than 50 lbs.															1				0	0.078125	0
12	Can run for 40 min.																1			1	0.078125	0.078125
13	Runs at 15 mph							1												0.666667	0.03125	0.020833
14	Rolls while collapsed																	1		1	0.078125	0.078125
15	Controlled by hand																		1	1	0.078125	0.078125
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.800486
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value		1	1	1	50	3	3	25	2	50	250	1	5	20	2	50	40	1	1			
Normalized Metric Happiness		1	1	1	1	0	1	0.666667	1	1	1	1	0	0.777778	0.6	0	1	1	1			

Table 8: Concept 2 scoring

Moped Example		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Area	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		1	0.078125	0.078125
2	Waterproof		1																	1	0.0625	0.0625
3	Seat recumbant and comfortable			1																0	0.078125	0
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												0.7	0.078125	0.0546875
5	Hold two paper shopping bags without falling under power								1											1	0.046875	0.046875
6	Holds 30 lbs of cargo									1										0.6	0.03125	0.01875
7	Hold 250 lbs driver										1									1	0.078125	0.078125
8	Human power option											1								1	0.0625	0.0625
9	Has 2' x 2.5' footprint												1							0	0.078125	0
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					0.4133333	0.0625	0.0258333
11	Vehicle less than 50 lbs.															1				0.4	0.078125	0.03125
12	Can run for 40 min.																1			1	0.078125	0.078125
13	Runs at 15 mph							1												0.3333333	0.03125	0.0104167
14	Rolls while collapsed																	1		1	0.078125	0.078125
15	Controlled by hand																		1	1	0.078125	0.078125
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.7034375
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value		1	1	0	50	3	3	20	2	30	250	1	5	60	2	30	40	1	1			
Normalized Metric Happiness		1	1	0	1	0	1	0.3333333	1	0.6	1	1	0	0.3333333	0.6	0.4	1	1	1			

Table 7: Concept 3 scoring

Moped Example		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Area	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		1	0.078125	0.078125
2	Waterproof		1																	1	0.0625	0.0625
3	Seat recumbant and comfortable			1																1	0.078125	0.078125
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												1	0.078125	0.078125
5	Hold two paper shopping bags without falling under power								1											1	0.046875	0.046875
6	Holds 30 lbs of cargo									1										1	0.03125	0.03125
7	Hold 250 lbs driver										1									1	0.078125	0.078125
8	Human power option											1								0	0.0625	0
9	Has 2' x 2.5' footprint												1							0.2	0.078125	0.015625
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					0.2333333	0.0625	0.0145833
11	Vehicle less than 50 lbs.															1				0	0.078125	0
12	Can run for 40 min.																1			1	0.078125	0.078125
13	Runs at 15 mph							1												1	0.03125	0.03125
14	Rolls while collapsed																	1		1	0.078125	0.078125
15	Controlled by hand																		1	1	0.078125	0.078125
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.7489583
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value		1	1	1	50	2	3	30	2	50	250	0	4	60	5	50	40	1	1			
Normalized Metric Happiness		1	1	1	1	1	1	1	1	1	1	0	0.2	0.3333333	0	0	1	1	1			

Table 6: Concept 4 scoring

Moped Example		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Area	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		1	0.07813	0.07813
2	Waterproof		1																	1	0.0625	0.0625
3	Seat recumbant and comfortable			1																1	0.07813	0.07813
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												0.8	0.07813	0.0625
5	Hold two paper shopping bags without falling under power								1											1	0.04688	0.04688
6	Holds 30 lbs of cargo									1										0.8	0.03125	0.025
7	Hold 250 lbs driver										1									1	0.07813	0.07813
8	Human power option											1								1	0.0625	0.0625
9	Has 2' x 2.5' footprint												1							0.2	0.07813	0.01563
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					0.29333	0.0625	0.01833
11	Vehicle less than 50 lbs.															1				0	0.07813	0
12	Can run for 40 min.																1			1	0.07813	0.07813
13	Runs at 15 mph							1												0.33333	0.03125	0.01042
14	Rolls while collapsed																	1		1	0.07813	0.07813
15	Controlled by hand																		1	1	0.07813	0.07813
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.7725
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value		1	1	1	50	2	3	20	2	40	250	1	4	60	4	50	40	1	1			
Normalized Metric Happiness		1	1	1	1	1	1	0.33333	1	0.8	1	1	0.2	0.33333	0.2	0	1	1	1			

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 difficultly 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.

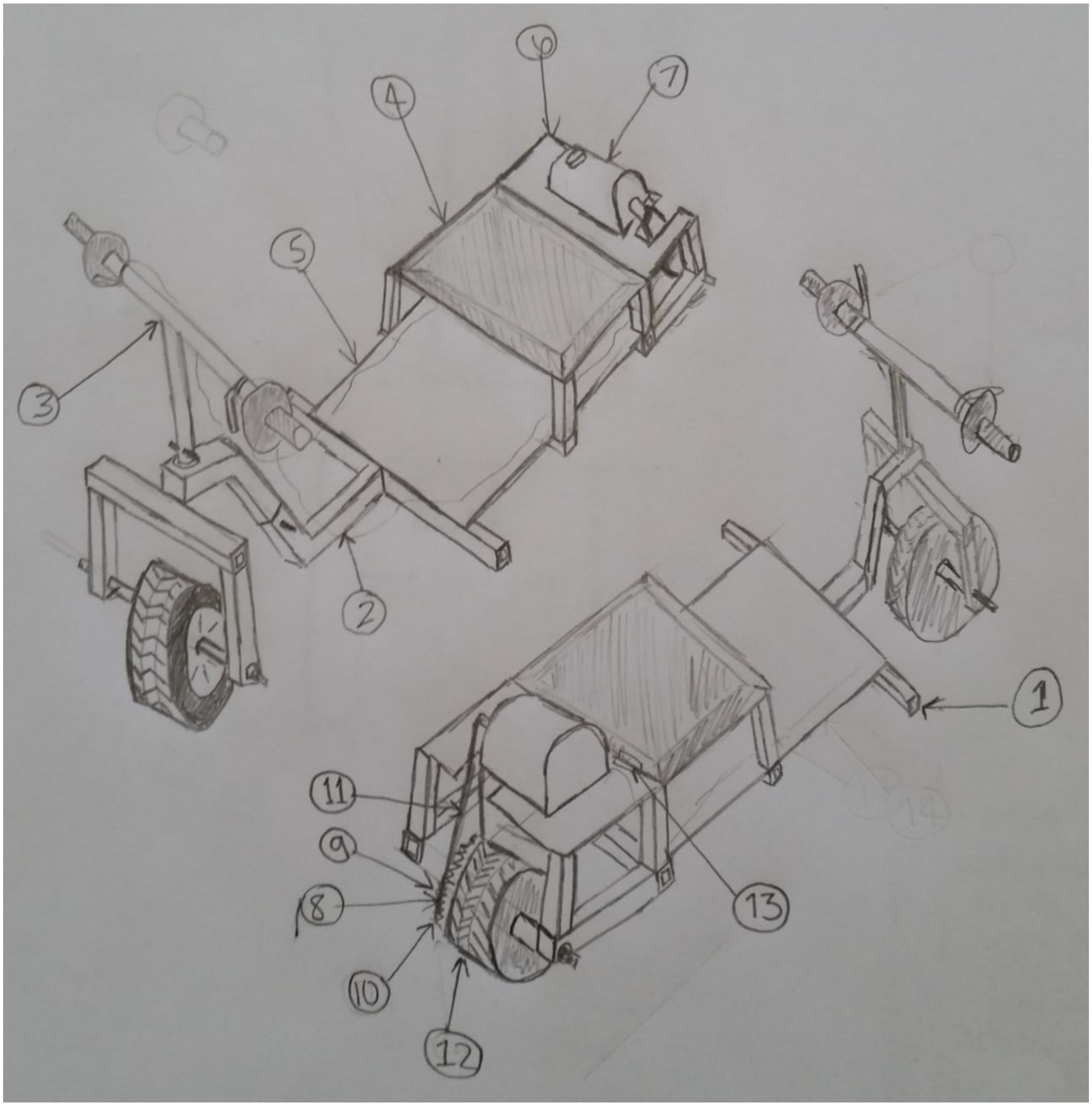
3.5.10 Legal

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

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

Table 10: Bill of Materials

Part Description	Source	Model #	Quantity	Price
2" x 2" x .120 (11-Ga) 6061 – 24” long	Shapiro Metal Supply		4	$40.00
2" x 2" x .120 (11-Ga) 6061 – 36” long	Shapiro Metal Supply		6	$90.00
6061-T6 Sheet .125"x2'x4'	Shapiro Metal Supply		1	$53.85
6061-T6511 Solid Round 1"x 72"	Shapiro Metal Supply		1	$22.16
6061-Multi Purpose 1" x .125"	McMaster-Carr (MC)	9056K36	1	$13.61
6061-Multi Purpose .75" x .125"	MC	9056K33	1	$10.45
Hand Brake/Throttle	ScooterParts4Less.com	N/A	1	$21.00
Cables	ScooterPaet4Less.com	N/A	1	$24.00

Bushing	MC	7815K68	2	$12.36
Hitch Pin	Home Depot (HD)	7010500	2	$9.96
Tire/Wheels	ScooterCatalog.com	SC-153-6	2	$89.90
Front Axle Nut	MC	90371A065	2	$7.20
2” Bulk Foam	HD	10030BULK2	1	$5.97
Vinyl Fabric	JoAnn Fabric	9131368	2/3 yard	$8.02
Motor	Ben Lake	N/A	1	$0.00
Clutch	Ben Lake	N/A	1	$0.00
Brake	OMB Warehouse	AZ2255b	1	$14.45
Sprocket	MC	6793K163	1	$57.09
Chain	MC	6261K174	1	$13.20
			Total:	$493.22

4.3 Draft detail drawings for each manufactured part

Figure 7: Front fork assembly embodiment drawing

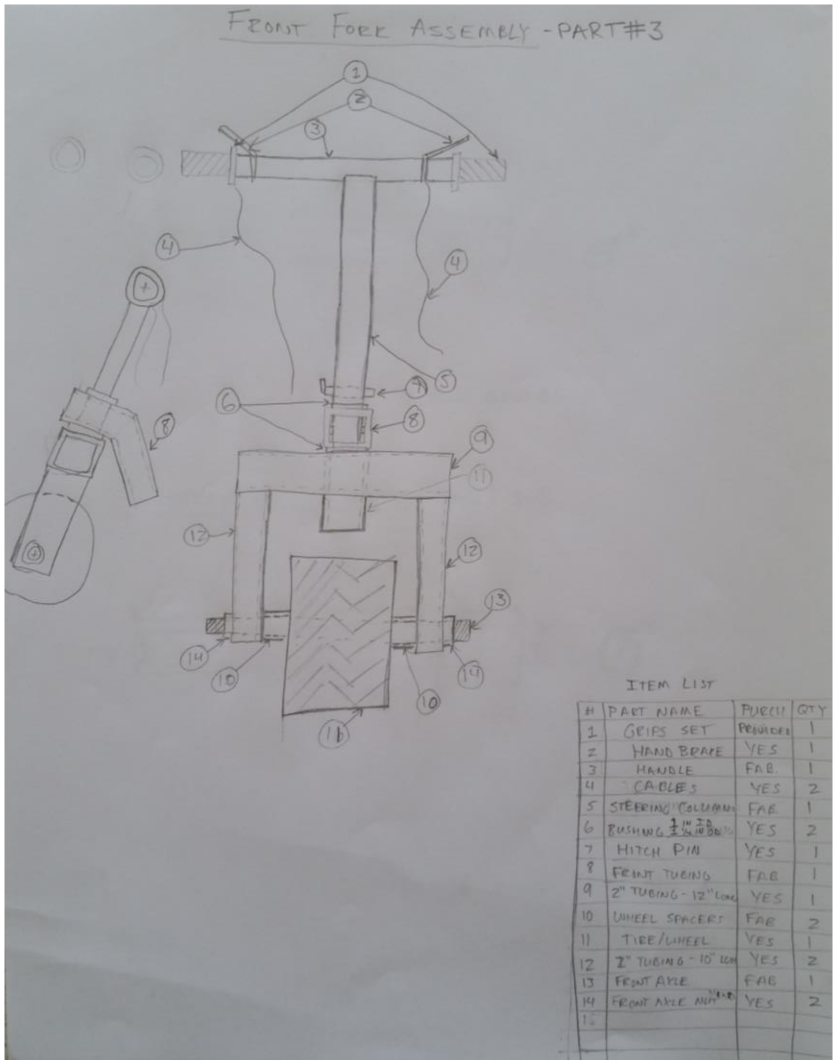


Figure 8: Handle and steering column embodiment drawings

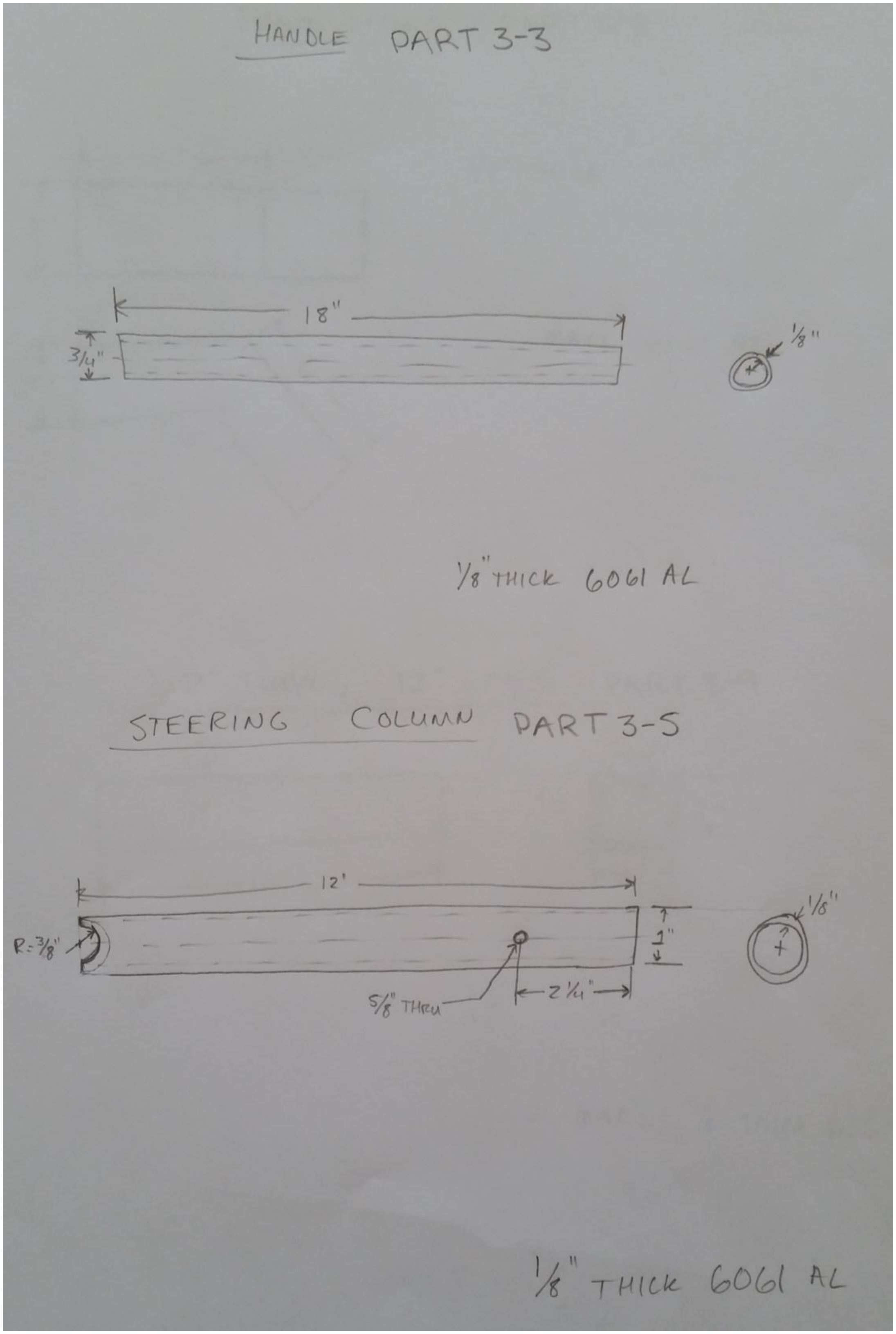


Figure 9: Front Tubing and 2" Tubing Embodiment Drawings

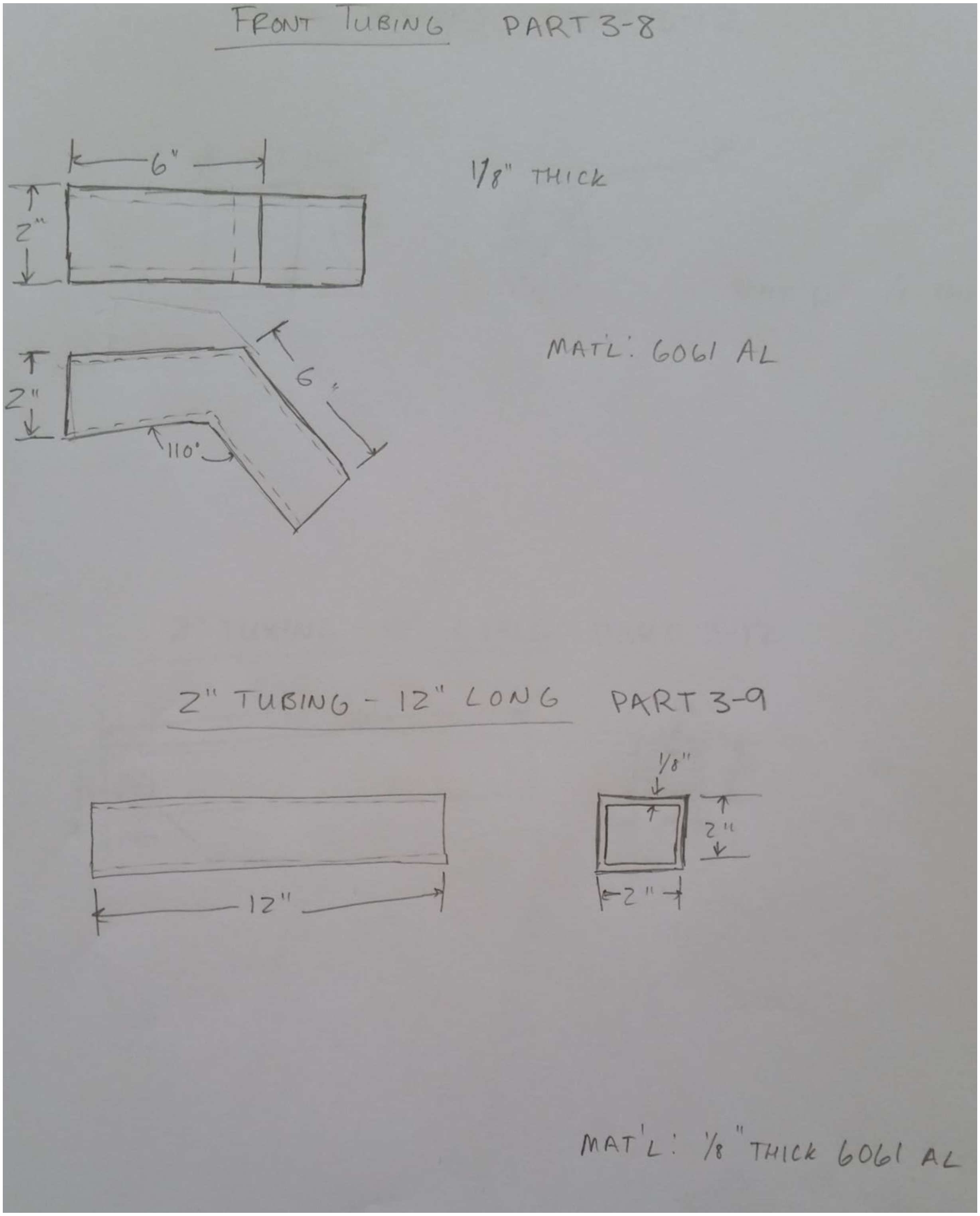


Figure 11: Wheel Spacers and 2" Tubing Embodiment Drawing

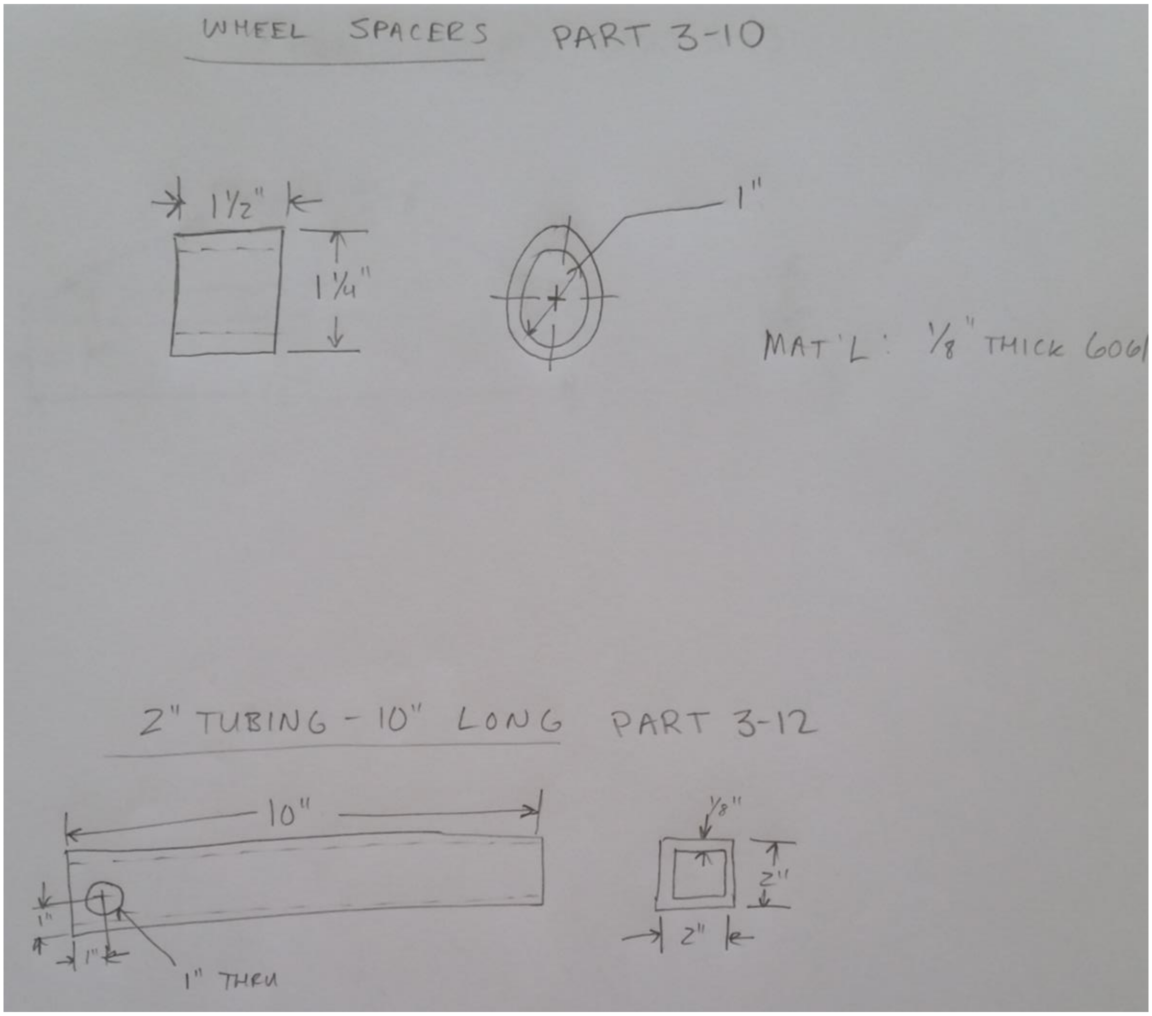


Figure 10: Front Axle Embodiment Drawing

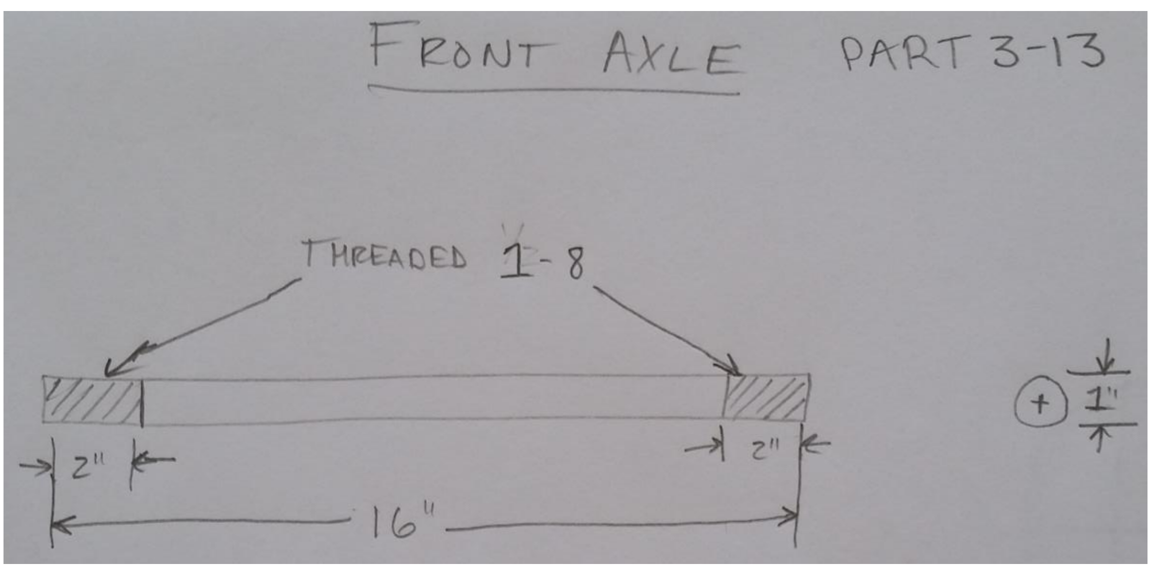


Figure 12: Seat embodiment drawing

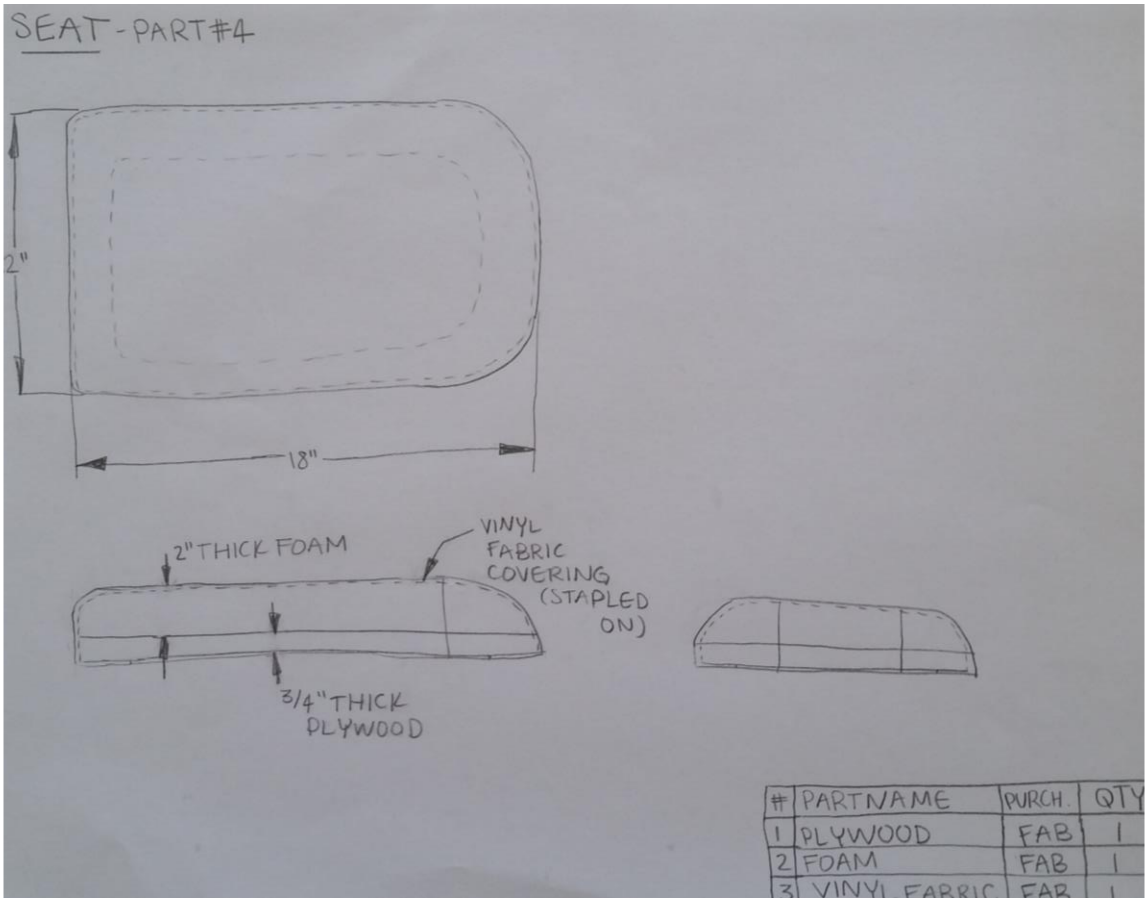


Figure 13: Hitch Embodiment Drawing

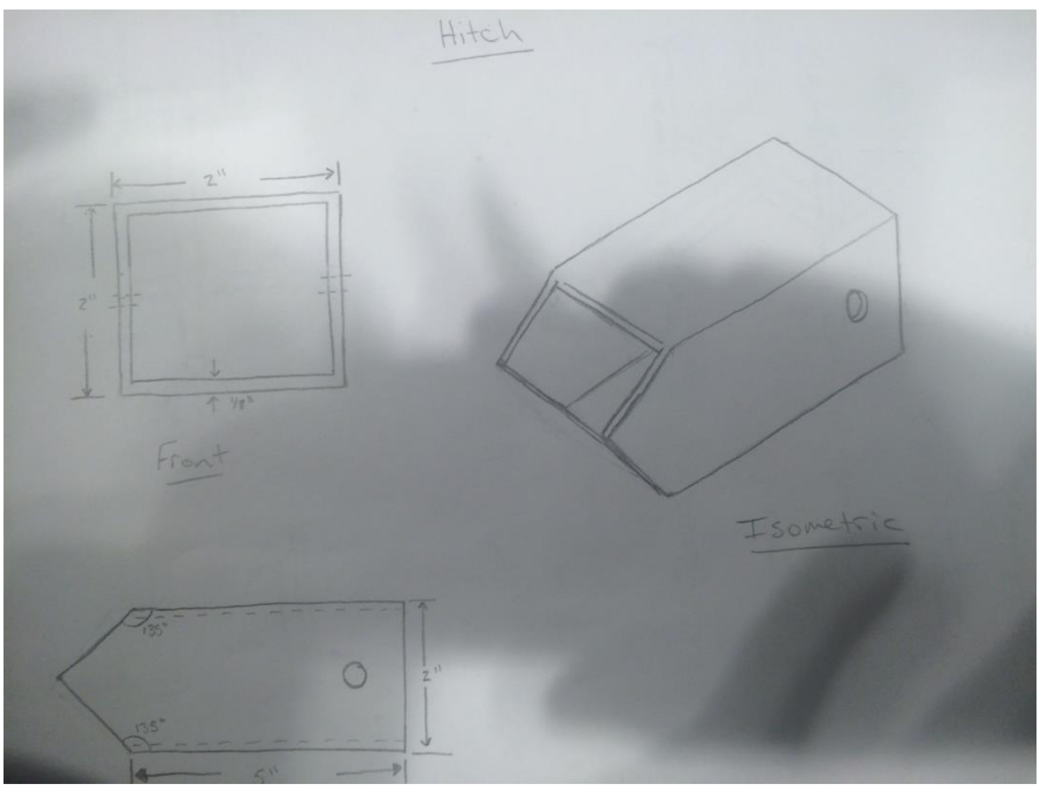
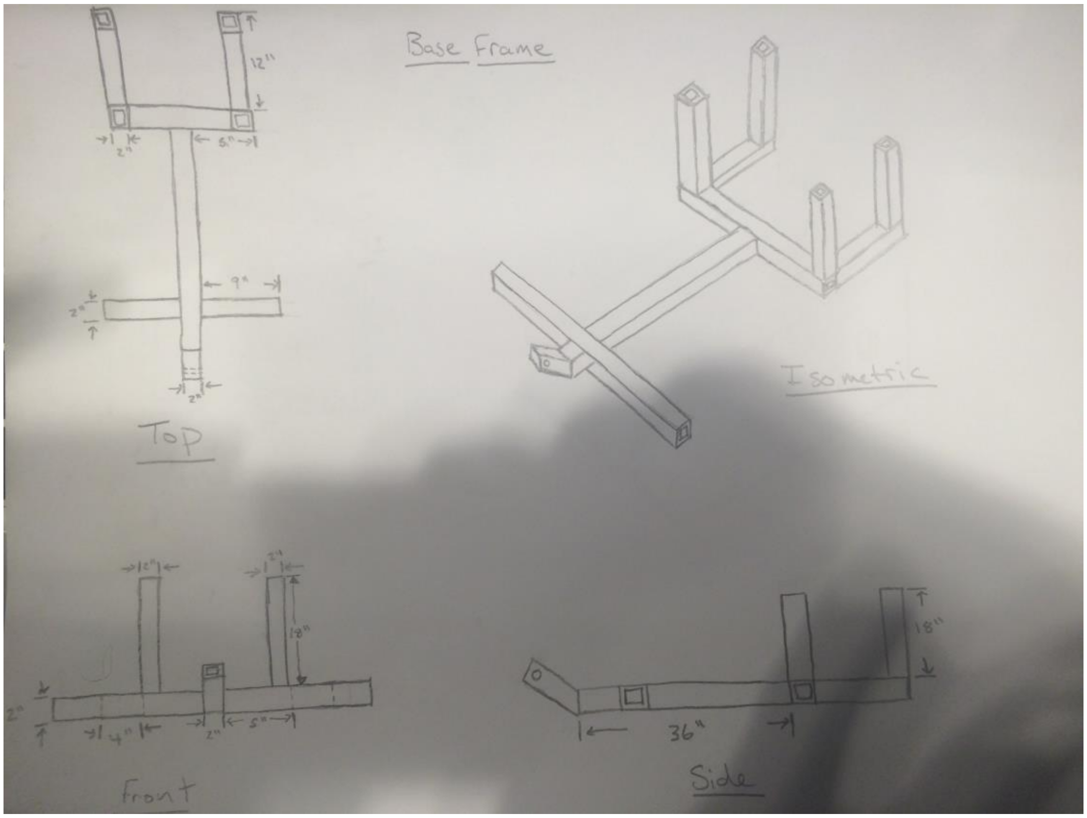


Figure 14: Base Frame Embodiment Drawing



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.

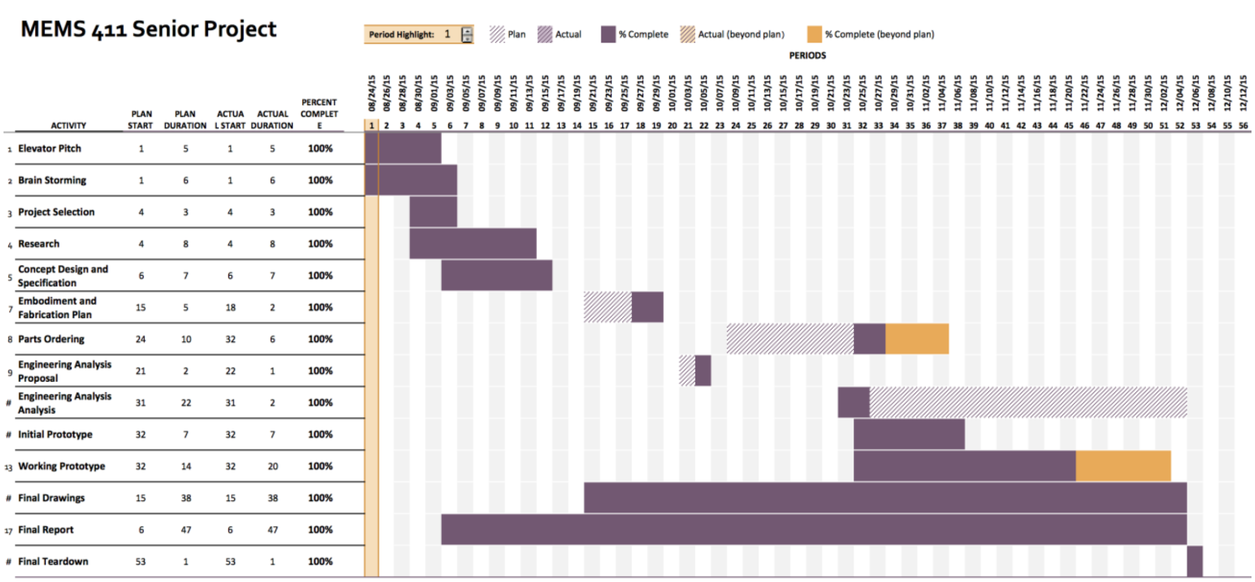
4. Seat. The seat needs to be comfortable for a full-sized man rider. We decided a 12"x 18" foam-padded seat would work well. Since we are purchasing a piece of plywood from The Home Depot for the platforms, we are using this for the seat base. Two-inch thick all-purpose foam seems thick enough for the 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 design with a 6:1 gear ratio on the clutch to effectively transfer the engines 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 mopeds 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

Figure 15: Gantt chart



	ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
1	Elevator Pitch	1	5	1	5	100%
2	Brain Storming	1	6	1	6	100%
3	Project Selection	4	3	4	3	100%
4	Research	4	8	4	8	100%
5	Concept Design and Specification	6	7	6	7	100%
7	Embodiment and Fabrication Plan	15	5	18	2	100%
8	Parts Ordering	24	10	32	6	100%
9	Engineering Analysis Proposal	21	2	22	1	100%
#	Engineering Analysis Analysis	31	22	31	2	100%
#	Initial Prototype	32	7	32	7	100%
13	Working Prototype	32	14	32	20	100%
#	Final Drawings	15	38	15	38	100%
17	Final Report	6	47	6	47	100%
#	Final Teardown	53	1	53	1	100%

5 Engineering analysis

5.1 Engineering analysis proposal

Figure 16: Engineering Analysis Proposal Form

ANALYSIS TASKS AGREEMENT

PROJECT: _Moped 3_NAMES: _Luke Duschl__INSTRUCTOR: __Malast/Jakiela___

__Ben Lake___

Megan Rupp

Brandon Staffeil

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:

Ben/Luke: SolidWorks analysis regarding weight capacity.

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

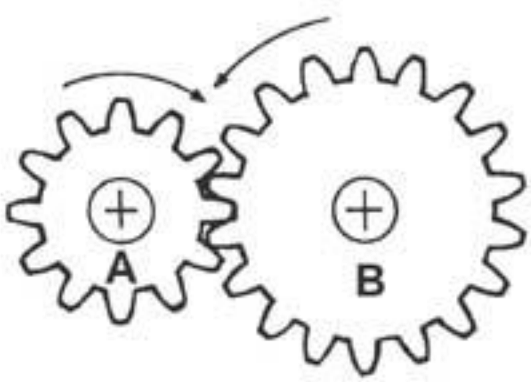
5.2.1 Motivation.

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.



Gear A on engine has 10 teeth

Gear B on rear wheel has 60 teeth

60/10=6:1 Ratio => R=6

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

[2]

where ω = engine speed in RPM, r=tire radius

5.2.3 Methodology.

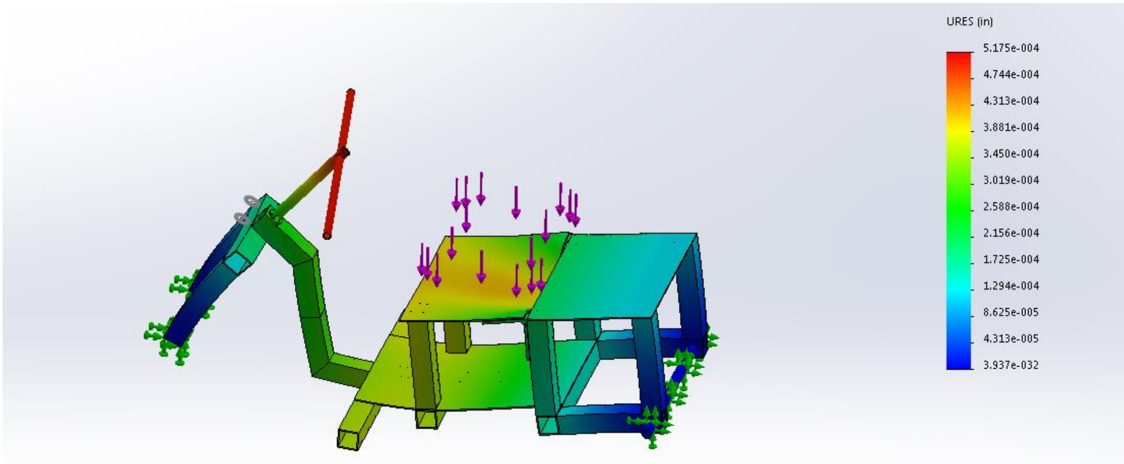
For the FEA analysis, we used CAD software to load our frame design with a 300-pound distributed force on the seat with the axles fixed.

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.

Figure 17: FEA analysis 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.

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 18: Missouri motor scooter requirements [1]

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.

Figure 15: Cut pieces of tubing for the frame

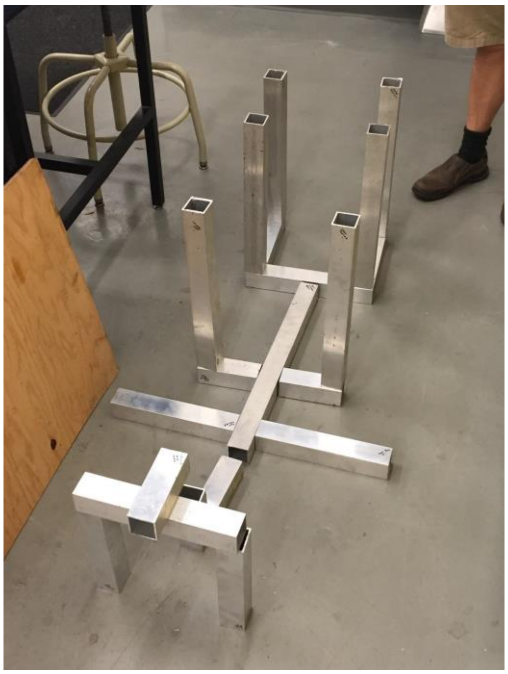


Figure 19: Luke on the completed frame

6.2 A final demonstration of the working prototype

Figure 20: Photo of final prototype

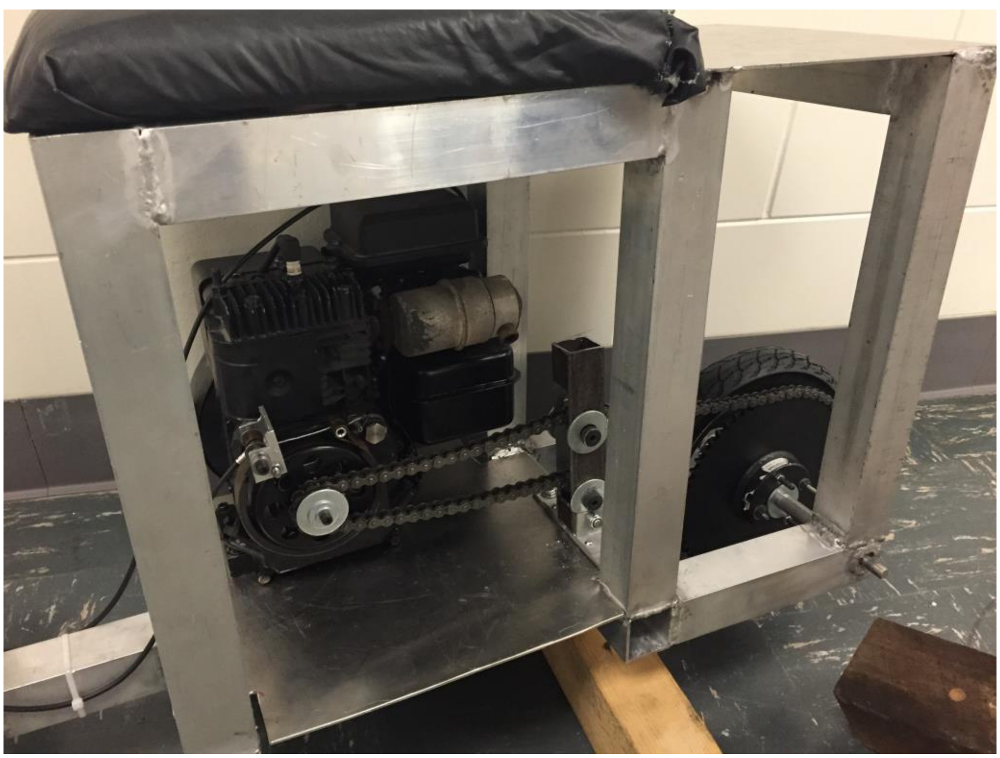
Figure 22: Video clip of final prototype

Figure 24: Welded frame

Figure 23: Completed frame with seat

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 27: Full assembly drawing

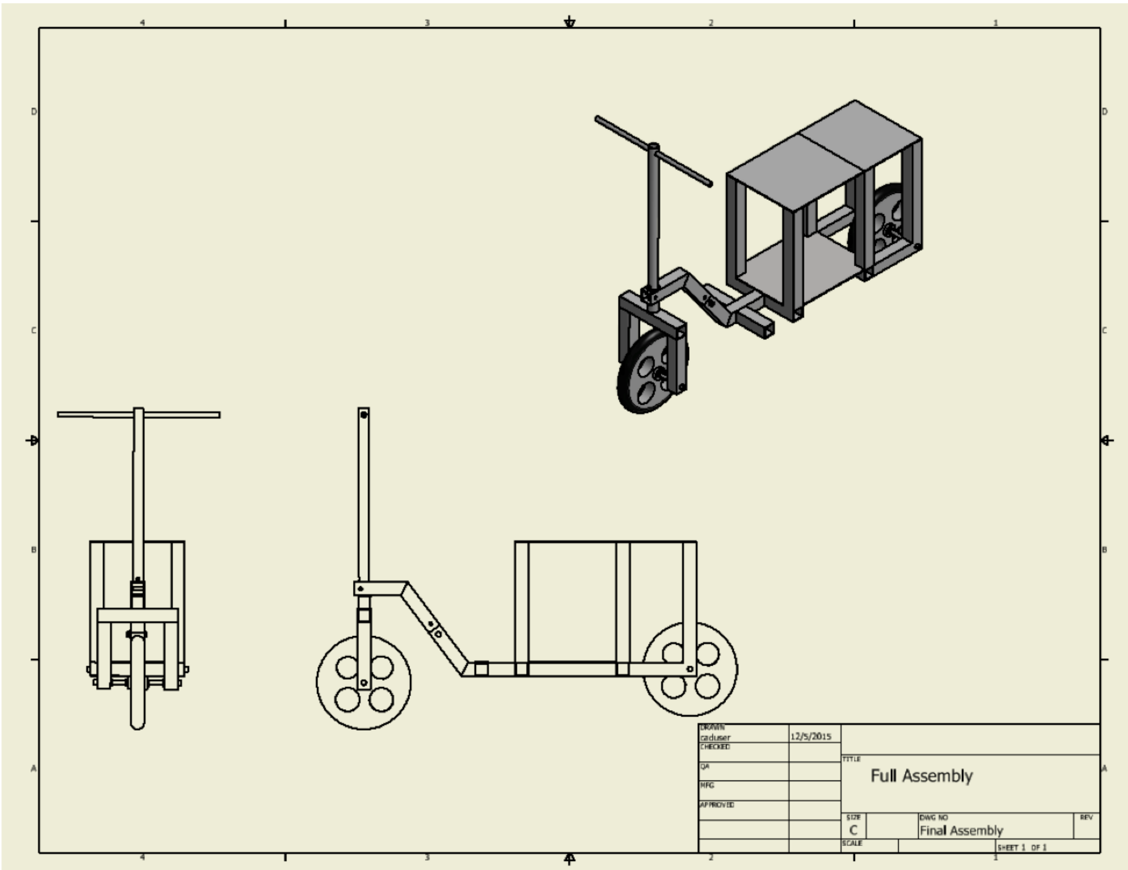


Figure 29: Handlebar assembly drawing

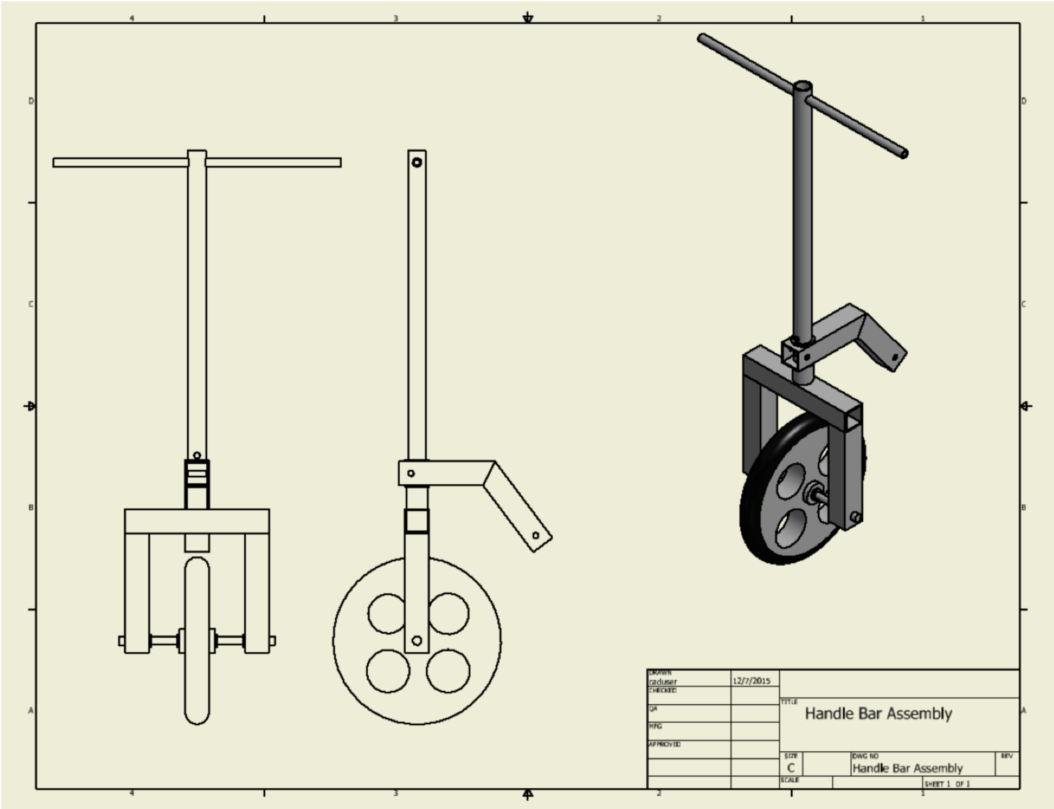


Figure 28:Vertical handlebar bar rod drawing

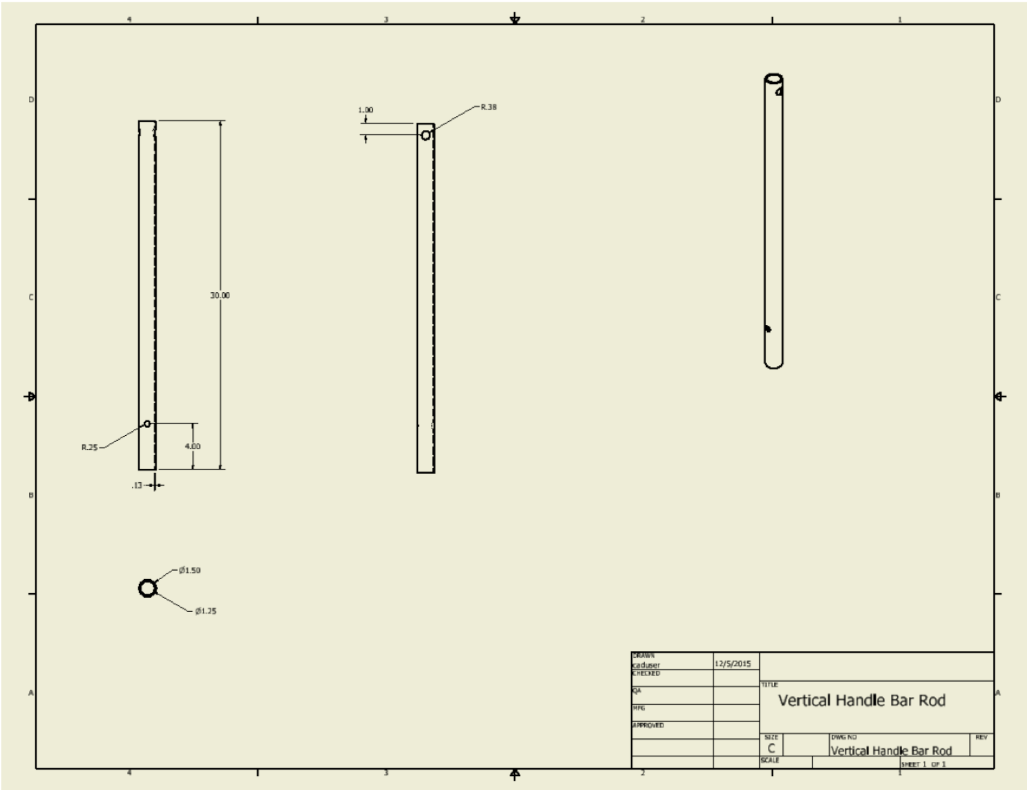


Figure 31: Horizontal handlebar rod drawing

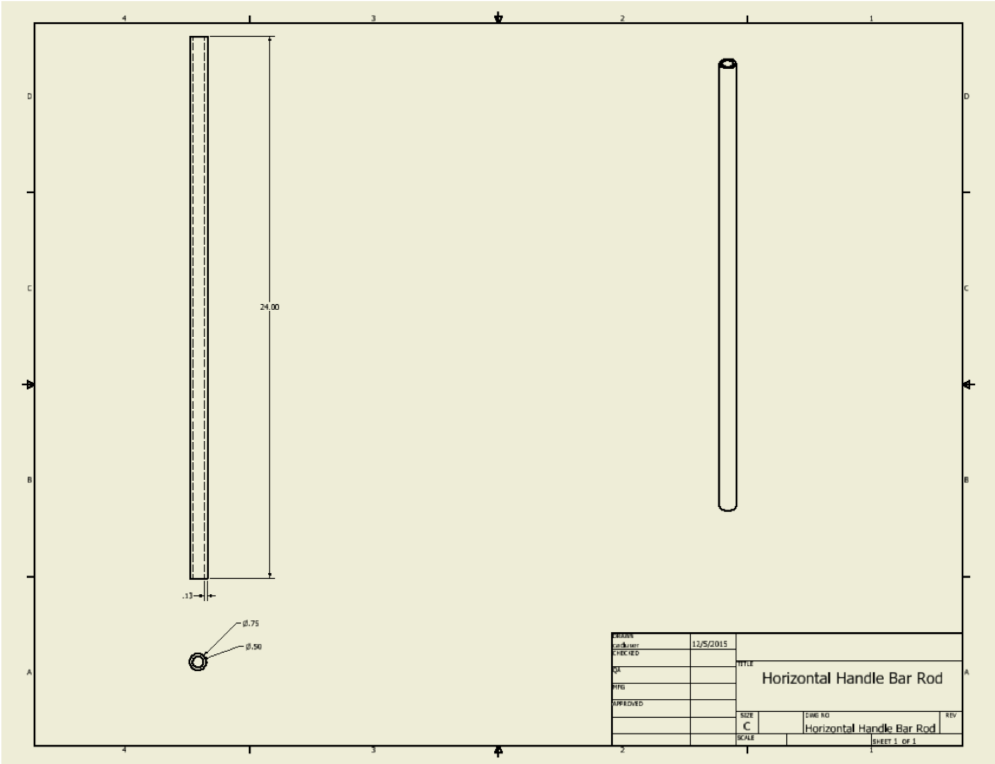


Figure 30: Neck tube drawing

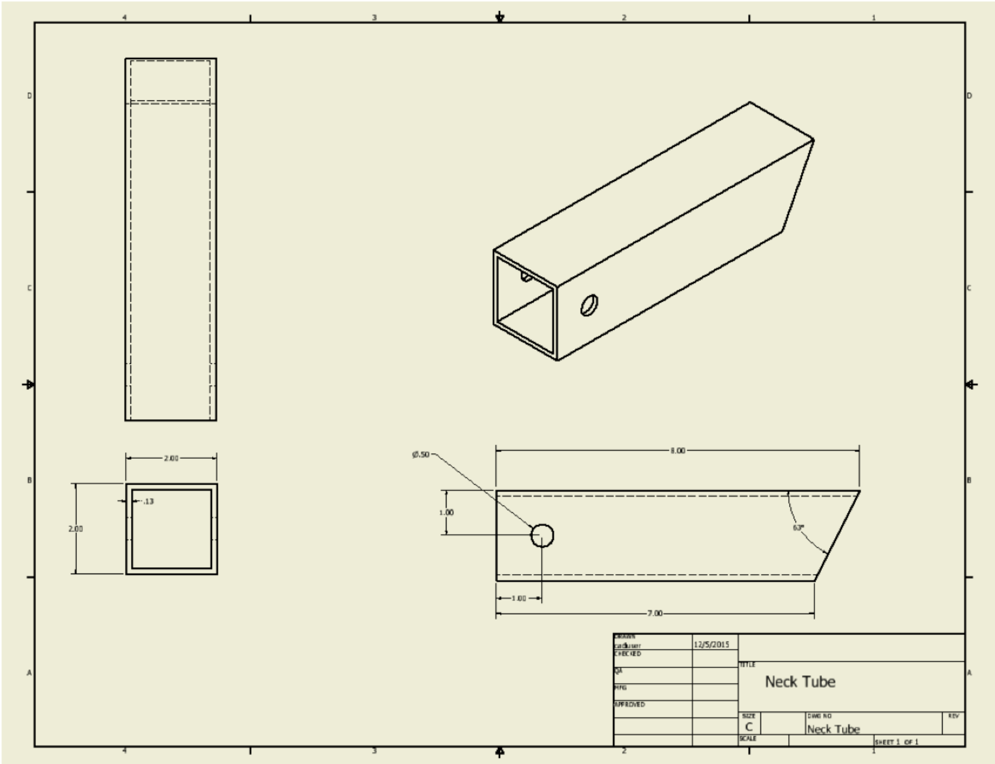


Figure 33: Pin block drawing

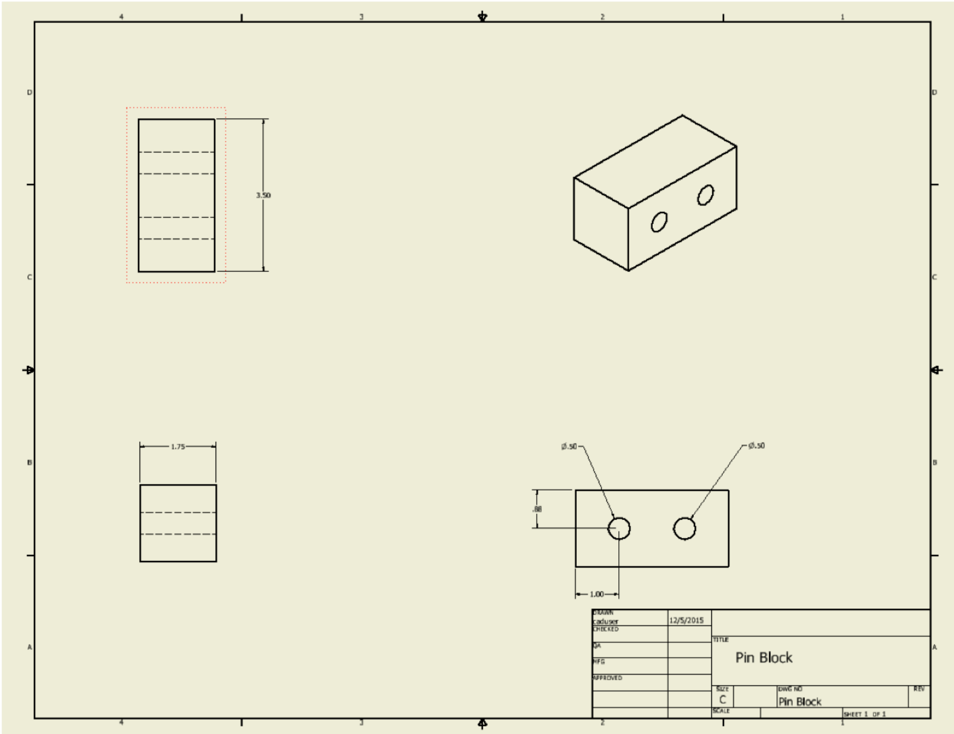


Figure 32: Front axle drawing

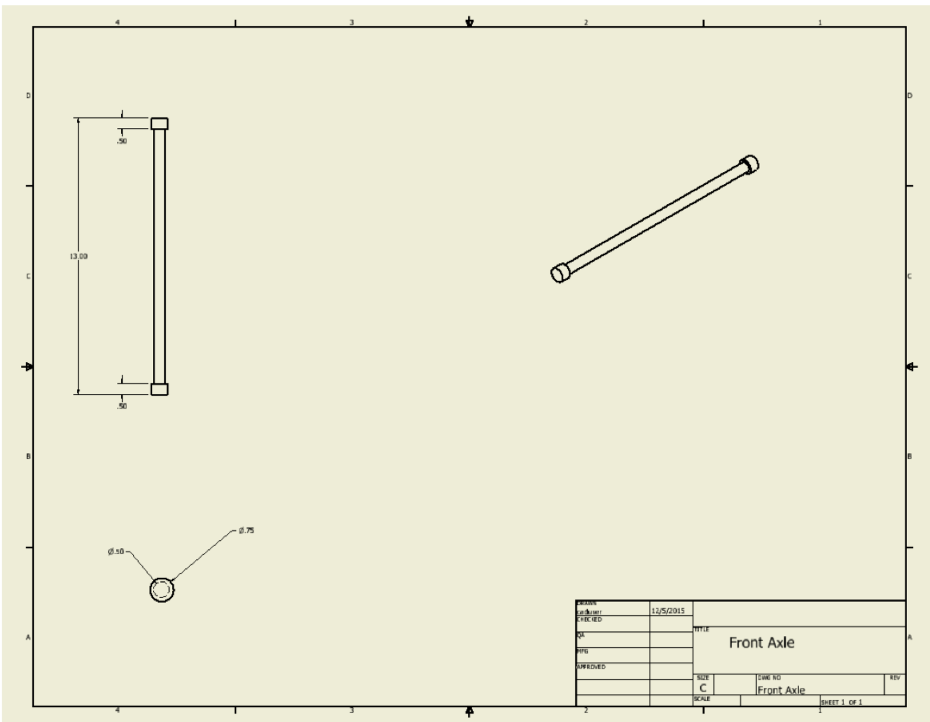


Figure 35: Handlebar spacer drawing

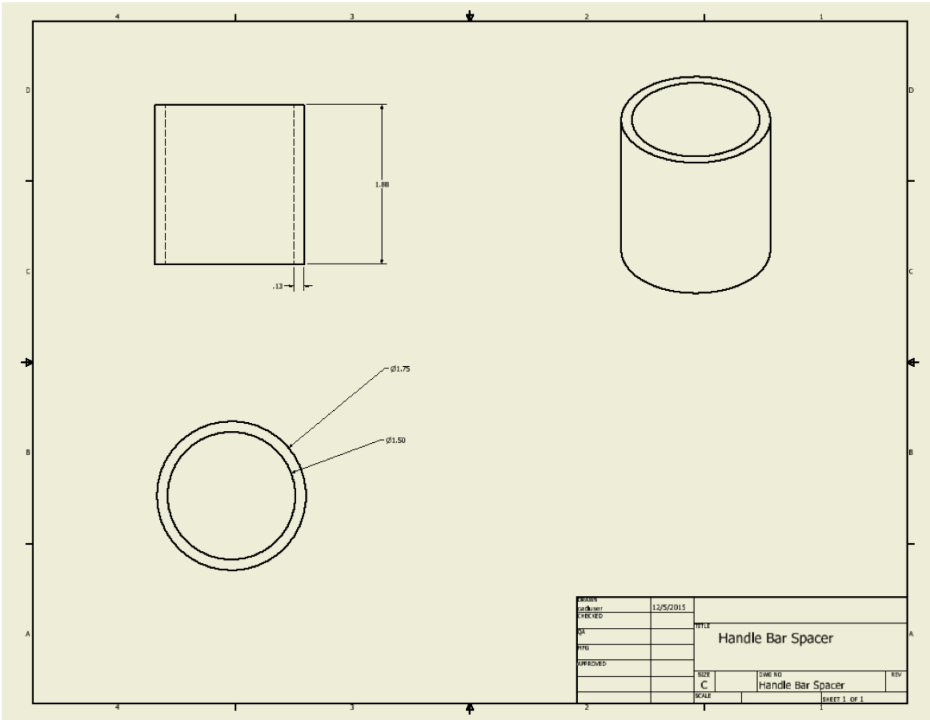


Figure 34: Rear assembly drawing

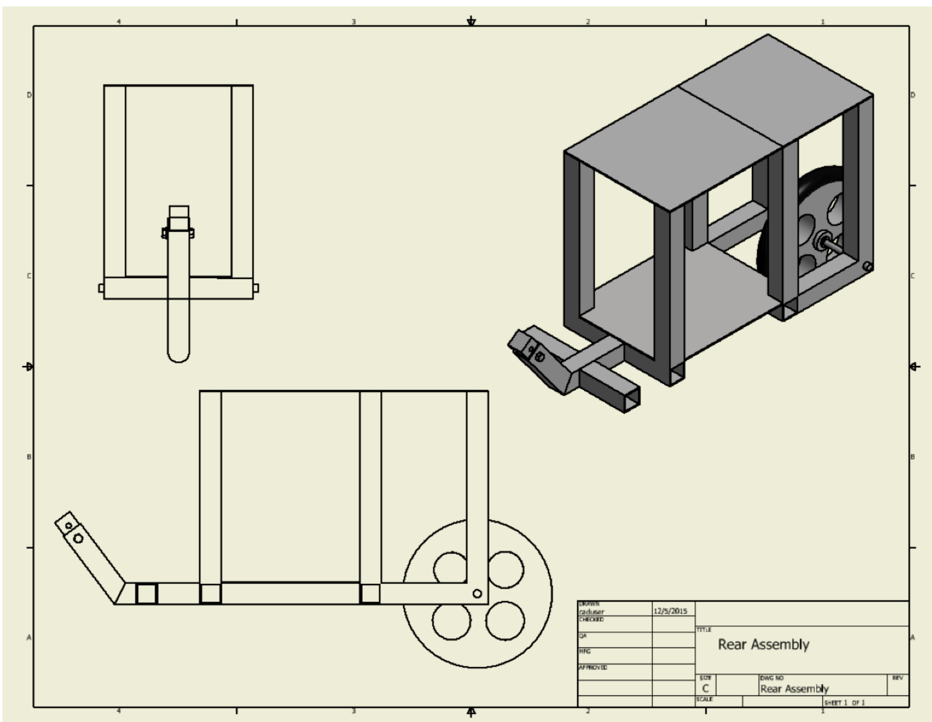


Figure 37: Seat plate drawing

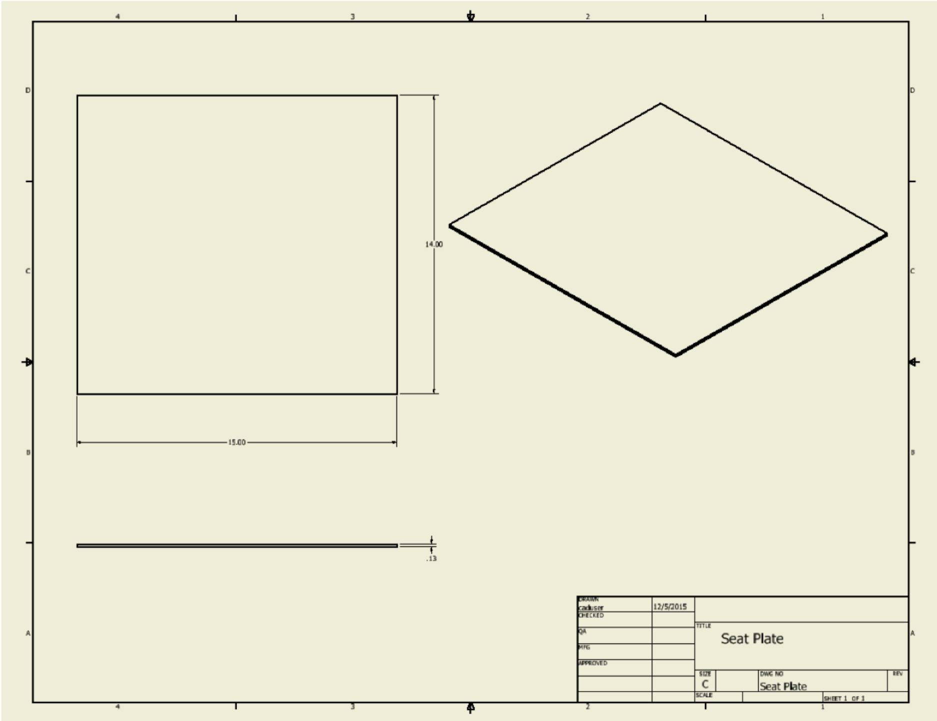


Figure 36: Engine plate drawing

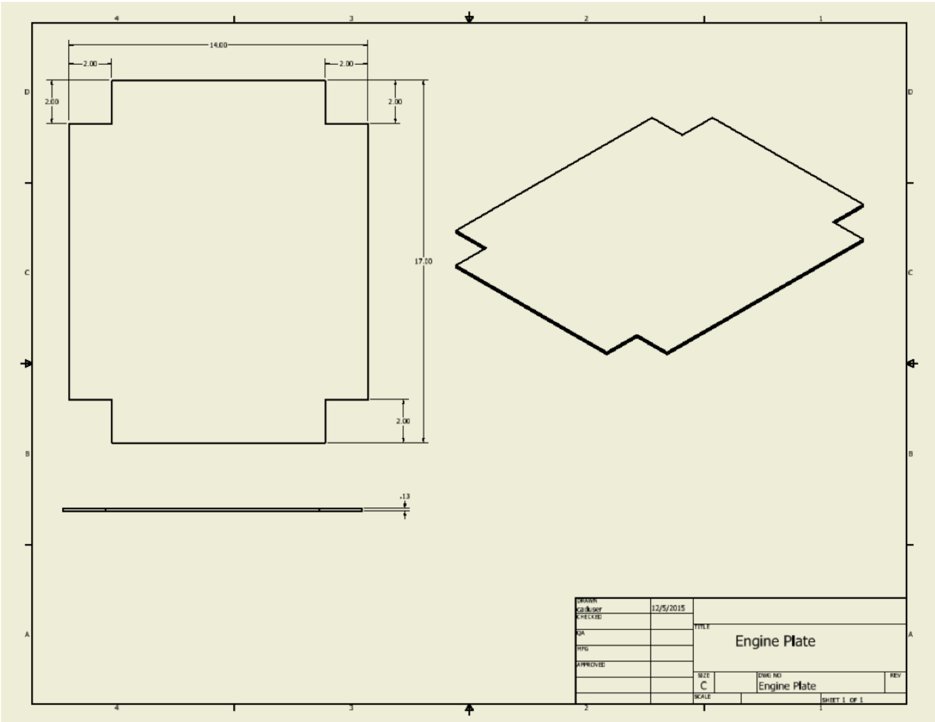


Figure 39: Back platform drawing

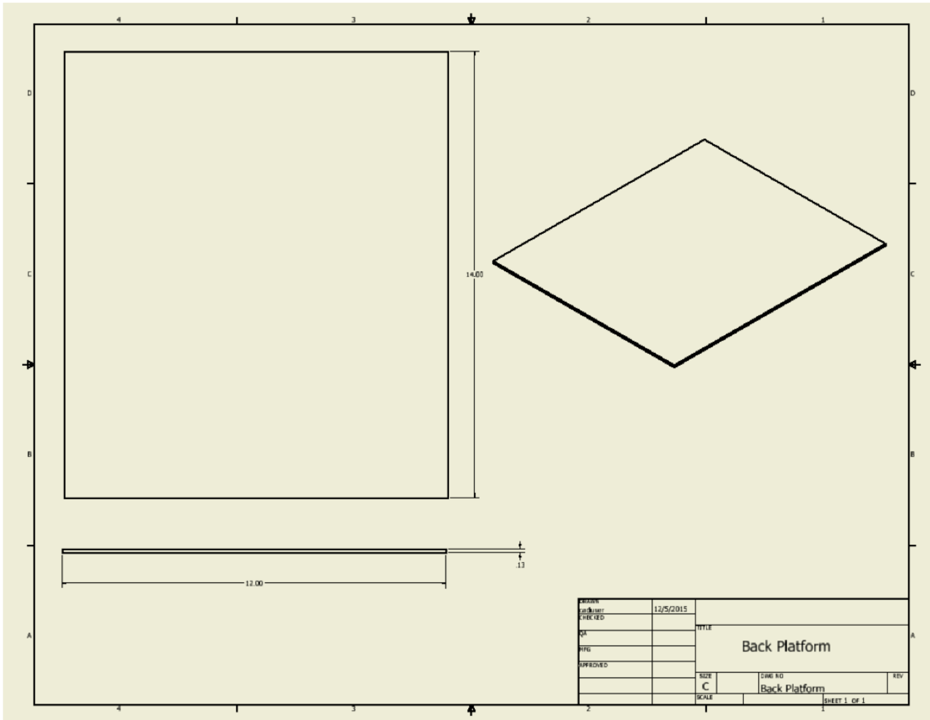


Figure 38: Rear frame drawing

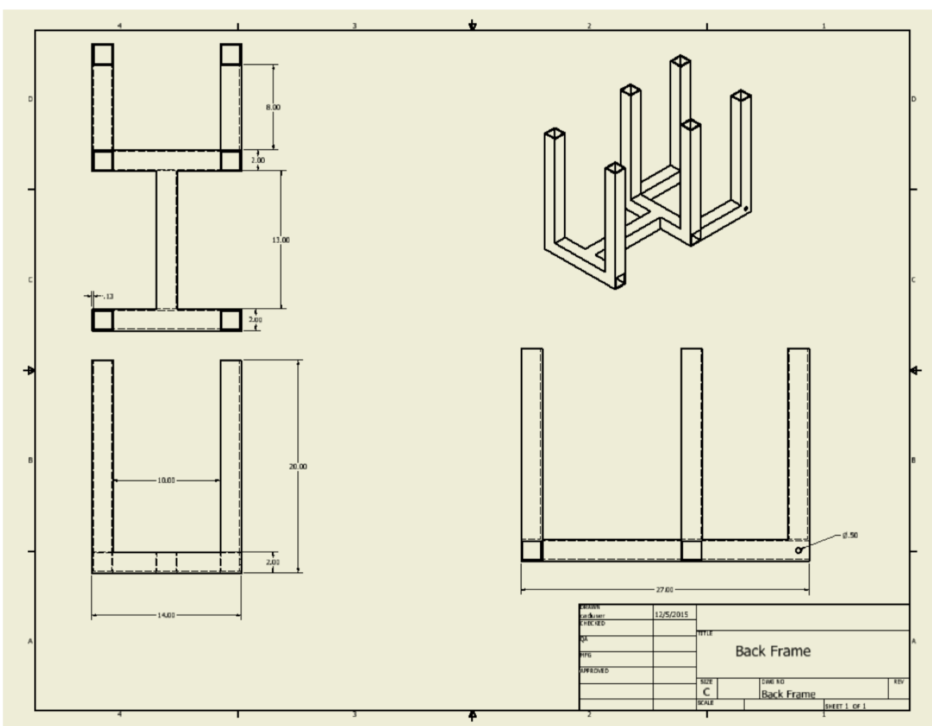


Figure 41: Back wheel spacer drawing

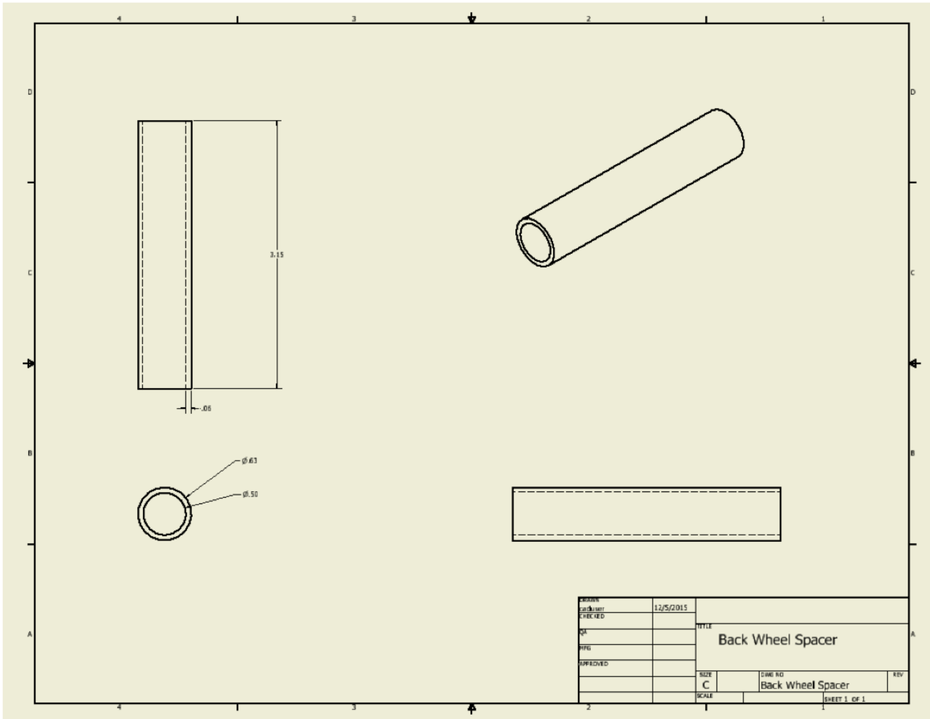


Figure 40: Back axle drawing

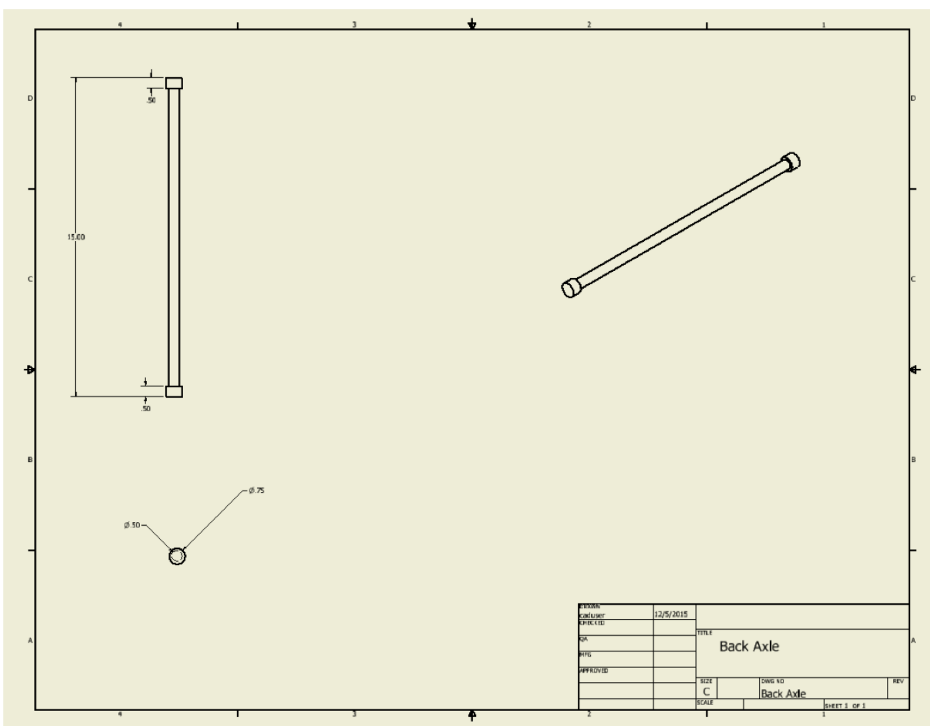


Figure 43: 18" tube drawing

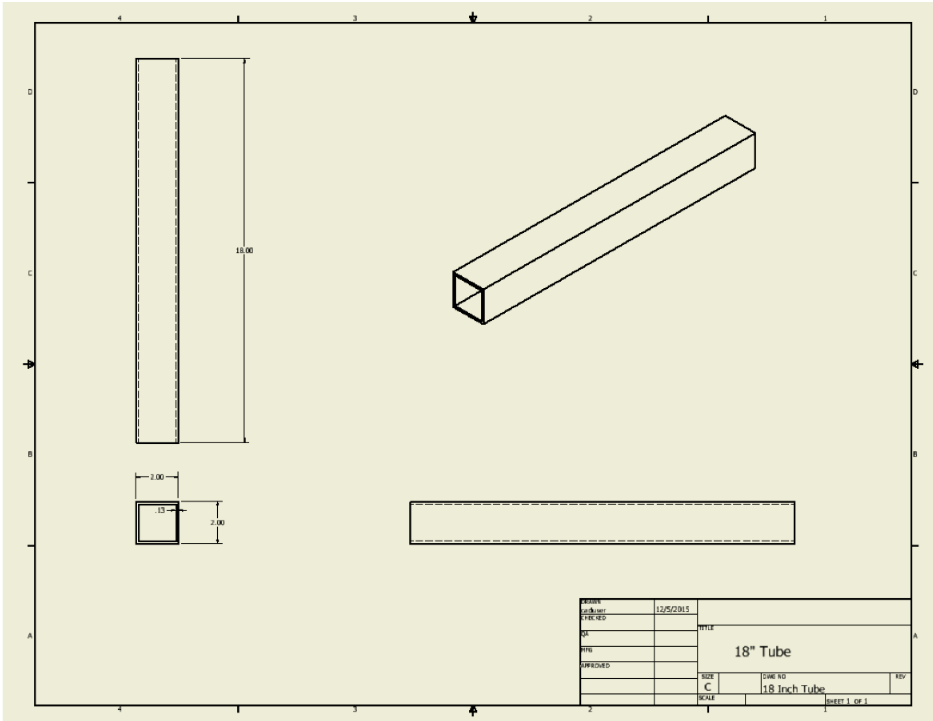


Figure 42: 14" tube drawing

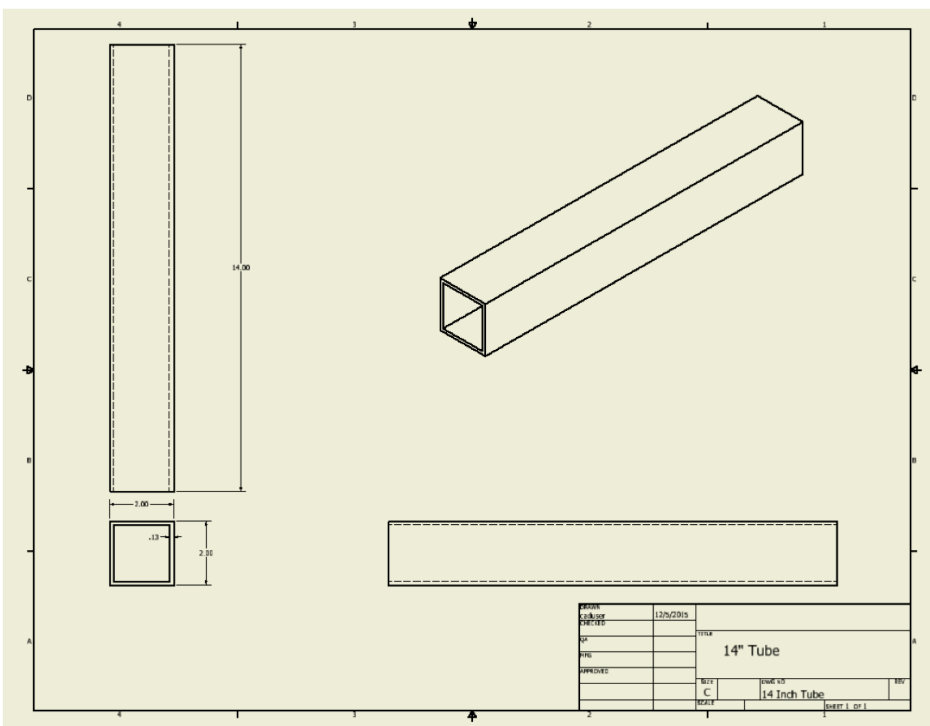


Figure 45: 13" tube drawing

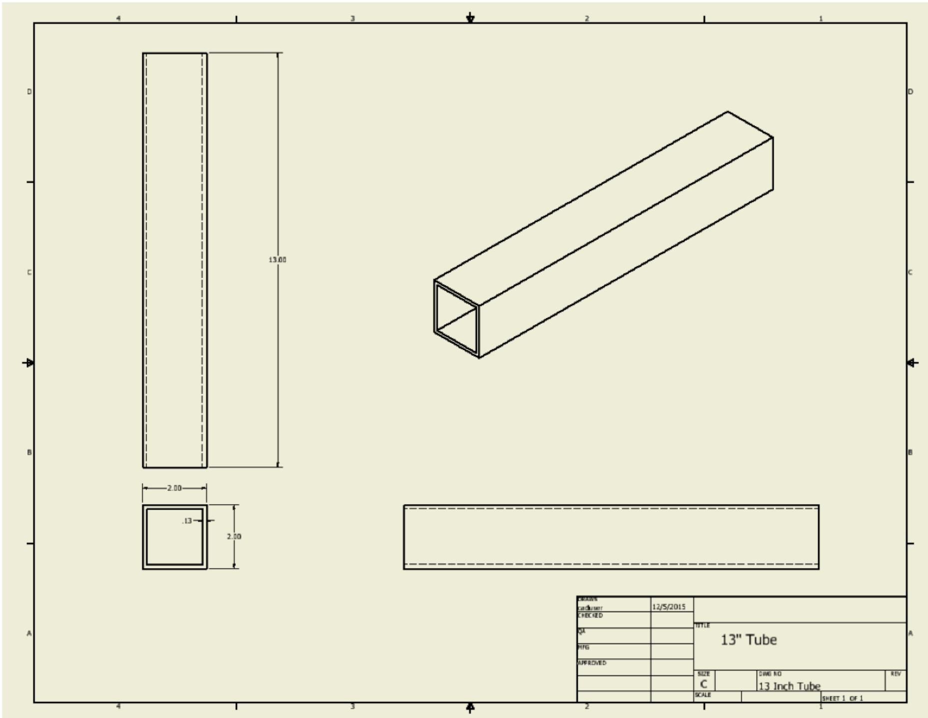


Figure 44: 12" tube drawing

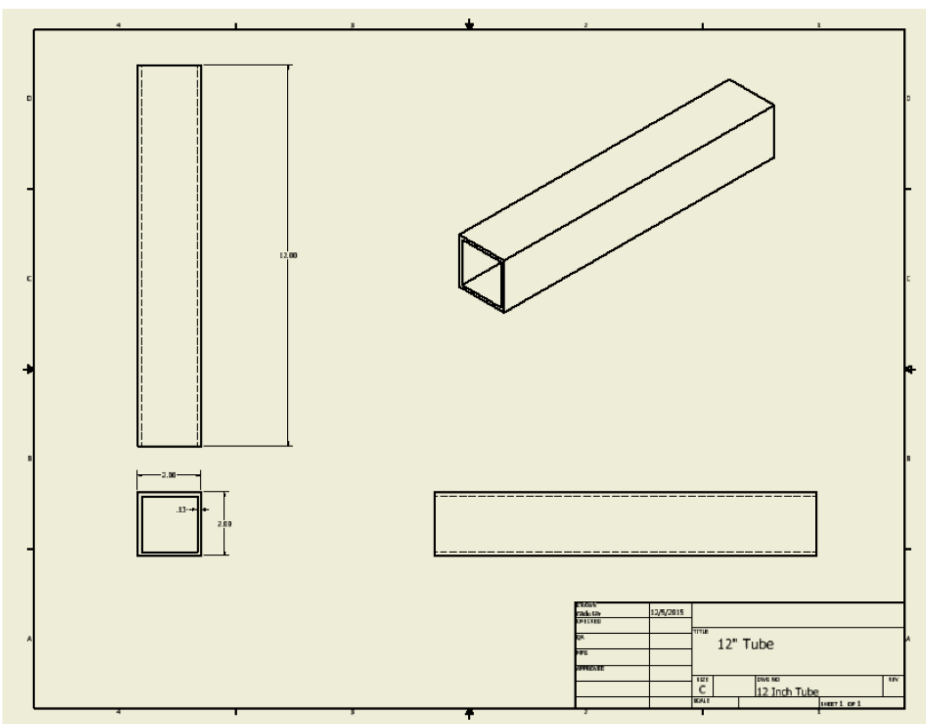


Figure 47: 10" tube drawing

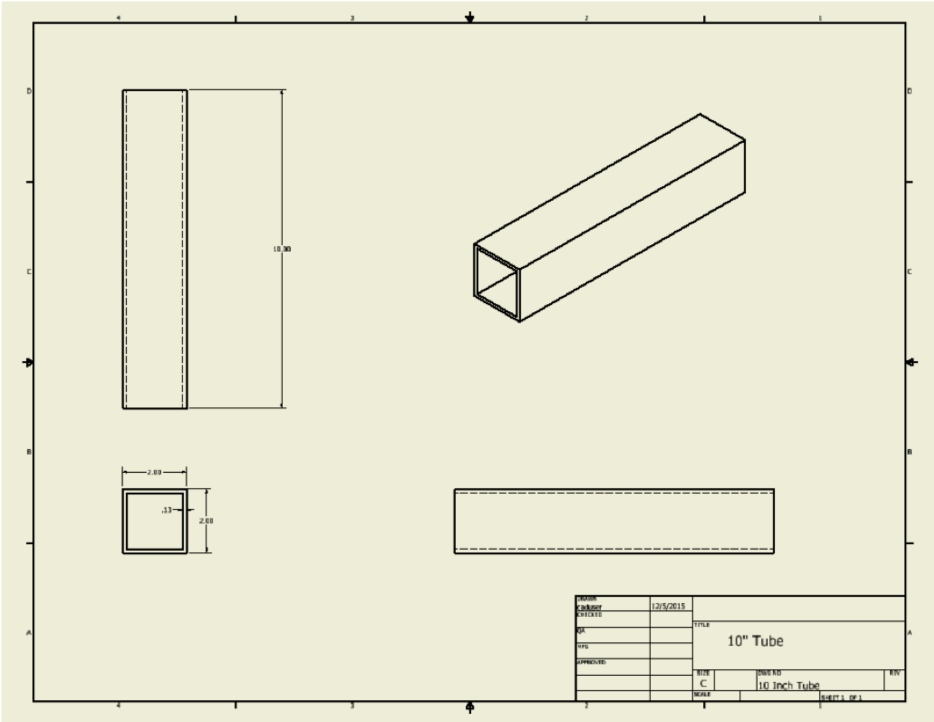


Figure 46: 10" tube with hole drawing

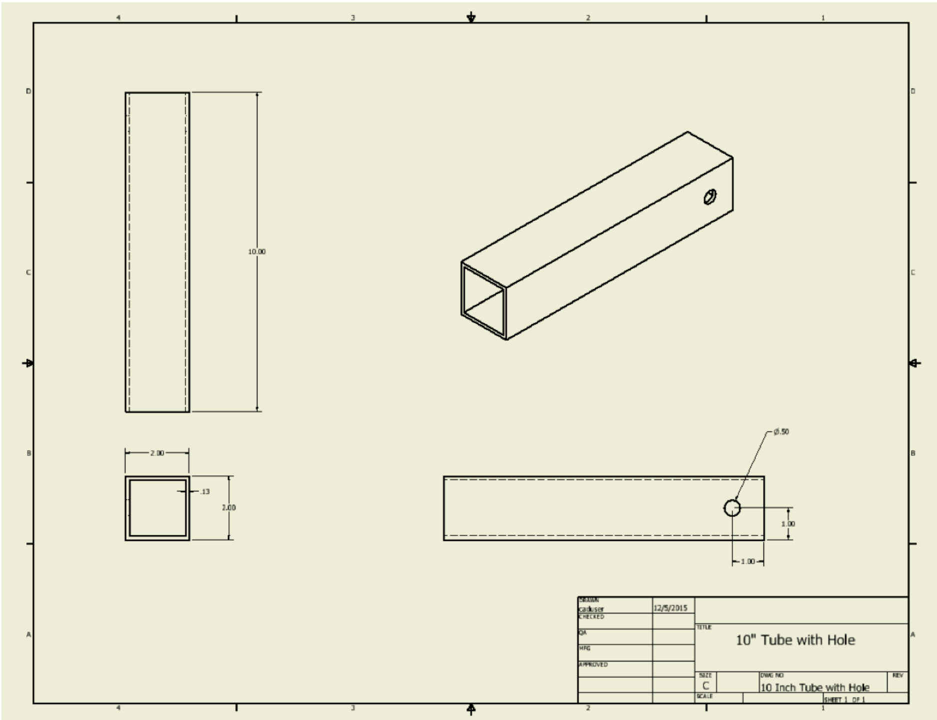
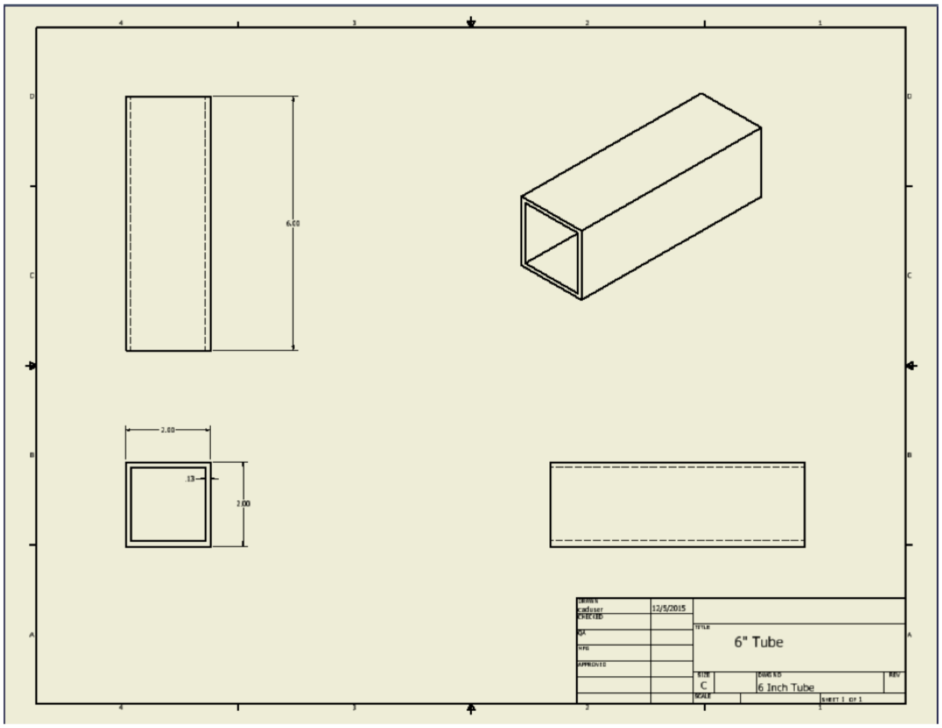


Figure 48: 6" tube drawing



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.

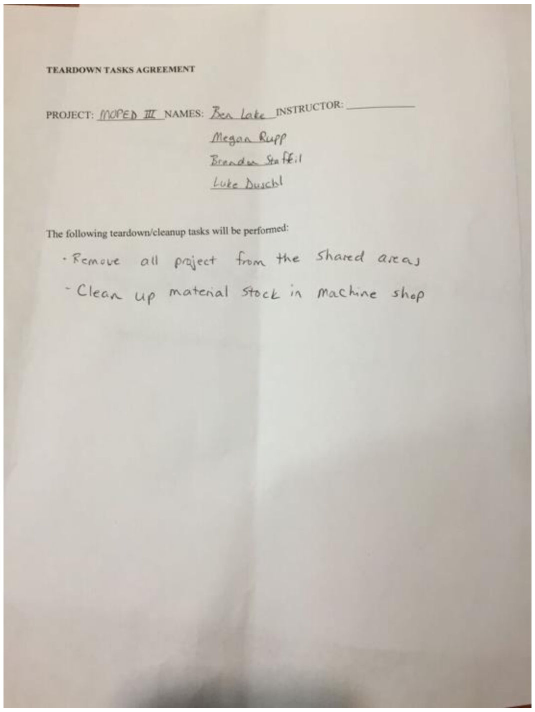
7.2.2 A link to a video clip version of 1

https://youtu.be/CLNItJy2pyM

7.3 Teardown

Teardown was discussed with the instructors.

Figure 50: Tear down form front



TEARDOWN TASKS AGREEMENT

PROJECT: MOPED III NAMES: Ben Lake INSTRUCTOR: ________

Megan Rupp

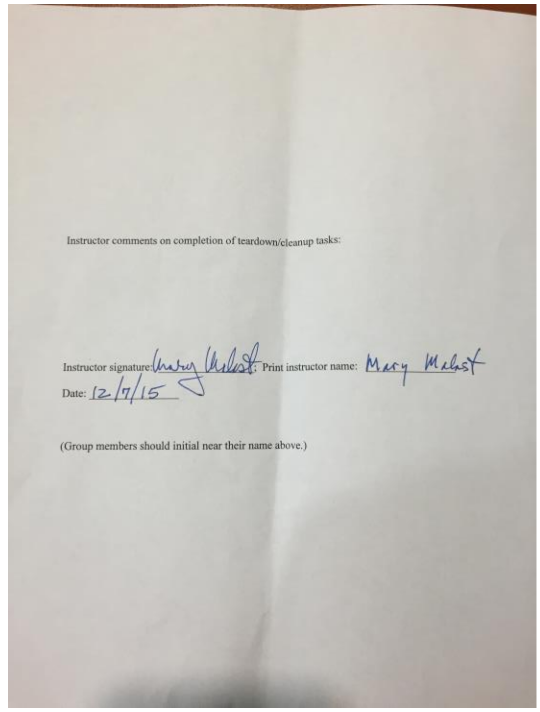
Brendan Staffil

Luke Buschl

The following teardown/cleanup tasks will be performed:

- Remove all project from the shared areas
- Clean up material stock in machine shop

Figure 49: Tear down form back



Instructor comments on completion of teardown/cleanup tasks:

Instructor signature: Mary Malast Print instructor name: Mary Malast

Date: 12/7/15

(Group members should initial near their name above.)

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

Final Prototype		Metric																				
		Holds one rider	Waterproof	Recumbent Seat	Motor Size	Number of Wheels	Gross BHP	Speed	Number of Bags	Weight of Cargo	Weight of Rider	Human Powered	Collapsed Footprint Area	Time to Set Up	Steps to Set Up	Weight of Moped	Operation Time	Rolls As Collapsed	Hand Controlled	Need Happiness	Importance Weight (all entries should add up to 1)	Total Happiness Value
Need#	Need	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18			
1	Can carry one person	1																		1	0.078125	0.078125
2	Waterproof		1																	1	0.0625	0.0625
3	Seat recumbant and comfortable			1																1	0.078125	0.078125
4	Street legal as moped in MO				0.3	0.1	0.3	0.3												0.9	0.078125	0.0703125
5	Hold two paper shopping bags without falling under power								1											0.5	0.046875	0.0234375
6	Holds 30 lbs of cargo									1										0.5	0.03125	0.015625
7	Hold 250 lbs driver										1									1	0.078125	0.078125
8	Human power option											1								0	0.0625	0
9	Has 2' x 2.5' footprint												1							0.2	0.078125	0.015625
10	Takes 90s and fewer than 5 steps to set up and collapse													0.7	0.3					0.5866667	0.0625	0.0366667
11	Vehicle less than 50 lbs.															1				-0.5	0.078125	-0.039063
12	Can run for 40 min.																1			1	0.078125	0.078125
13	Runs at 15 mph							1												0.6666667	0.03125	0.0208333
14	Rolls while collapsed																	1		1	0.078125	0.078125
15	Controlled by hand																		1	1	0.078125	0.078125
Units		Binary	Binary	Binary	cc	Integer	HP	MPH	Integer	Lbs.	Lbs.	Binary	Ft^2	Seconds	Integer	Lbs.	Minutes	Binary	Binary	Total Happiness		0.6746875
Best Value		1	1	1	50	2	3	30	2	50	250	1	0	0	0	0	40	1	1		1	
Worst Value		0	0	0	0	3	0	15	0	0	0	0	5	90	5	50	0	0	0			
Actual Value		1	1	1	50	2	3	25	1	25	250	0	4	30	3	75	40	1	1			
Normalized Metric Happiness		1	1	1	1	1	1	0.6666667	0.5	0.5	1	0	0.2	0.6666667	0.4	-0.5	1	1	1			

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
   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
   We used this source to get an equation for the theoretical top speed equation and verify our calculation.