GNG2101 Final Report

Summer Working Accessibility ReelChairs

Submitted by

[C4B, Team 12]

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April 19th 2019

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Abstract

This report outlines the development and testing process for the engineering product development in the theme of Accessibility. We worked on the “Working Summer Accessibily” project in particular, which aims to design an apparatus that permits someone confined in a wheelchair to perform a productive activity. The methodology adopted for this product development is the Iterative Engineering Design Process. All the steps and their respective intermediate and final results are documented in this report, ranging from the engineering and customer relationship to the microeconomic topic. The final product proposed at the end is a reel mower attachment to the electric wheelchair of the client which accommodates his summer work plans.

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1 Introduction

1.1 Our Mission

We believe that everyone should have the opportunity to be engaged in their home and community without mobility being an issue. With about 250,000 Canadians that need to use a wheelchair in their daily routine, we took it upon ourselves to design a tool that would allow people to expand what they thought was possible. We achieved this with the design we created called the “Reelchair”. It allows the user to easily cut their grass without needing to leave their wheelchair.

1.2.1 The Client

Our client’s name is Austin, a young man who suffers from Cerebral Palsy. Lately he has been wanting to help his mother with household chores and his mother also thinks this would be a great idea. A team from GNG 2101 F2018 developed a Snow Plow for Austin. This semester Austin’s mother has requested for a Lawn Mower attachment for his wheelchair. It was requested that we build an attachment that would allow Austin to mow his lawn using his wheelchair.

1.2.2 The Client’s Requirements

Our goal for this project was to create a tool that would allow our client to help mow the lawn. In addition, the device needed to be safe, lightweight and easy to use. The device needed to be relatively easy for austin's mother to attach and remove from his wheelchair. Austin has limited motor function with his hands so the device needed to be propelled only by the wheelchair and also be simple for Austin to control. Safety was also a major consideration because this was a device that Austin would be able to use independently or without direct supervision.

1.3 What Makes us Unique

There are many features that make the “Reelchair” stand out from similar designs. The “Reelchair” is very simple to attach and remove and can be done in less than 2 minutes. We also incorporated a shock absorption that helps give the grass an even cut and helps keep the customer in control. This is achieved by preventing the mower from kicking back if it hits

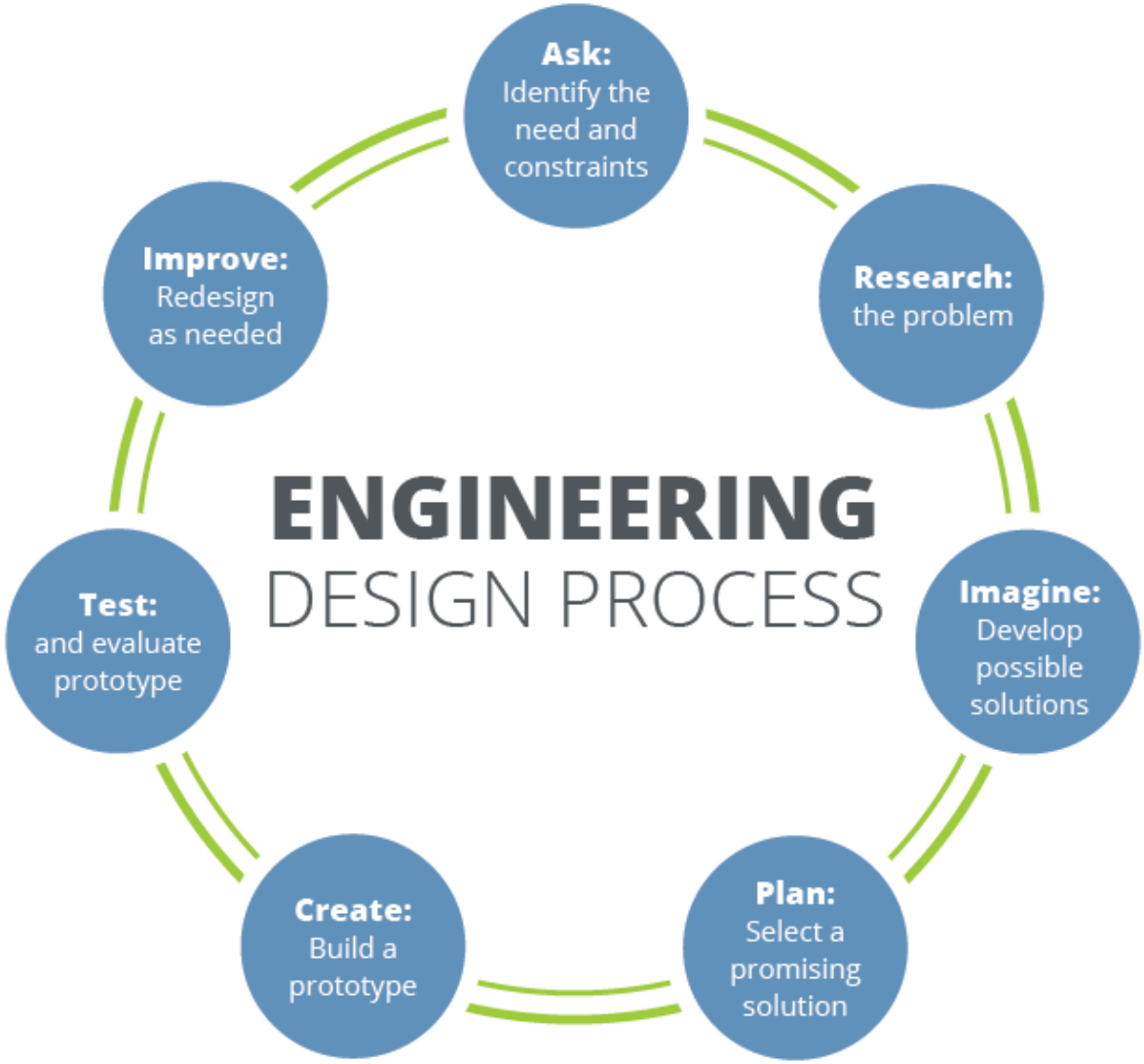
uneven terrain. The user can also chose to use the shock absorption system or simply not attach the springs, which gives the user more control over the function of the Reelchair. The steel guard we implemented protects the customer from any potential debris, and ensures that the users legs are not in danger of touching the spinning blades.

Most importantly, the “Reelchair” is propelled only by the customer’s wheelchair and directly attaches to the sides of the wheelchair using two steel brackets. The frame was designed to be lightweight without sacrificing stability or the comfort of the user. The “Reelchair” is unique because it preserves the typical functionality of a Reel type lawn mower and adds even more features.

2 Engineering Design Process

2.1 The Iterative Design Process Model

Fig. 1: University of Colorado Boulder. (2018) *TE Engineering Design Process.* Retrieved from https://www.teachengineering.org/k12engineering/designprocess



2.2 Implications of using this Process

For this project, an iterative approach was taken. We had the ability to meet with our customer several times and the time to create several different prototypes. We initially drafted a large

number of potential designs and refined them to create a single design to present to our client. After receiving feedback we repeated this process while slowly incorporating new features into our design. This ensured that the best product was produced while constantly keeping our customers needs in mind. Using this process it became clear that the more prototypes that were created, the better the final product would be. By planning to complete multiple prototypes it forced the team to begin building physical prototypes very early. This created an attitude that it was okay to fail early on because through iteration it would help make the final product that much better.

3 Need Identification and Product Specification Process

3.1 Problem Statement

Austin suffers from cerebral palsy and is confined to a motorized wheelchair. He wishes to be able to help out in the summer by mowing the lawn from his chair. Our goal is to develop a functional lawn mower attachment for his wheelchair which will allow Austin to mow his lawn.

3.2 Benchmarking Data

Table 1: *Benchmarking data*

Metric	REEL Scotts 2000-20	OURS	GAS Husqvarna 7021P	ELECTRIC Black and Decker MM2000
Horizontal Length Of Mower	2	1	4	3
Weight Of Mower	2	1	4	3
Guard Strength	4	3	1	2
Time for Assembly /Disassembly	1	4	2	3
Strength Of Joint	4	3	1	2

This table represents the basic benchmarks our product needed to compete with others. This gave us an idea of how useful and how well our product would last over time.

3.3 Metrics

Table 2: ***List of Metrics***

Metric#	Need#	Metric	Priority [1]	Units
1	5	Horizontal Length Of Mower	2	Inches
2	1	Weight Of Mower	1	lb
3	4	Guard Strength	1	newtons
4	2	Time for Assembly/ Disassembly	2	seconds/minutes
5	3	Strength Of Joint	3	Torque lbf
6	6	Price	4	CAD dollars

[1] Priority scale 1 being high, 5 being low

This table shows our metrics and their priority in the final product. Weight of the mower being the top priority made by the customer

3.4 Target Specifications

Table 3: ***Target Specifications***

Metric	Marginal	Ideal
Horizontal Length Of Mower	36”	16”
Weight Of Mower	30lb	15lb
Guard Strength	1N	200N
assembly/disassembly time	5 Minutes	<1 minute
Strength Of Joint	100 lbf	350 lbf
Price	$100	$50

This table shows the target specifications that we wish for our final product to follow.

4 Conceptual Designs

Fig. 2: ***Conceptual Designs by Carter Macklin***

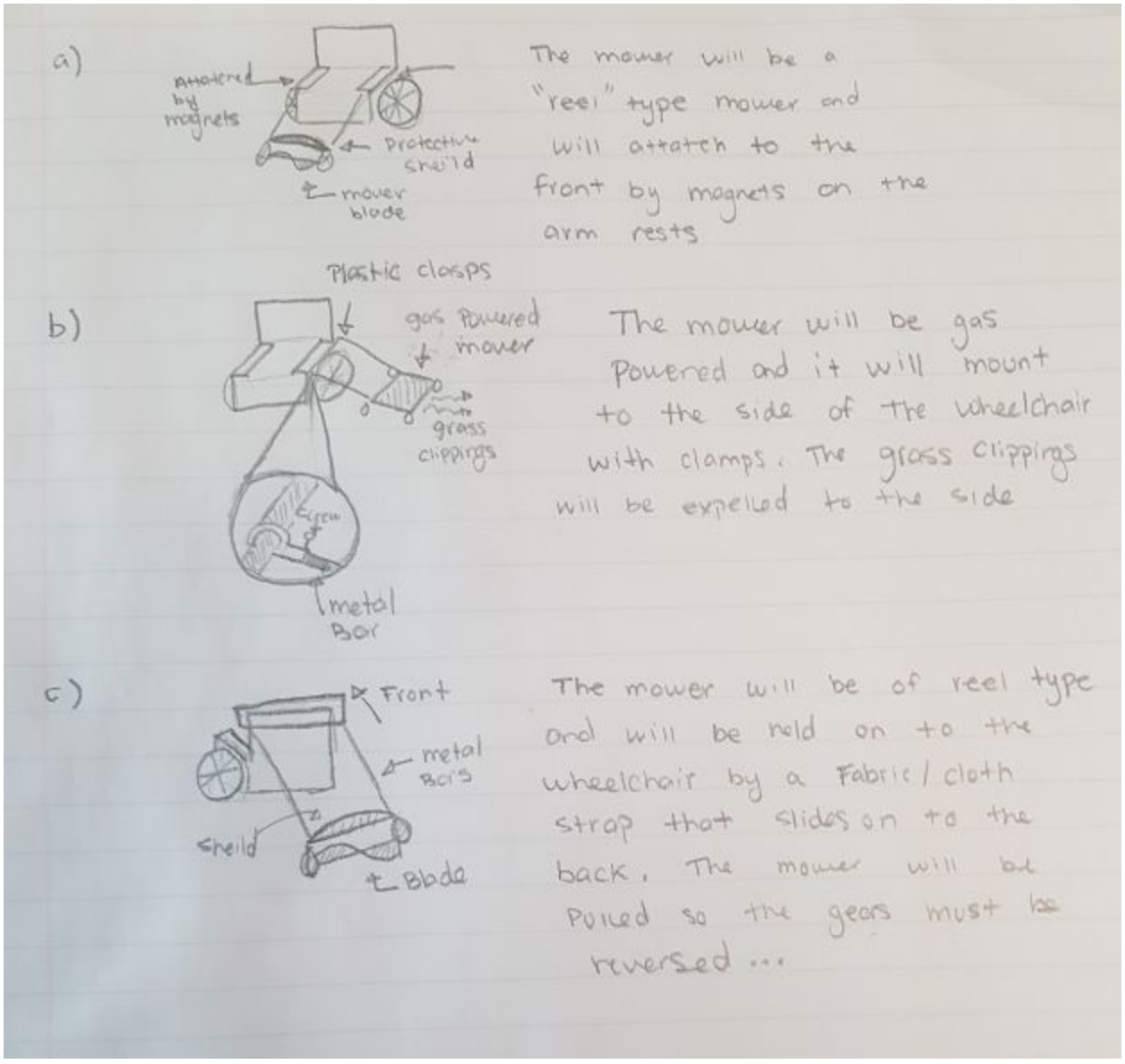


Fig. 3: ***Conceptual Designs by Diana Voninala Rakotonirina***

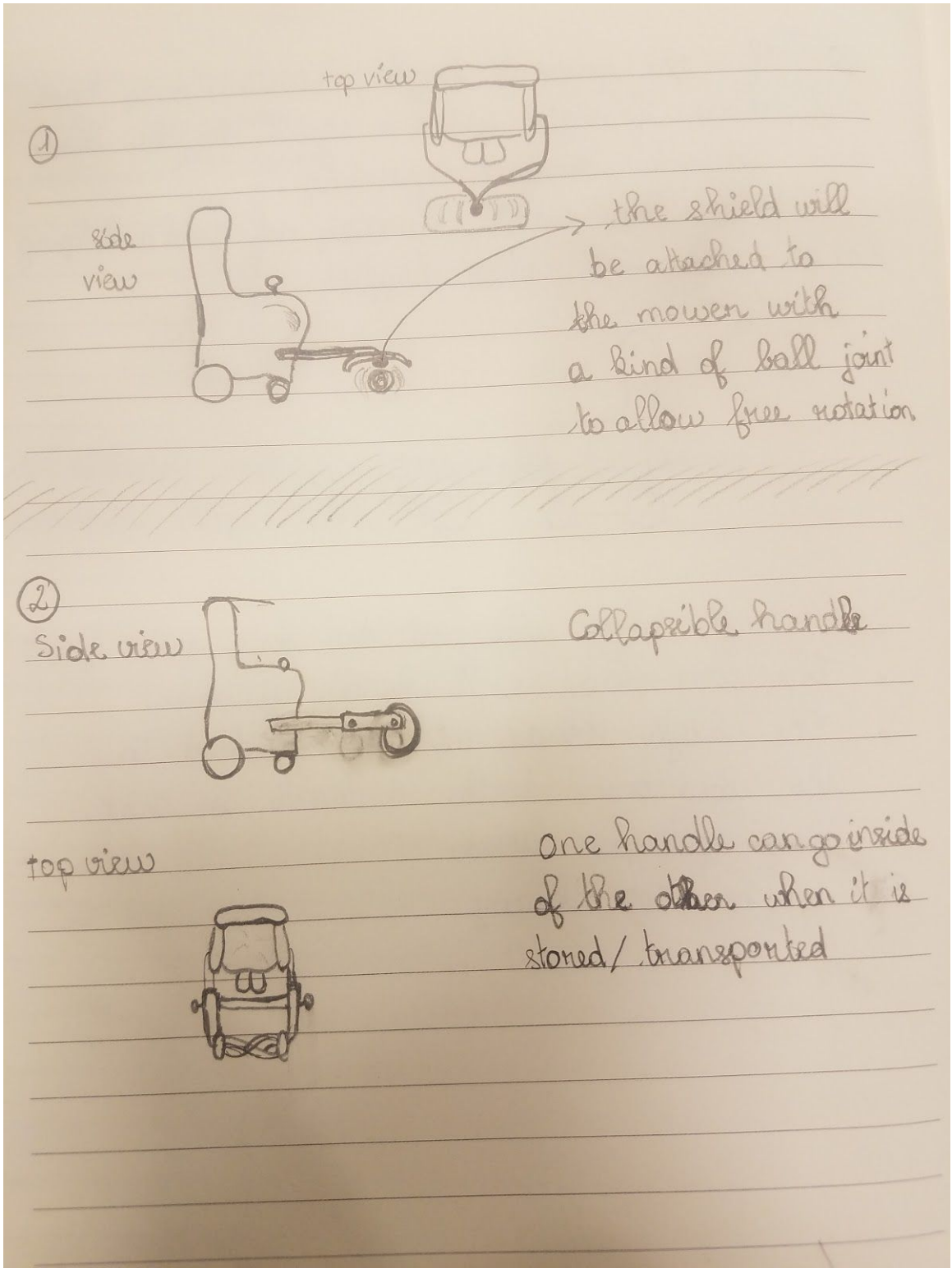


Fig. 4: ***Conceptual Designs by Najib Chowdhury***

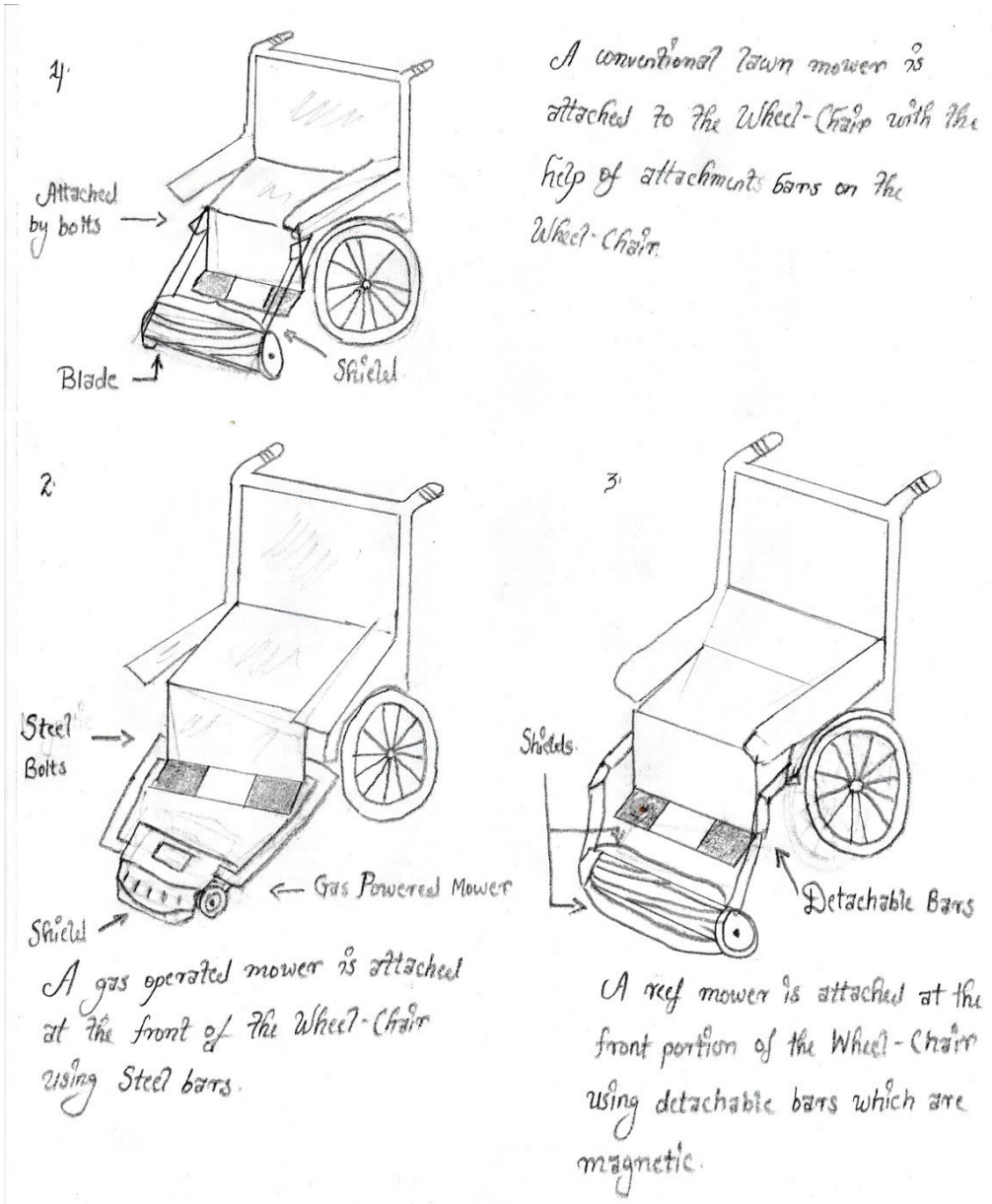
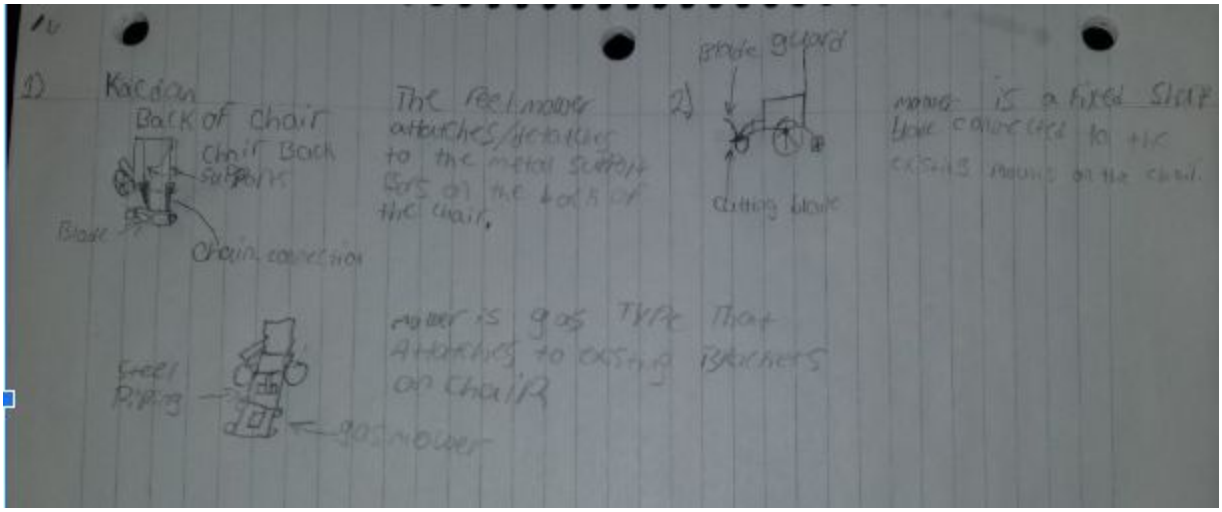


Fig. 5: ***Conceptual Designs by Keadaan Caine***



5 Project Planning and Feasibility Study

5.1 Project Plan

Fig. 6: ***List of Tasks Required to Complete the Project***

#	*Task Name*	*Task Owner*	*Required Resources*	*Completion Deadline*
1	D – Detailed Design and Prototype 1	Everyone		Feb 10
2	E – Project Presentation	Everyone		Feb 11-15
3	F – Business Model	Everyone		Mar 3
4	G – Prototype 2 & Customer Feedback	Everyone		Mar 10
5	H – Economics Report & 1 Minute Video	Everyone		Mar 17
6	I – Design Day	Everyone		Mar 29
7	J – Acquire Parts for Functional Prototype	Everyone		Feb 13
8	K – Test Straight Bar vs Axial Bar	Everyone		Feb 2
9	L – Client Meeting 2	Everyone		Feb 7
10	M – Client Meeting 3	Everyone		Feb 28
11	N – Decide/Compute Axial or Straight Bat	C	Data K	Mar 4
12	Implement Spring System			Mar 5
13	Physical Prototype (Wooden)	C,K,N		Mar 11
14	Obtain “Reel” mower	K		Feb 28
15	Project Deliverable C	Everyone		Feb 3

Fig. 7: (Cont'd) ***List of Tasks Required to Complete the Project***

#	Task Name	Task Owner	Required Resources	Completion Deadline
16	Improve Wooden Prototype			Mar 23
17	Final Prototype	Everyone		Mar 29
18	Perform more accurate measurements	D,K,C		Mar 20
20	Acquire additional materials	K,C	Money	Mar 21
21	Elaborate visuals for presentation	D,N		Mar 29

Fig. 8: ***Initial Project Timeline: Gantt Chart***

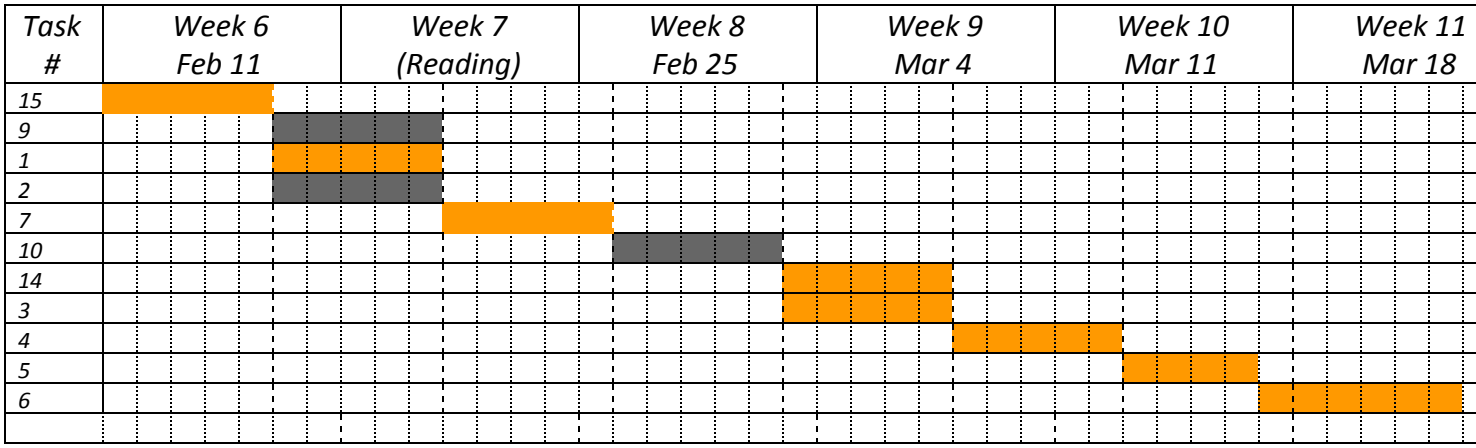


Fig. 9: ***Prototype Bill of Materials and Parts (BOM)***

Part Name	Description (Identify prototype #)	Quantity	Unit Costs ($CAD)	Extended Cost (Qty x $)
Reel Mower	Prototype 1	1	20	20
Square Tubing	Main Frame	3	15.09	45.27
Bolts/Nuts	Fastening	4	0.88	3.52
~~*Cotter Pins(s)*~~	~~For Axial Joint~~	~~2~~	~~0.04~~	~~0.08~~
Steel	Joint Reinforcement	1	14.00	14.00
Springs	shock absorbing system	2	free	N/A
	Total			$ 81.79

5.2 Feasibility Analysis: T.E.L.O.S

Technological:

This product requires mostly fabrication knowledge as there is no coding or electrical work that needs to be done for the project. The skills that we obtain in the labs should prepare us well enough to be able to fabricate the product.

Economical:

After the BOM was completed we were slightly under budget, but we were estimating items would cost the maximum possible. This means that some of the parts (the mower) can be purchased at a reduced price. If this product were to be sold, it would be able to be sold for well over the cost of production because the idea is so niche and would be specific to each customer.

Legal:

With regards to our design there are no legal issues associated with releasing our solution to the public. Although the product employs the use of parts from a manual lawn mower, the Mower itself is not the primary idea of the product that we would consider selling or patenting. The attachment that allows for the mower to act as an accessory for the Wheelchair is the idea that we would consider patenting.

Operational:

With respect to our weekly meetings we have faced no organizational constraints so far. The meetings so far have been coordinated in a way that enabled to us enough time to Discuss our progress and compute the weekly deliverables. As of now, the only concern is the acquisition of the Wheelchair so that we can test our final prototype before the deadline. With the hours in the Brunsfield Centre, we will be able to complete our project During our normal meetings.

Scheduling:

The first prototype is due on February 10th . Once all the materials are acquired the process of constructing the attachment should only take a few hours to build. The biggest challenge will be getting all the required parts especially the mower. The final product is due on Design Day. Moreover, if the prototype works as expected we will have plenty of time to improve on it.

6 Analysis:

6.1 Prototype 1 Analysis

Table 4: ***Testing Data for Prototype 1***

Metric	Marginal	Ideal	Measured
Horizontal Length Of Mower	36”	16”	1.992”’
Weight Of Mower	30 lbs	15 lbs	0.0396 lbs
Guard Strength	1N	200N	0.01N
assembly/disassembly time	5 Minutes	<1 minute	<1minute
Strength Of Joint	100 lbf	350 lbf	0.01 lbf
Price	$100	$50	0$

The first Prototype was a 3D printed model. The purpose of the prototype was to provide an idea of what the product would look like in a 3D space. As a result the testing data was lackluster, this was expected beauce the prototype was made of plastic while the final product would be made of steel.

6.2 Prototype 2 Analysis

During the construction of Prototype 2, wood was used for the main frame that would serve as the support for attaching the reel mower as an accessory. However, during the construction of the prototype we came to realise the obvious structural integrity that was compromised with the choice of material used. The employment of wood made it difficult for it to be incorporated with the moving parts of the mower which put a lot of stress on the wooden frame. Moreover, the force from the movement of the mower made it weak during initial trials making it infeasible for further trials. Given the weak nature of the prototype we were able to gauge types of forces we needed to consider during our final prototype so as to mitigate the issues faced in Prototype 2.

6.3 Final Analysis

Table 5: Final *Specifications compared with marginal and ideal targets*

Metric	Marginal	Ideal	Final
Horizontal Length Of Mower	36”	16”	16”
Weight Of Mower	30 lbs	15 lbs	17.5 lb
Guard Strength	1N	200N	N/A
assembly/disassembly time	5 Minutes	<1 minute	0:45-1:15
Strength Of Joint	100 lbf	350 lbf	70,000 PSI
Price	$100	$50	$81.79

The tests were repeated for the final product and it was more than satisfactory for all the metrics we tested. There is no data available for the shield because the shield had not yet been properly integrated into the design because the bolts to hold it in place were not available.

6.4 Description of Tests Used

We based our joint strength with the average MIG weld on two steel tubes. The result was more than satisfactory in terms of strength and stability. Length and weight were simply measured with tape measure and scale. For assembly time we each assembled our final product foue separate times and had a stopwatch record each time. The result was four slightly varying times from four different people that gave us an average.

7 Prototyping, Testing and Customer Validation.

For this project we produced 3 prototypes before our final product was completed. 2 of which were 3d printed out of PLA (Polylactic acid) and the other out of pine. The main purpose of our 3d printed models was to see how the design would look in person, so to say, instead of as a computer model. This gave us ideas on aesthetic improvements we could make, as well as structural. Aesthetically we believed our models were up to par but our stability was

compromised with the springs inserted along the straight tube to the mower. This allowed us to make the necessary changes in our frame to be able to withstand the downforce. We also concluded that we would change our guard mounting position to improve safety of the customer.

Our wooden prototype was the deciding factor for our final material, frame design as well as mounting hardware. We concluded that the frame must be made of a metal as the wood snapped and fell apart upon mounting and testing on the wheelchair. we would add a supporting bar between our 2 mounting arms. This keeps them level and gives the frame more stability.

Our customer was shown our models and designs before the final solution was built to insure we would have the necessary features they required. This included a guard to protect the user from debris, an easy to use mounting system and a lightweight frame. The customer approved the steel tubing material as a viable option for our frame.

8 Final Solution

Our final solution consisted of a pre built reel lawn mower that was purchased second hand off kijiji. We welded the original mounting for the handle of the reel mower to attach to our steel bar frame. The frame then connects to a pre existing mounting bracket on the front left and front right tow hook of the motorized wheelchair. The bracket has 1 hole on each side to allow a bolt to pass through the bracket and through steel frame. A nut is then hand tightened to hold the frame securely to the bracket.

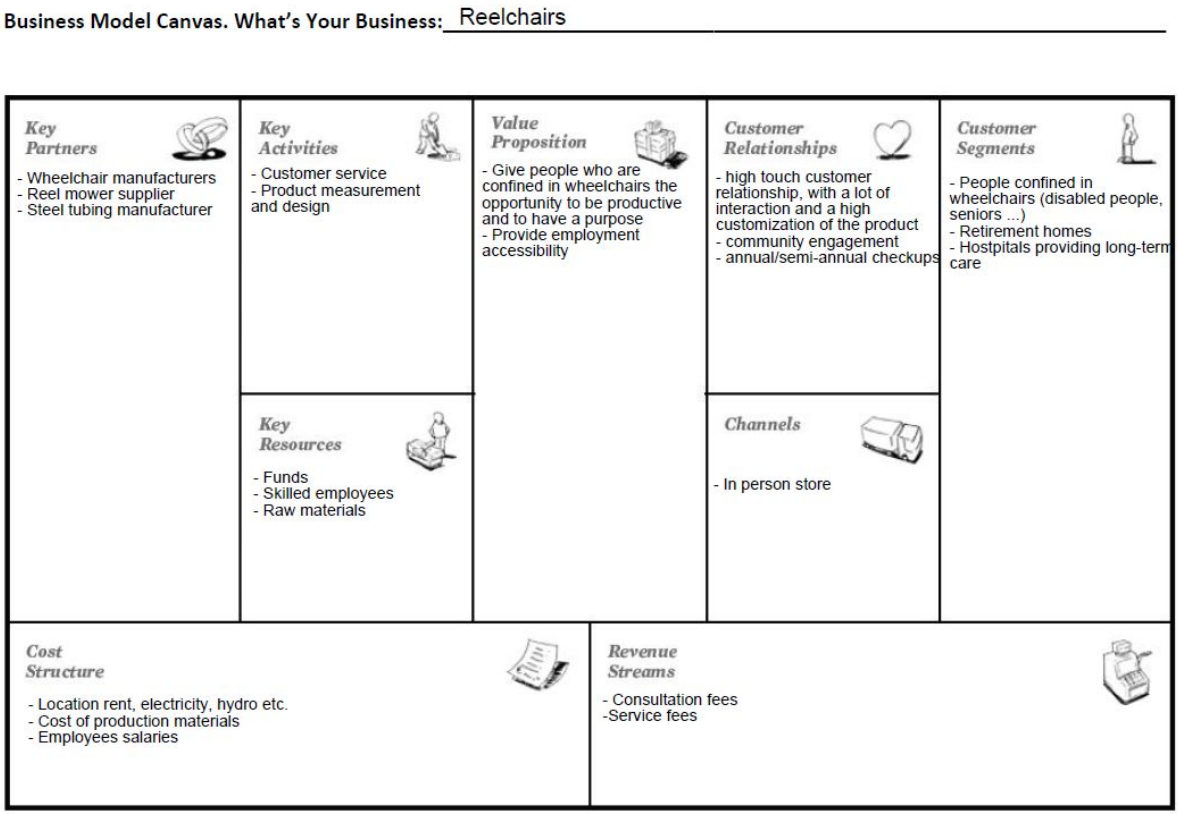
Fig. 10: ***Final Product***

Fig. 11: ***Brackets on the side of the wheelchair***

9 Business model

What we noticed during the making of our product is that it highly relies on customization. Not only the wheelchairs have different standards, but the accessibility needs and other type of needs can vary for each client. We will need to interact closely with them to assess all of the specifications. Therefore, a High-Touch Business Model is suitable for a prospective mass production of the reel-mower. Alongside, we will need a physical workspace for the administrative part of the business, for the customers to come and inquire our services, and for the manufacturing itself. A second business model is then necessary to qualify our work, and it is the Brick and Mortar Model.
These analysis permitted us to elaborate the following Business Model Canvas:

Fig. 12: ***Business Model Canvas***



10 Economic Analysis

With this project, we believe we will offer more than just a reel mower. We will provide a purpose and a lucrative activity for people confined in wheelchairs. But with the high customisation we are proposing, we have to set rigourous and high business targets so that our community engagement does not hold our profits back. We are targeting 42,000 out of the 288,000 Canadians [1] in wheelchairs to acquire a mower attachment in our first three years of operations. It implies that we have to dedicate an important portion of our revenue to marketing. The rent data corresponds to a 3,400 sq ft industrial space, with cutting and welding being our main activities directly related to the project which require power and equipment. The salary data represent the remuneration of 5 workers paid $ 33,000 yearly. We have come to issue this forecasted income statement.

Table 6: ***Forecasted Income Statement of the three first years of operations***

Description	**End of the third year**
Revenue	
Sales (6,000 x $295)	$ 1,770,000
Operating Expenses	
Marketing	$ 350,000
Electricity and utilities	$ 15,000
Salary	$ 403,200
Production Materials	$ 600,000
Depreciation	$ 1,000
Rent	$ 127,500
Total Operating Expenses	$ 1,496,700
Operating Income	$ 273,300
Interest Expense	$ 4,000
Pre-tax Income	$ 269,300
Income Taxes (25%)	$ 67,325

Net Income	$ 201,975

11 Conclusions and Recommendations for Future Work

First of all, regarding our fabrication, our prototype tests allowed us to realize primary deficiencies about our design, such as the bar strength. But, as the constraints we faced prevented us from testing all of the components, we had some compatibility issues with the final metallic product:

- the spring we ended up buying turned out to be too strong for our structure and the range of force it will be subjected to.
- the shield and the screws we acquired could not attach to the handles after the modifications we had to make.

Next and more importantly, this project has not been only for learning to identify to issues, but the improvement as well. On the technical aspect, we would work on developing a compatible guard, use a more flexible spring, and maybe simplify the whole spring system completely if possible. The esthetic aspect of the product needs work as well, such as painting and polishing.

Finally, we also acknowledge that coordination and commitment played an important role this project taught us how important it is for an engineer to focus equally on planning, empathising, analysing the market and the business but not only on the making component.

12 Bibliography

[1] Emma M. Smith, Edward M. Giesbrecht, W. Ben Mortenson, William C. Miller, “Prevalence of Wheelchair and Scooter Use Among Community-Dwelling Canadians”, viewed on March 16th, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4992144/

APPENDICES

APPENDIX I: User Manual

The user manual must include the features of the product, the functions and the capabilities of the product, the installations instructions written in detail, safety guidelines, precautions and health issues if any. The guide must also include a troubleshooting section, which includes technical instructions.

Features of the Product:

1. Like conventional Lawn Mowers the ReelMower's primary task is to cut or mow the grass of the lawn.
2. The ReelMower is especially designed for accessibility.
3. The ReelMower is capable of moving along with the user's movement and direction.

Installations Instructions:

1. To install the ReelMower directly on to the wheelchair, first you must attach the mainframe of the ReelMower to the wheelchair using bolts to the brackets along the sides of the wheelchair.
2. If the wheelchair does not possess pre-installed brackets proceed to install the brackets first along the sides using the U-Bolts to hold against the sides. Below is a visual representation of how the brackets should look like after installation.

Fig. 13: Brackets attached along the sides of the wheelchair

3. After the brackets are installed proceed to step 1 by inserting the mainframe through the brackets.
4. Using the bolts provided with the ReelMower, fasten the mainframe to the brackets sufficiently to prevent it from detaching during use.

Safety Guidelines and Precautions:

- During the use and operation of the ReelMower, ensure that there are no individuals in the path of the mower.
- As a precautionary measure, steel guards have been installed at the front of the mower's blades and behind it to prevent any possible accidents.
- Keep the product away from children.
- The ReelMower is intended to be used under supervision to ensure no unforeseen circumstances occur.

Troubleshooting:

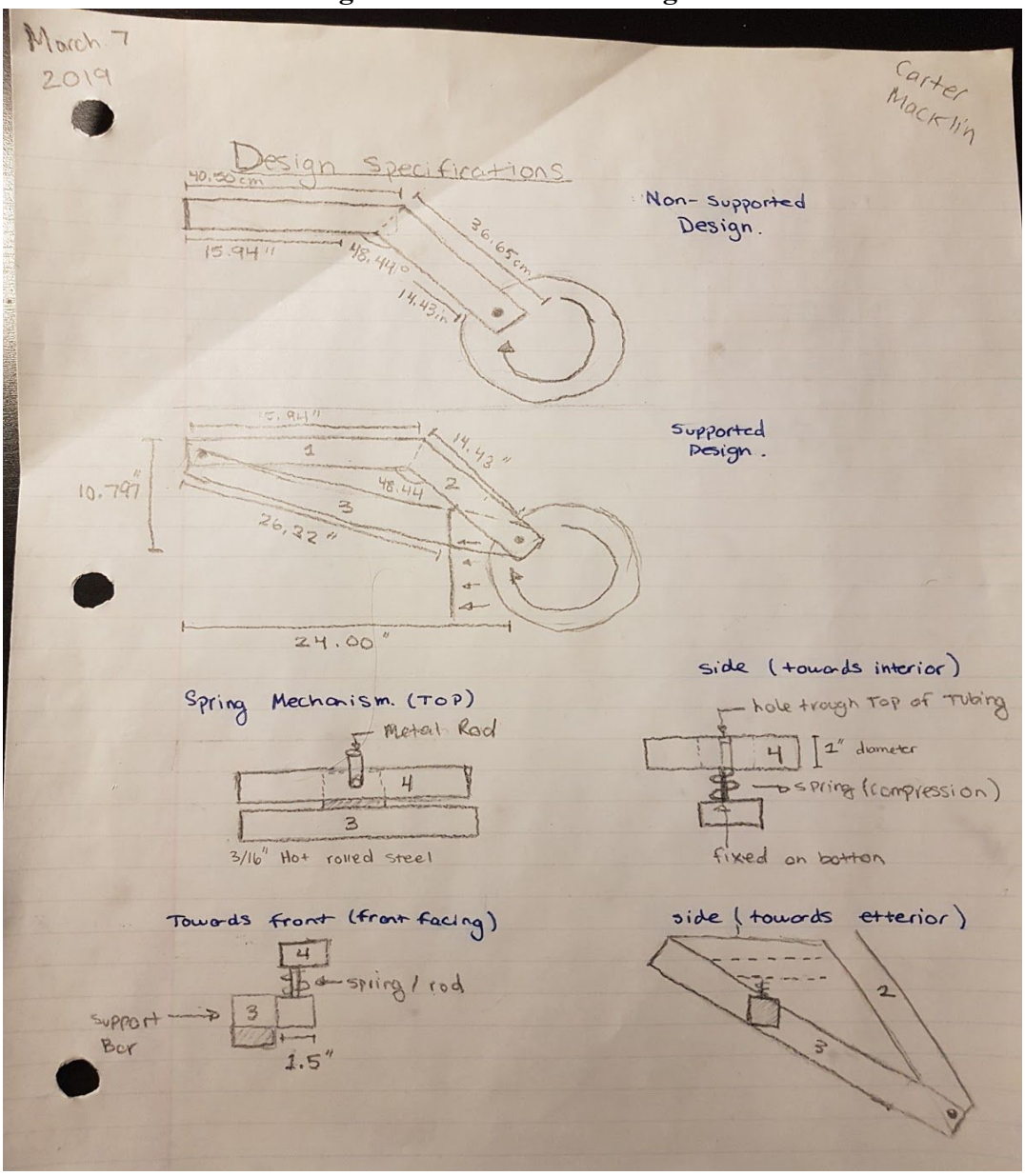
The clearance between the brackets and the mainframe is quite small. Therefore, during installation you might come across that the mainframe and the brackets do not fit. To resolve this issue make sure that the mainframe and brackets are both aligned. Performing this step will ensure that the mainframe slides into the brackets smoothly.

1. During the operation of the ReelMower the product may produce noise which can be easily resolved by adding lubricant to the moving parts of the mower. This will prevent it from producing any noise and also ensure that the moving components are not worn out prematurely.

APPENDIX II: Design Files

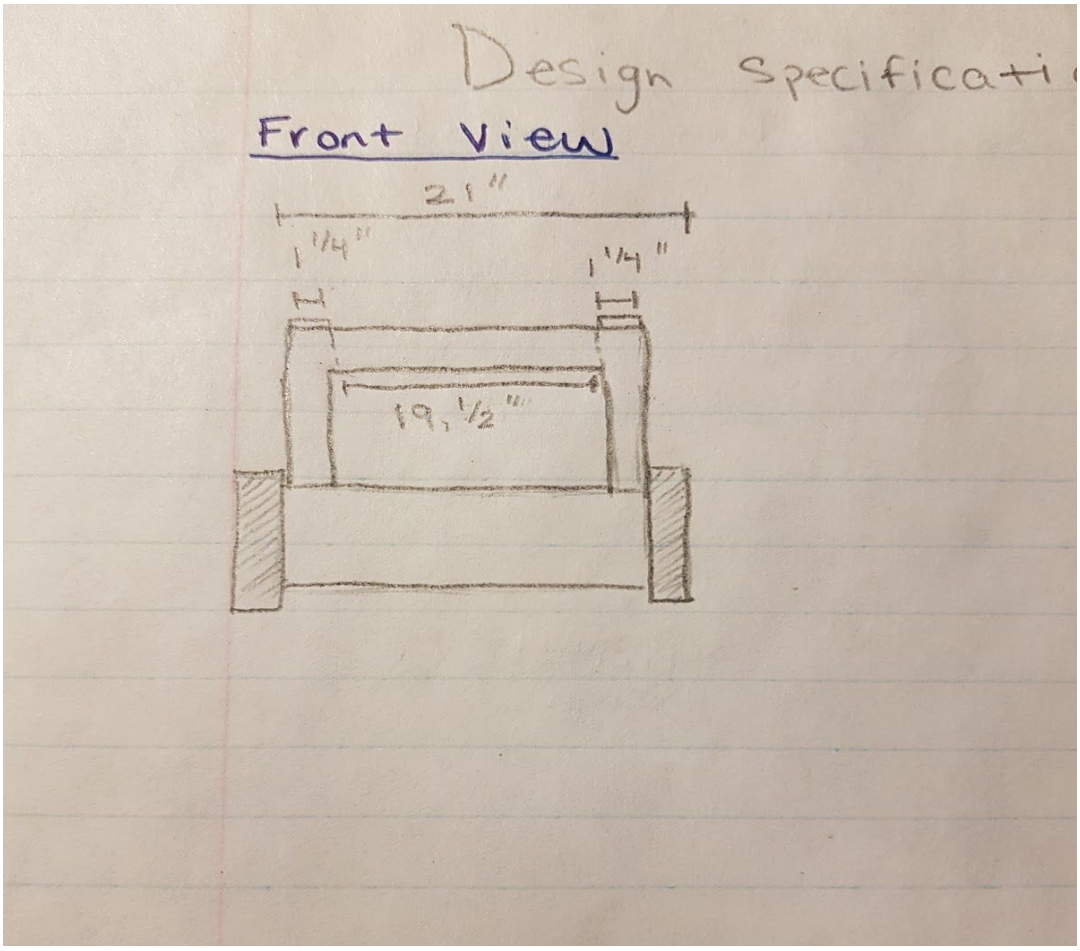
Include all design files with explanations so the client or other students next term can take your project to the next level. Also provide location on MakerRepo.

Fig. 14: Basic Product Design I



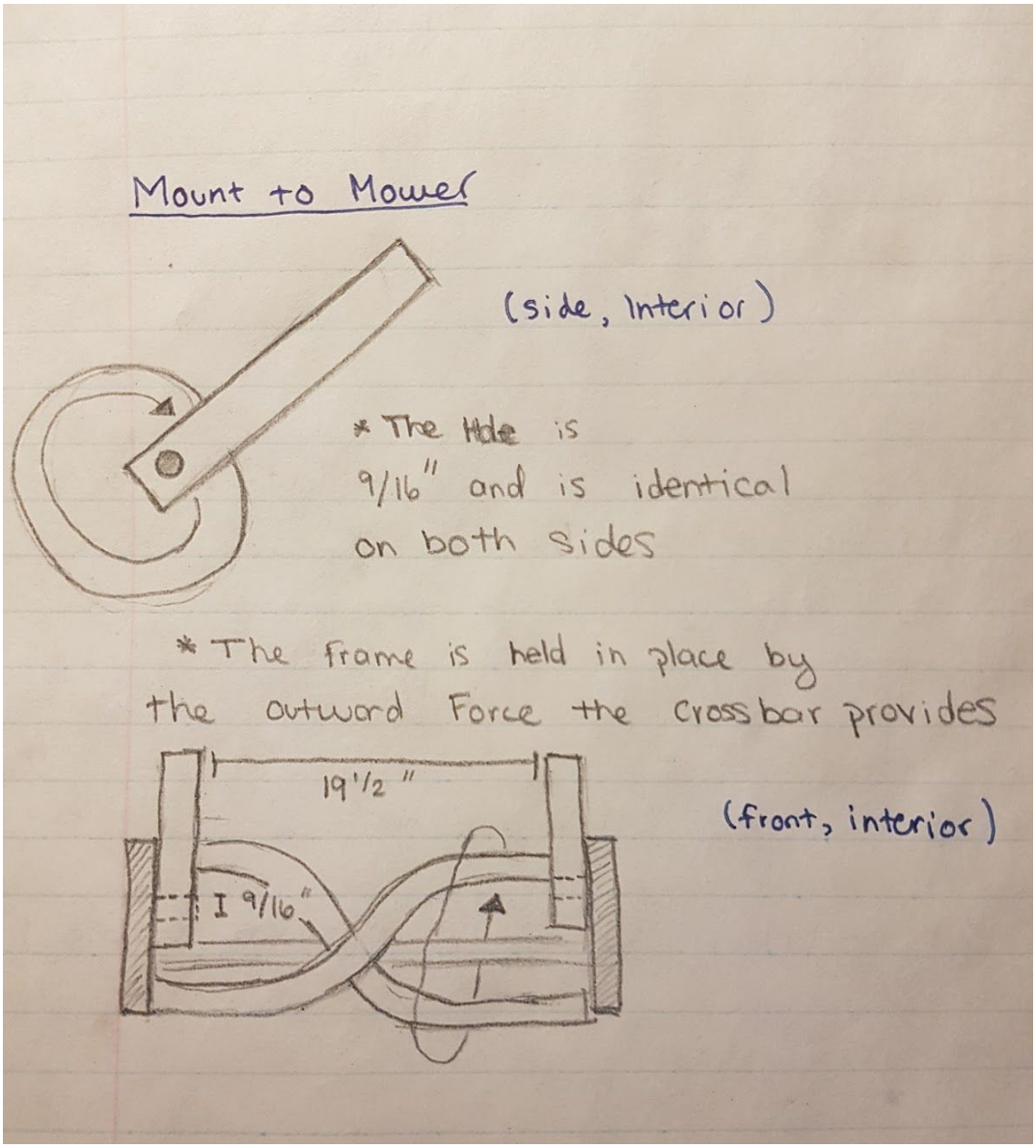
As per the client's need and design, the ReelMower includes 1 foot clearance between the user's footrest and the mower.

Fig. 15: Basic Product Design II



The ReelMower is ideally meant to be less in width in comparison to the user's wheelchair to allow more degree of mobility.

Fig. 16: Description of Mower Mounting System



The mainframe is mounted to the mower itself using the existing attachments of the original mower.

3D Models of Initial Prototypes:

Fig. 17: Front, Top and Side View of Prototype-I

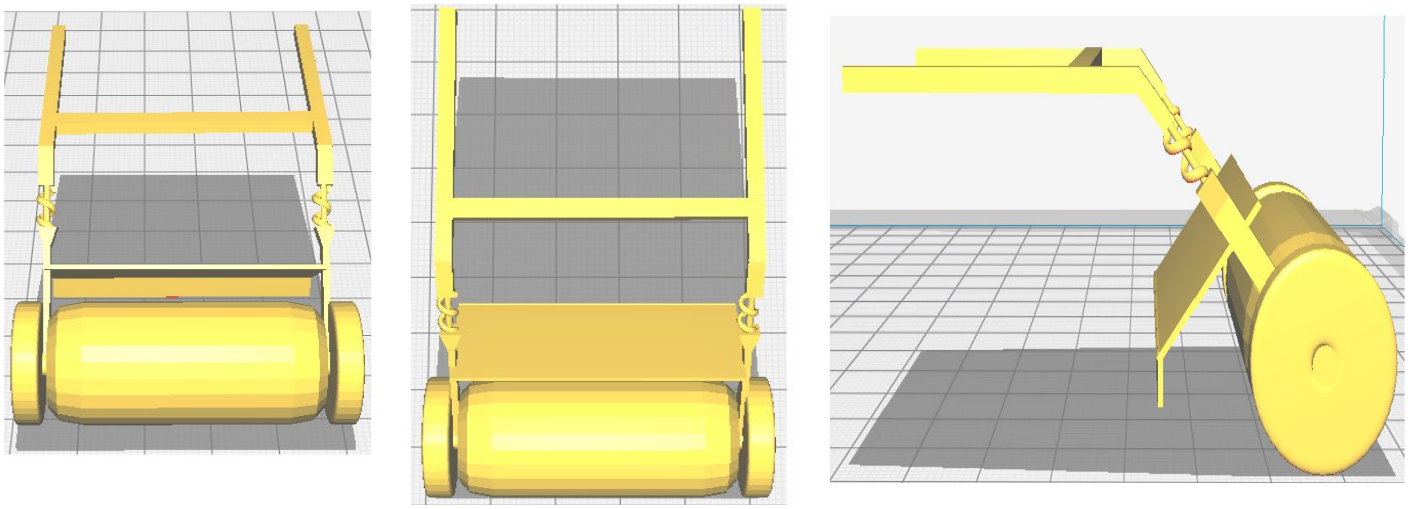


Fig. 18: Front, Top and Side View of Prototype-II