Scooter ASEE NCS 2020 Abstract

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I am a Mechanical Engineering graduate from Ohio Northern University, Class of 2020. I was a part of the 2020 Scootie Gang Capstone Team. The team consisted of 4 members, now all graduated mechanical engineers.

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Scootie Gang

Executive Summary

Scootie gang has been asked to create a foldable lightweight scooter. The customer base for this product is college students as the goal is to make it lightweight, easily portable and less enduring to use so students can carry it with them to and from class without too much effort. Currently, transportation options for students include skateboards, bicycles, cars, and scooters. However, the current scooter options are not lightweight or easily portable. The main constraints of this scooter are to have less lower leg useweigh no more than 20 pounds and have more than two wheels. The customer, a current college student, has given these constraints as her boundaries for use and weight. Scootie Gang has come up with a three wheel, more secure, lighter weight and more portable scooter to ride.

Problem Definition

Objective

The goal of this capstone is for the team to build a scooter that is light enough to be carried and be able to fold down to a portable size. The customer is an ONU student who lives off campus and has a further commute and needs an easier way to get to campus. A broader customer base is college students who need to get across campus quickly. They need to be able to transport this scooter easily and therefore it must follow the weight limit.

Motivation

Our customers need to be able to get to class quickly and efficiently. This means that they need to be able to move across campus without exerting lots of energy and be able to take their vehicle with them wherever they go. When was the last time that you went to class and got there quickly but it took you forever to lock up your bike? This is why we are creating a scooter that can be carried and stored inside the classroom. It is also ideal that the user uses less leg movement for stability concerns.

Constraints

Students must be able to carry this scooter with them. It must be under 20 pounds and must also be able to roll over obstacles on the sidewalk without distressing the user. The client has also stated that she would like to have a larger base that would be difficult for her feet to fall off of and for the handles to be sturdy. The client has stated that she would like to feel secure on the scooter. With other scooters that are commercially available, she complains that they feel like they are going to fall apart when you use them. The client would like to change how the scooter feels when being used. The last condition for use is that the scooter must have a way to stop. The user has asked that the brakes be applied through the handles but for the driving application of this scooter this would be difficult. This has been explained to the client and the client has approved of the foot brakes after realizing hand brakes may be a safety issue. The scooter is equipped with a foot brake that will allow the user to push anywhere on the bar at the back of the board and the brake force will be equally applied to each wheel. A table of the constraints can be seen below in Table 1.

Table 1: Constraints

Wider base (approximate width of at least 7”)
Light weight (20lbs)
Hand Brakes
Travels 5 mph max
Able to drive on different surfaces
Must support 235 lbs

Evaluation Metrics

Our customer has asked that the scooter have more stability than those currently on the market. The more stable the scooter can be the better. The client did not state that the scooter needs to be electric but she would prefer less leg movement than a normal kick scooter. The scooter needs to be able to be carried in and out of class so the lighter the scooter the better. The scooter needs to be more portable than that of a normal scooter. This was achieved by a simplistic folding mechanism instilled on the scooter and makes it easier to store and carry. A table of the evaluation metrics can be seen below in Table 2.

Table 2: Evaluation Metrics

Stable (More is better)
Portable (More is better)
Leg Involvement (Less is better)
Can ride on multiple surfaces (Seasonal Conditions)
Cost (Less is better

ABET Considerations

The scooter being designed has many benefits economically, environmentally, physically and in safety. Economically, this is cheaper than an electric or gas scooter because there is no need to buy gas to use it and no power is being used to charge it. The design that was chosen focuses on physical power produced by the user versus gas or electric that could be harmful to the environment. Since the scooter is not powered by gas it will not emit fumes that will harm the environment. Also, the scooter is not electric so it will not need to be charged daily which would be a disadvantage to the environment. This scooter does not give the body as much exercise as walking but will still give the user an arm workout by rotating the pedals to move the scooter to their destination. The scooter will be equipped with a chain guard to ensure safety for the user. The scooter will also have reflectors installed so the user can be seen while riding.

Lastly, the easy manufacturability, or being able to take apart and put back together, of the scooter allows for easy assembly and replacement of parts.

Background

There are multiple scooter companies on the market currently. Razor being the most well known for their scooters, however, most of their scooters on the market do not have the weight limit built for a college student. The A5 Lux Scooter is a two wheel Razor scooter with a weight limit of 220 pounds built out of anodized aluminum [1]. However, our customer has requested more than two wheels, for stability purposes, and also requested the least physical exertion as possible. Another company that sells scooters is called Xootr. Xootr prides itself in its light and foldable scooters, however they only sell kick scooters [2]. This leaves other purely mechanical markets open. Another new electric scooter company is Unagi. Unagi uses magnesium alloy for their handlebars which is super lightweight and uses a carbon fiber tube. Their design is very slick and pristine, however their scooters are around $900 which is much more than the average college student will purchase [3]. GoTrax is another electric scooter company who has a very good folding mechanism but is high in weight and cost [4].

Another new type of scooter is the Space Scooter USA. This scooter uses a foot pump action to operate. It is a two wheel scooter which forces the rider to keep their balance as they pump the base with their foot as shown in Figure 1. Aside from issues with ease of use, the Space Scooter USA is at a great cost of about $150. The two wheel and foot pump action approach doesn't allow this design to fit our criteria however because our customer would like to have more than two wheels and also not a foot brake which we think would include using a foot pump to propel [5].

Figure 1: Space Scooter USA [5]

In addition to the Space Scooter USA redesign of a scooter, there is also the AODI Scooter. This scooter has three wheels and uses a swaying hip movement to propel the rider forward. The scooter has two bases, one for each foot, as shown in Figure 2 [6].

Figure 2: AODI Scooter [6]

Along with researching these scooter companies, we researched different methods of movement. Within this, we discovered the Leveraged Freedom Chair and Mobility Worldwide [7, 8]. The Leveraged Freedom Chair is a wheelchair which uses two levers in order to improve mechanical advantage for the user. The chair uses both arms in order to pump the wheelchair just like a normal one but instead of pushing on the wheels like a normal one, the levers are in front of the wheels, as shown in Figure 3.

Figure 3: Leveraged Freedom Chair [7]

Mobility Worldwide is another wheelchair which has been modified for the user. Where the Leveraged Freedom Chair allows the user a bigger advantage with levers, Mobility Worldwide allows the user to use pedals to propel themselves, just like on a bike, but using their hands to pedal instead. By pedaling, the user turns gears and a bike chain in order to move the front wheel resulting in the back wheels moving, as shown in Figure 4. The final prototype design chosen is based off of Mobility Worldwide's hand pedaling system.

Figure 4: Mobility Worldwide Wheelchair [8]

The main takeaway for each of the current options is the weight of each option. On average Xootr Scooters weigh 11 lbs, being the lightest of the options compared. Xootr is the most lightweight option because it has two small wheels instead of three wheels. The other options listed above range from 22-25 lbs and are not built to endure different terrains making them not ideal candidates.

Stakeholders

The main stakeholders for this design are college students. They will be the primary intended users, therefore the height and weight ratings will be aimed towards this group. Another stakeholder would be the parents of a college student. These stakeholders would be the ones potentially paying for the scooter. It is important to take into consideration whether or not a parent would consider buying the scooter. The suppliers and vendors of the materials are also a stakeholder as they are providing the material to build the scooter. Another stakeholder would be the colleges the students using the scooters go to. The colleges are drawing those students there and if popular enough the colleges could invest in the scooters to allow for all students to be able to ride them. The last stakeholder would be the companies selling the scooter; because by selling the scooter they are also backing the scooter and its abilities.

Standards and Codes

There are multiple road regulations, codes and standards regarding scooters that have been found. The NHTSA states that if the scooter is a stand up scooter, instead of having a seat, then it is not legislated nationally and would instead be legislated at a city level so it changes from town to town [9]. As far as national codes and standards regarding scooters, these can be seen in Appendix D.

Materials

The materials that were used are aluminum tubing for the steering column and wood for the base. Aluminum can be purchased in tubes for reasonable cost. It also offers excellent machinability and strength to weight ratio. The base will be made out of a high quality maple plywood, no thicker than ¾". This will be the surface that the user will be placing their feet on to ride the scooter. All of the sprockets will be made out of steel and will have a ratio of 2.82:1. This means that for every rotation that the user puts the handles through, the wheels will rotate approximately 3 times. For the handles, old bike handles will be used to allow easy grip, while still being durable.

Potential Solutions

Full Electric

This scooter is a design that allows for the rider to stand on the scooter, and the scooter will propel the rider without any physical exertion from the rider. This ideally would drive only 5 mph, per the customers request, and have a battery life that would last all day. The rider would then plug the scooter into a charger when needed. The batteries would stay in the base of the scooter, and the user would control the speed through the handles. This would allow for the user to eliminate leg effort in propelling the scooter, which is exactly what the customer requested. The base would be a rectangular box to accommodate the batteries that the motor needs as well as any controls would be located inside.

Kick Assist

This scooter design is one that still has an electric motor but this motor is not able to propel the scooter on its own. The rider will still have to input some energy into the system, the electric motor will just reduce the amount of physical input. A similar design idea as the fully electric, with all components inside the rectangular base. This idea was not taken forward because of how heavy the components would cause the scooter to be.

Two Levered Propel

The last alternate idea the team discussed was doing two levers like in the Leveraged Freedom Chair. For this idea, the user would have two handles which could be pushed forward and backward in order to propel the user. The team decided not to use this idea because of the awkwardness in moving the levers back and forth depending on the width of the user. The width of the user changes how easy it would be to get full movement out of the levers. Ideally, the levers would be at shoulder width, however, the levers would be attached to the wheels making it hard to adjust them based on the user.

Proposed Solution

In order to evaluate the scooter to continue with, we applied the Pugh's Method shown in Table 6 the Appendix C. This method used the following constraints and evaluation metrics to rate: A wider base, portability, weight, maximum speed, stability, ease of use, charge time and battery life. From these metrics, the pedal scooter seemed to be the best option.

Our client has stated that she would like to have less leg use while using the scooter. To accommodate this request, the group has come up with a pedaling mechanism that the user can "pedal" like a bike with their hands. The handles will be perpendicular to the steering shaft. The steering shaft will support a sprocket that a roller chain will sit on. The roller chain will transfer power to the drive wheel, which is the front wheel. Braking will be performed by pushing down on a bar located at the back of the scooter putting pressure on the back two wheels similar to Razor scooters. It is difficult to adjust the height of the pedaling mechanism due to the roller chain length being fixed.

This scooter allows for the user to stand up and pedal with their hands. The user will be able to propel themselves at speeds up to 5 miles per hour without excessive force having to be exerted. To achieve this, a gear reduction will be utilized.

For the scooter to be portable it needs to fold. On the front corners of the base will be two self locking hinges. One side of the hinge will be connected to the base while the other side will be connected to the braces holding up the steering column. The hinges lock at 90 degrees and at 0 degrees. For this application 90 degrees would be the scooter in the upright position and 0 degrees would be the scooter folded. The hinge is equipped with a latch that when pressed unlocks the hinge and will allow the user to fold the scooter. Figure 6 in Appendix E shows the hinges. This design shall have all the features listed above and will meet the clients constraints and evaluation metrics stated. The final prototype is shown in Appendix J.

Manufacturing

The base which is made of wood was cut to size using a saw and then the cut edges were sanded to remove any splintering pieces of wood the saw left. The kick board was cut to size the same way with a saw and then sanded. The two pieces were put together with hinges that were bought to allow the scooter to fold down. Next, the trucks were extended to fit the wheels of choice. An axle-like piece of bar stock was cut to get two pieces the same length. Those two pieces then went to lath where holes were drilled into one side 1.5 inches deep. These holes were then tapped to match the thread the trucks came with so the extended shaft could be easily added. The other side of the extension pieces were tapped on the outside for a nut to be added to keep the wheel from coming off. The last piece added to the trucks was a stopper made from circular bar stock. This stopper was also lathed and was created to stop the wheel from moving and hitting the wood base while being used. A picture of this piece can be seen below in Figure 5.

Figure 5: Metal stopper attached to trucks

The coasting mechanism was the next part added but it needed some changes. First, one of the rims on the outside of the mechanism had to be cut off so the tire could be added. Secondly, the shoes or brake pads inside the mechanism needed to be removed to eliminate the braking aspect of the mechanism. This was done to ensure that the scooter will still coast when the user stops moving the handles but also so the mechanism does not act as a brake. Further discussion about the brake being removed can be seen in the risk section. Forks were used to attach the coasting mechanism to the steering column. The forks were from the bike we got the coasting mechanism from. The forks were cut down, flattened, and then welded to the sides of a carbon steel sleeve that would later be attached to the steering column. The next aspect of design to be worked on was the steering column. For starters the pedal and gear device was removed from a bike and attached to the top of the steering column. Three holes were drilled into both pieces and bolts were used to attach the two pieces together. Next the sleeve with the forks was attached. This was attached by drilling two holes through the sleeve and the steering column. Two bolts and nuts were then used to keep the two parts together. Lastly the bearings were mounted to the steering column. In order to do this the steering column had to be shaved down then the bearings were attached using two collars between the bearing and the steering column. The bearings were put in the holders and the holders were attached to the kick board.

For a mass production of the scooter, using a laser table would be ideal for cutting out the wooden base of the scooter. A system of cutting/stamping out the different physical pieces of the scooter instead of hand cutting the pieces. To cut out the folding mechanism, a press or waterjet could be used to create the general shape. The pedaling mechanism would have to be pressed together with the sprocket and axle parts. Roller chain would be best put on by a human. The remaining pieces could be purchased from a vendor similarly to how it was done to complete the scooter now. After the rest of the parts are purchased, they could all be attached to the board either by a human or a robot.

Testing and Refinement

Scootie gang planned to test the prototype in the following areas: Plywood deflection, Steering range of motion, maximum height of obstacle, maximum user speed, security of locking mechanism, protection from the elements. To test each of these functions, Scootie gang will perform each of the tests outlined below. Below are the original test descriptions.

To test plywood deflection, Scootie gang traveled to the King Horn complex at ONU. While there they secured a section of plywood, similar to the final size of the prototype, so that it would not fall over. After the plywood was secured, they measured the height of the board when there was no weight applied to it. With the initial height recorded,they could place 100 pounds on the board and record the height again. After that height was recorded they placed another 100 pounds on the board to total 200 pounds. After the weight settled, they then recorded the height. If the board was not in danger of breaking, they then placed up to 300 pounds on the board in the same fashion as above, recording the height of each successive weight jump. After the scooter was completely put together it was tested again with 300 pounds easily passing the deflection test.

To test the steering range of motion, the scooter was propped up so that none of the wheels were touching the ground and the steering mechanism was free. The front facing position was called 0°. The person running the test, then turned the steering column until an obstruction did not allow any more turning. The maximum angle was measured from this position.The steering column was then returned to the 0° position. The steering test was then conducted in the opposite direction and the maximum angle recorded. Both right and left resulted in approximately 90° steering range.

To test the maximum height of an obstacle the user can navigate, the scooter must be completely operational. This test will require preparation. To prepare, Scootie gang will need to create blocks that are 0.5”,1”,1.5”, and 2” in height. The test will start and end with the user at rest. The first block (0.5”) will be placed in the way of the user's drive path. The user will then try to go over the obstacle. After an obstacle has been navigated, the test will start over and a larger block will be placed in the users path. The test will finish when the user can no longer drive over the obstacle.

To test the maximum user speed, the scooter must be completely finished. The test will begin with the user at rest. When the user is ready, they will begin moving forward. Shortly after beginning the user will enter a marked off section that is 20 ft long as fast as they possibly can. When the user enters the marked off region, a second person will start a stopwatch. When the user leaves the marked off region, the stopwatch will be stopped and the time recorded. This test will then be repeated until 6 people have had their time recorded. After all 6 people have completed their testing, an average will be taken and this will be the posted “max speed”.

To test the security of the locking mechanism the hinges were open and closed 100 times. During this testing when the hinges were either in the open or closed position the tester made sure the hinges stayed in the desired position. As stated, this was done 100 times and the hinges did not waver once concluding the confidence in the folding mechanism.

To test the protection from the elements, the scooter should be placed outside in the civil engineering concrete area. The scooter should be completely covered in water and left overnight. Pictures should be taken before and after. When this is completed, the test should be repeated for a whole week. Compare the before and after pictures from everyday side by side. If visible damage has occured the scooter will fail the test.

Ethical Issues

Many different factors of the proposed design of the scooter have been thought about to make the scooter environmentally ethical. Making the scooter completely human powered allows there to be little to no harm to the environment from the scooter. Economically, the scooter is cheaper than electric powered but they are more expensive than your typical kick scooter. This allows there to be the possibility that students without the financial stability may not be able to buy the scooter. This means those students have to start walking to classes earlier than the other students which means they are getting ready earlier resulting in a loss of sleep which could potentially impact grades. The design proposed does not have many ethical issues as stated above making it a great investment.

Risk

A risk that was addressed was the open chain and sprocket system. With the chain and sprocket open the user could easily get something caught in the system and get hurt. This issue was addressed with a chain and sprocket guard. The chain guard consists of a PVC pipe that the chain will lay in. The PVC pipe will be attached with screws and metal straps.

Conclusion

After using Pugh's Method the decision to go with the pedaling concept is the clear choice. Also, using aluminum over carbon fiber because of the cost prohibitive nature of carbon fiber. Using the pedaling mechanism and an aluminum and wood combination would allow for the most inexpensive combination possible for the user. The user wanted less leg use than a normal scooter requires. The pedal mechanism allows for the user to get to higher speeds easily with less physical exertion. This scooter would mainly attract college students who live on a bigger campus. This would allow students to shorten their time to their destination tremendously compared to walking. If these were to be mass produced and sold, the selling price of $500 would be necessary to make a profit off of materials and time.

There are a couple of ways the scooter could be improved. One way is by changing the brakes. The customer asked for hand brakes and the current scooter has a foot brake. Implementing hand brakes on this specific scooter would have been difficult because of the pedaling action. Another aspect that would improve the scooter is the wheels. The current wheels are solid and this causes for a rough ride for the user. Pneumatic wheels would be the better choice for the scooter and the desired constraints and evaluation metrics. A way to increase the speed of the scooter is to get a longer chain to switch to the larger gear located at the top of the steering column. This would increase the gear ratio which would increase the speed. The current scooter did not meet the weight constraint the customer desired. If the scooter was made out of lighter materials such as carbon fiber instead of steel, aluminum, and wood the scooter would make the 20 pound weight limit. Due to not being on campus the pedals are still on the scooter instead of normal bike handles for ease of use for the rider. Lastly, to improve this project a broader client base would've allowed more knowledge about what a college student really needs when commuting across campus. This would allow the design of the scooter to fit more users.

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Appendix:

Appendix A: Project Management

Team Roles:

- Mallory Taylor: Budget Manager
- Nate Rausch: Builder
- Brittney Masters: Meeting Minutes
- Kasie Moeller: Team Leader

Gantt Chart:

Table 3: Gantt Chart

Task	Start Date	End Date
Submit initial proposal	1	6
Project review board 1	7	7
Redesign project following PRB 1	7	13
Re-budget for redesigned project	8	13
Project review board 2	13	13
Redesign project following PRB 2	14	16
Re-budget for redesigned project	14	16
Order major parts and components	16	28
Winter break	16	17
Start Building Project	17	28
Project Review Board 3	22	22
Testing	22	28
Final Refinement	23	29
Showcase	30	30
Final presentations	31	31
Graduate	32	32

From our original gantt chart to the one pictured above a lot of events were added. Tasks that were added were drawings, prototyping, and refining drawings. These tasks were not added to the original gantt chart because we were not sure when they would fit into the timeline. Additionally, some of the original dates were refined giving us more or less time to work on the tasks that need to be done. These changes will help us to manage our time better and get tasks done on time.

Appendix B: Budget

Table 4: Budget

	Qty	Part Number	Description	Vendor	$ (each)
	1	B01I3X8U70	Havoc Skateboard trucks	Amazon	$18.00
	1	B07BHK7V86	Bracket - Self Locking Hinges	Amazon	$11.99
	1	2243t43	Water Resistant 6" Wheel	McMaster Carr	$22.52
	2	2243t41	Water Resistant 4" Wheel	McMaster Carr	$27.64
	1	9056K28	3' Alum 6061 Round Tube 1" 1/4" Wall (steering)	McMaster Carr	$25.67
	1	6546K52	2' Alum Rect Tubing 1/16" wall (handles)	McMaster Carr	$10.08
	1	6628K284	3' 1144 Carbon Steel Rod 1/2" Dia (shafts)	McMaster Carr	$8.61
	1	2939n31	3' Low carbon steel half Oval (forks)	McMaster Carr	$25.09
	1	7767T48	3' Low carbon steel Round Tubing (steering)	McMaster Carr	$51.27

Table 5: Donated Items

Donated Items	Vendor
Plywood	Freed Center
Forks	Dr. Rider's Mini Bike
Handlebar's	Brittney's Bike
Sprockets	Dr. Rider's Mini Bike and Brittney's Bike

The requested budget is $720.00 this can be seen in Table 4. This changed from the original budget, $1,105.00, request because of a change in design. The change in design allowed the team to find more reusable, cheaper and even some donated parts. Because the new solution can be made from bike parts and other easily found objects, the new budget was found and decreased from the original. As shown in Table 4, there is a remaining $218.79. The remaining money would've been used for traveling to the ASEE conference which was canceled due to COVID-19.

Appendix C: Pugh's Method

Table 6: Pugh's Method

Elements	Base Line Kick	Motor Battery	Kick Assist	Pedal
Wider Base	S	1	1	1
Portable	S	-1	-1	1
Light weight	S	-1	-1	S
5 mph max	S	1	1	S
Stable	S	1	1	1
Ease of Use	S	1	1	1
Charge Time	S	-1	-1	S
Battery LIfe	S	-1	-1	S
	(+)	4	4	4
	(-)	-4	-4	0
	Total	0	0	4

Appendix D: Standards and Codes

Table 7: Standards and Codes

ASTM F15.58	Powered Scooters and Skateboards
ASTM F963	Standard Consumer Safety Specification for Toy Safety
ASME Y14. 5 - 2009	Dimensioning and Tolerancing
ASTM F2641 - 08(2015)	Standard Consumer Safety Specification for Recreational Powered Scooters and Pocket Bikes
ASTM F2642 - 08(2015)	Standard Consumer Safety Specification for Safety Instructions and Labeling for Recreational Powered Scooters and Pocket Bikes
ASTM F2264 - 14	Standard Consumer Safety Specification for Non-Powered Scooters
OHSA 1926.601	Motor vehicles

ASME Y14.100	Engineering Drawing Practices
ASME Y14.24	Types and Applications of Engineering Drawings
ASME Y14.36	Surface Texture Symbols
UL 2849	Battery Safety for electric scooters
UL 2272	Battery safety for mobility scooters

Appendix E: Engineering Drawings

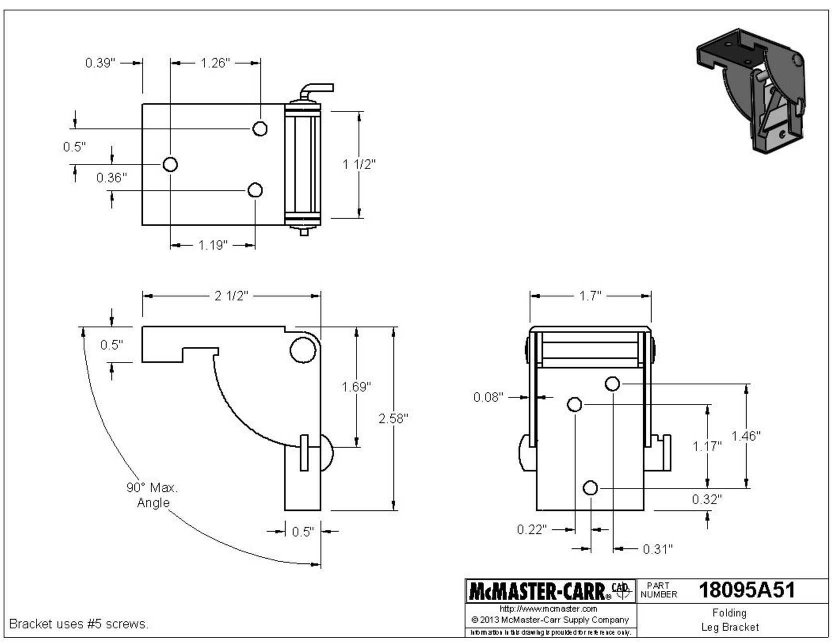

Figure 6: Hinge drawing with dimensions

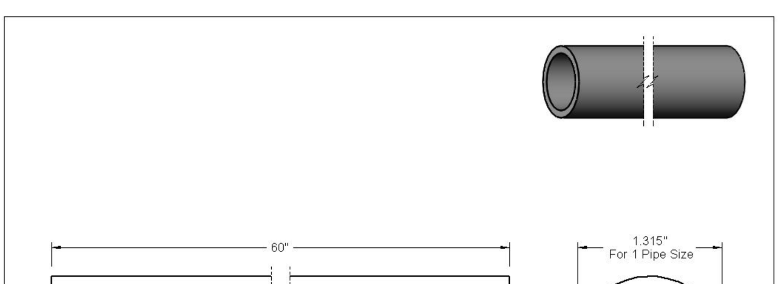

Figure 7: Chain Guard Pipe

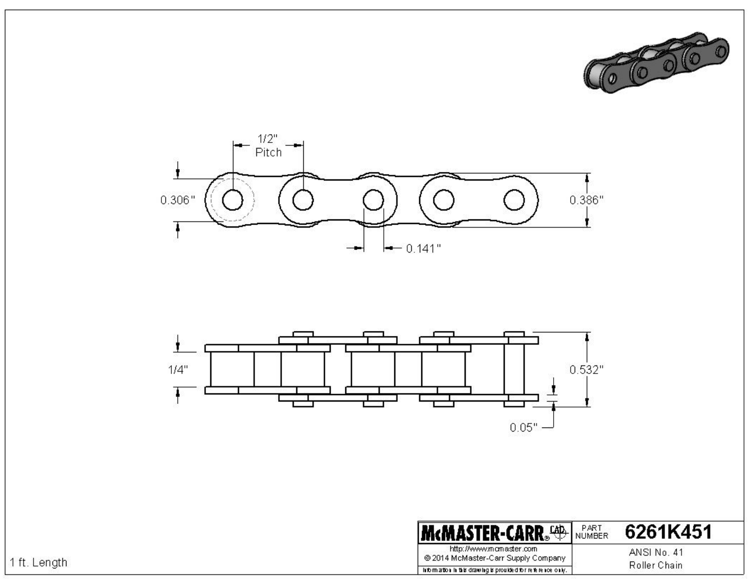

Figure 8: Chain

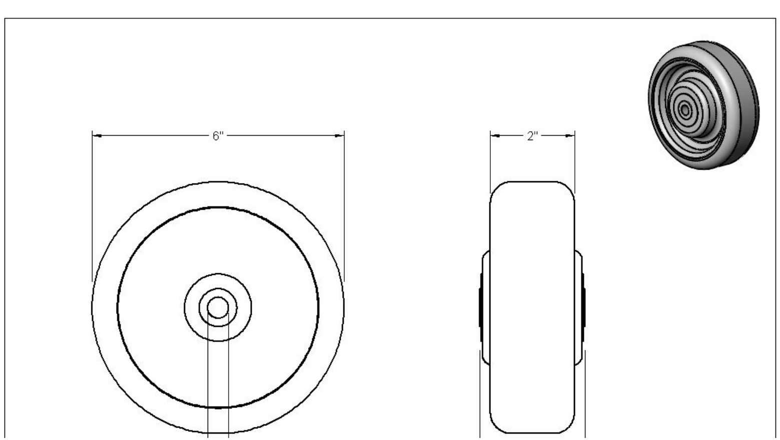

Figure 9: Wheels

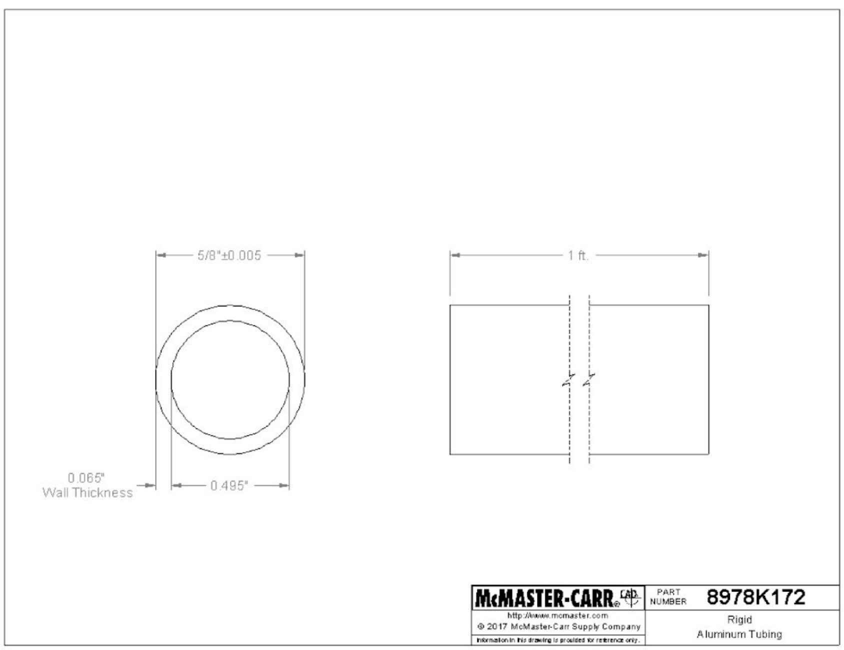

Figure 10: Steering Column Tubing

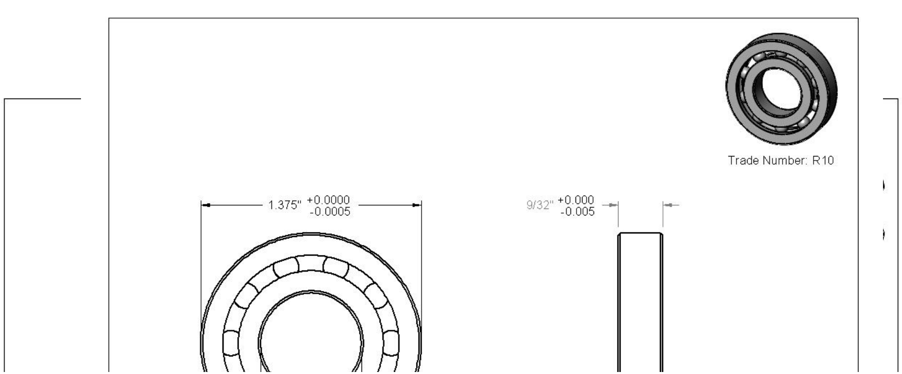

Figure 11: Bearings

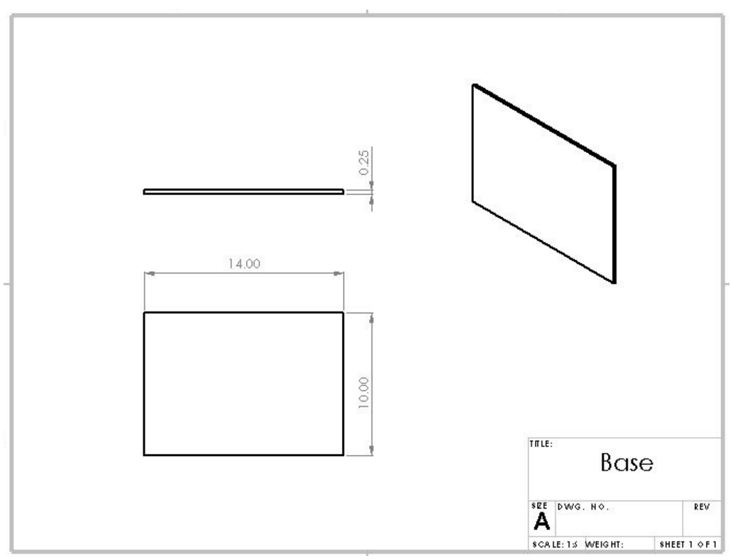

Figure 12: Base with dimensions

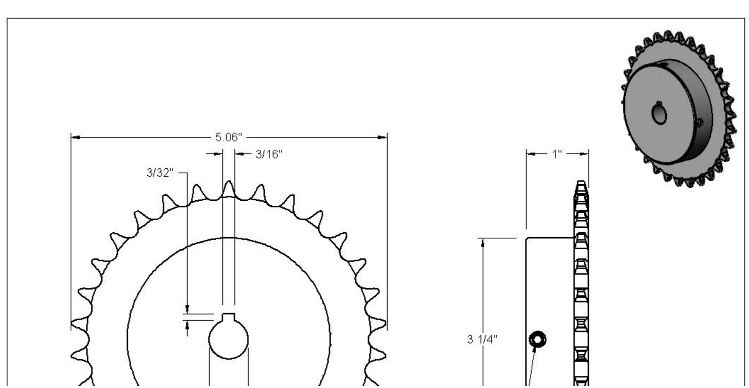

Figure 13: Larger Sprocket

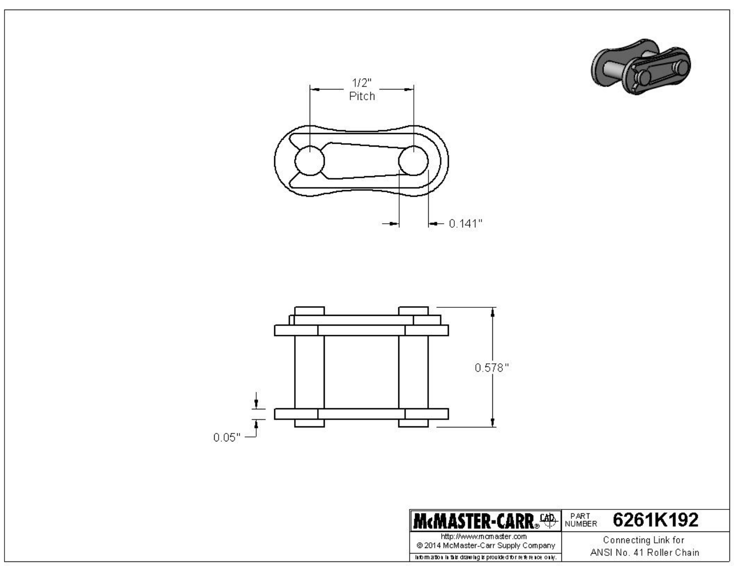

Figure 14: Attachment Link

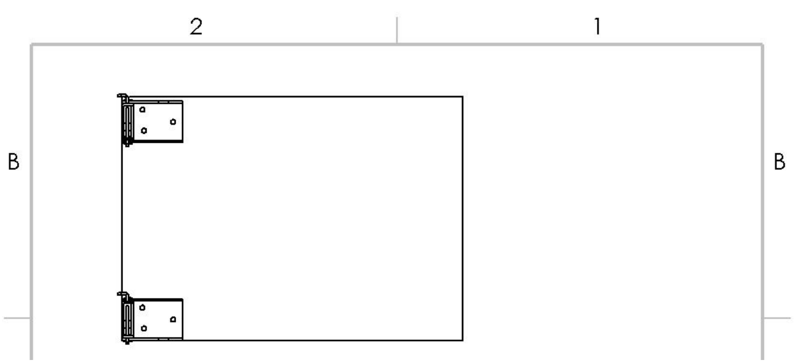

Figure 15: Folding Mechanism

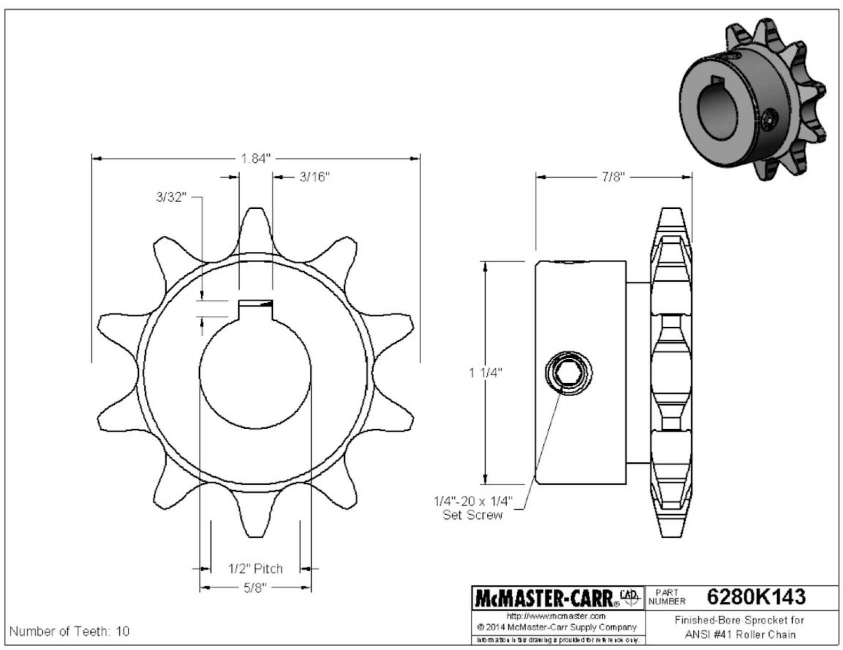

Figure 16: Smaller Sprocket

Appendix F: Parts List

Table 8: Parts List

Vendor	Part #	Description	Quantity
McMaster-Carr	2243T41	4" Wheels	2
McMaster-Carr	2243T43	6" Wheel	1
Menards	1231098	4' x 8' Plywood	1
McMaster-Carr	8978K17	6' 5/8" Tube axle Alum.	1
McMaster-Carr	2737T322	Sprocket (large)	1
McMaster-Carr	2737T118	Sprocket (small)	1
McMaster-Carr	6261K174	Bike Chain	5
McMaster-Carr	6261K192	Attaching Link	1
McMaster-Carr	94975A157	Pin	2
McMaster-Carr	48925K93	PVC - for handlebars	1
McMaster-Carr	6546K49	3' - Aluminum Rectangular Tube	1
Amazon	T-HA-BLU-5.25x5	Havoc - skateboard trucks	1
McMaster-Carr	9056K36	3' - Steering Column	1
McMaster-Carr	9657K284	Pack of Springs	1
McMaster-Carr	7961T5	Plywood Coating	1
McMaster-Carr	60355K506	Bearings	2
McMaster-Carr	7512K58	5' - Wire	1
McMaster-Carr	3897T5	Crimps	1

Appendix G: Shear and Moment Diagrams

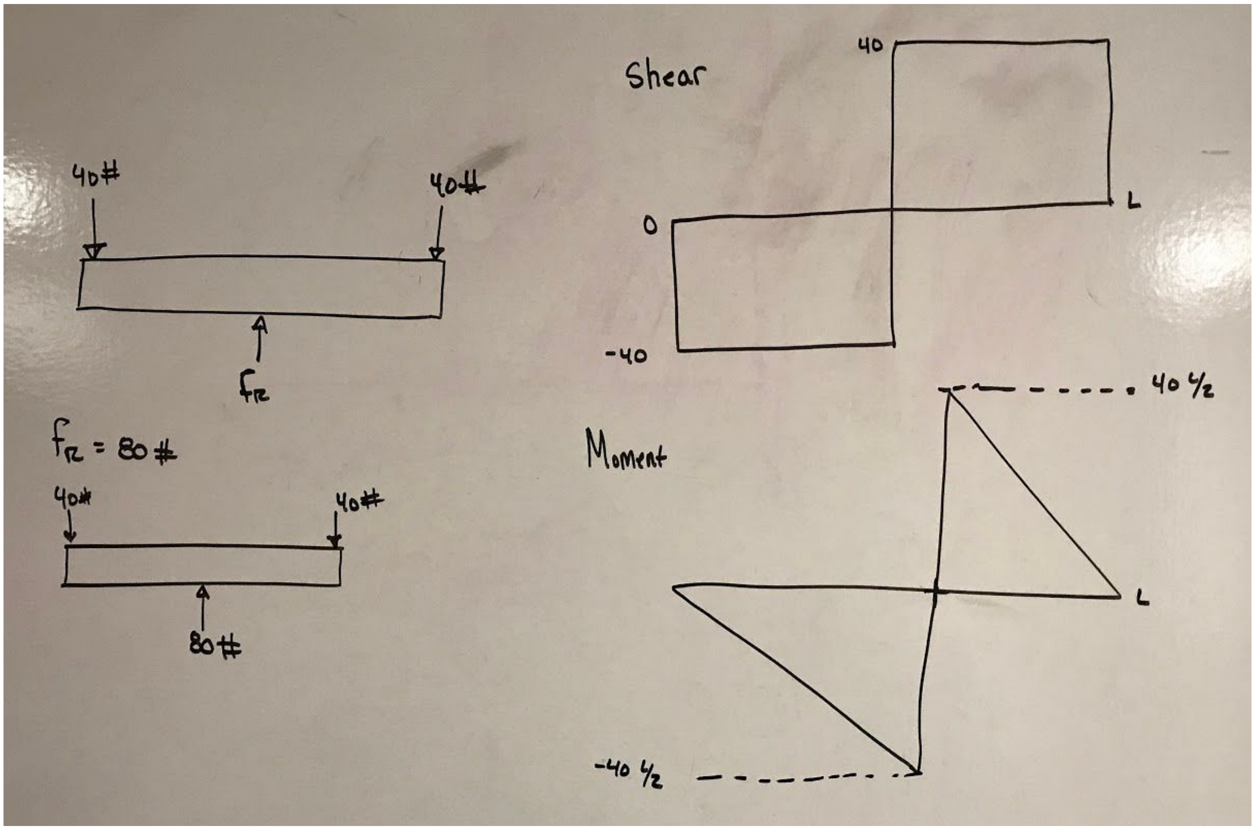

Figure 17: Shear and Moment Diagrams for Handles

Appendix H: Force Diagrams

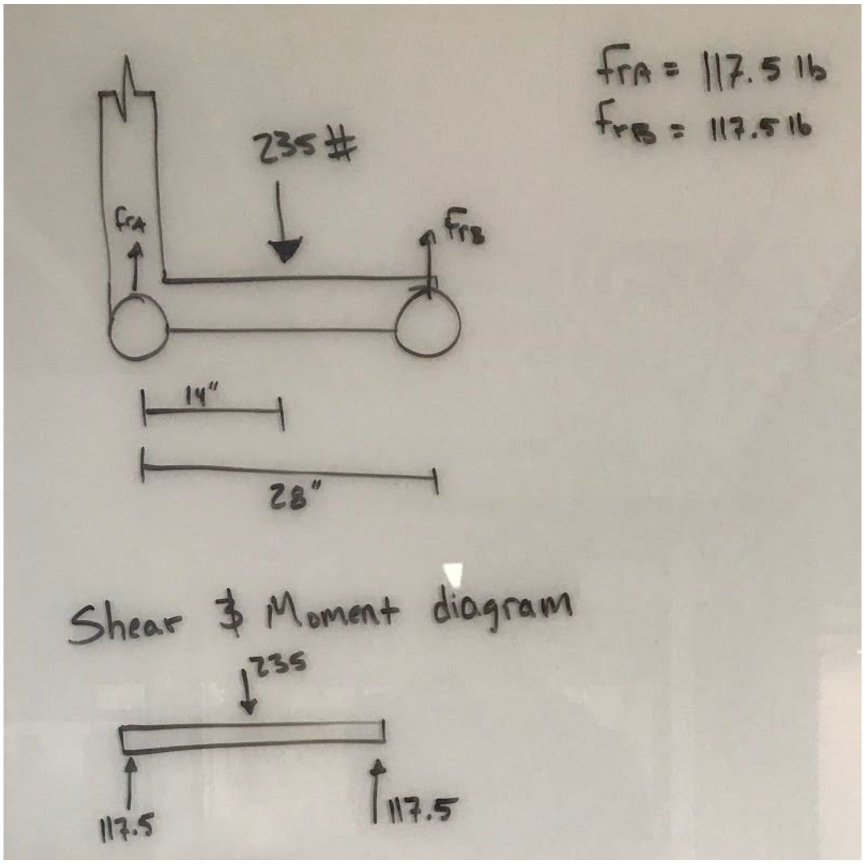

Figure 18: Force Diagram for Base

Appendix I: Calculations

Table 9: Calculations

MPH	5.000
FPM	440.000
Wheel Diameter (in)	6.000
Wheel Diameter (Ft)	0.500

Inputs :

Max speed: 5 MPH

Wheel Diameter: 6 in

Gear Ratio: 3

Equations:

$$FPM = Max\ Speed * 88$$

$$Wheel\ Diameter\ (ft) = Wheel\ Diameter\ (in)/12$$

$$RPM(bottom) = FPM/(2\prod(Wheel\ Diameter\ (ft)/2))$$

$$RPM(Top) = RPM(bottom)/Gear\ Ratio$$

Using the inputs and the equations above the answers in Table 9 can be obtained.

Appendix J: Pictures

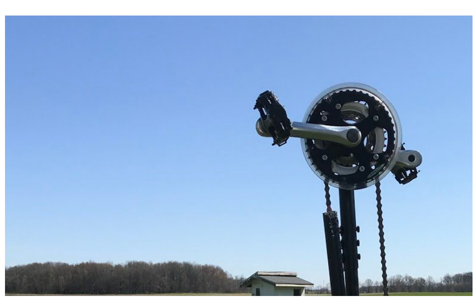

Figure 19: Full Scooter

Figure 20: Folding Mechanism

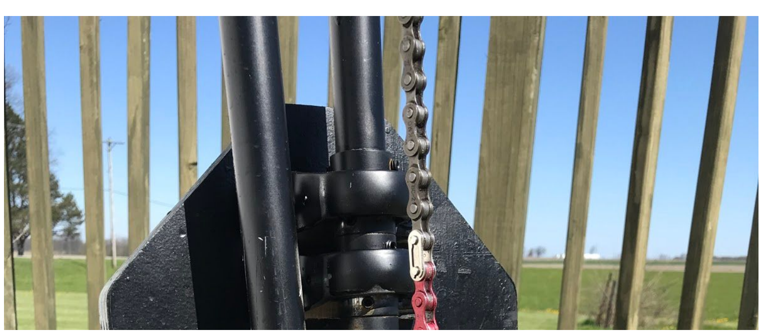

Figure 21: Bottom Sprocket System

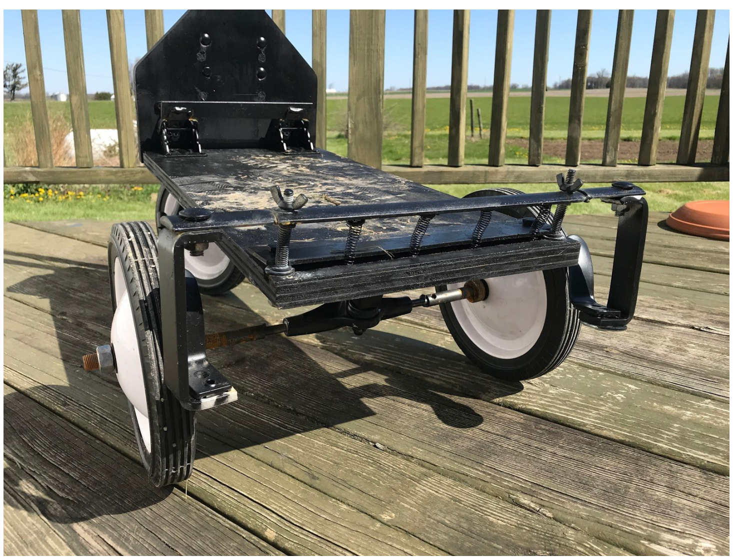

Figure 22: Brakes