GNG2101 Final Report

SpeedPlow – Winter Wheelchair Accessibility Device

Submitted by

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Abstract

This report is a thorough description of our team's design project, which consisted of innovating an interchangeable, lightweight product, that allows the client to plow snow while remaining in his wheelchair without any need of assistance. This product was named the Speed Plow and met the client's specific needs and wants. In the report, we begin by introducing the reader to the client, and why this product is relevant. We also mention the design process we used, design challenges, and the prototyping process, leading up to our final solution. In the end we discuss our business model canvas, an economics model and suggestions for future work on the project.

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1 Introduction

1.1 Overview

The client is suffering from Cerebral Palsy, which was diagnosed 10 years ago. He has limited motor skills and is currently in an electric wheelchair. Instead of staying inside all winter, he would like to go outside and shovel his driveway. Our team set up with the task of designing a product that would help his needs. This was first done by interviewing the client and following the design process seen in class and presented in this document.

Our problem statement was: Innovating an interchangeable, lightweight product, that allows the client to plow snow while remaining in his wheelchair without any need of assistance.

1.2 Differentiation in our design

What ended up making our product better than the existing products in the market in certain aspects. The first one being cost, as it was much cheaper to manufacture than most benchmarked products. Also, this product is lightweight, can be used in different wheelchair models, it easy to install, and can operate without the user exerting any force, which are some of the specific requirements mentioned by our client.

1.3 Observations from the client

During our interviews, we gathered some important information about the client:

- Client suffers from Cerebral Palsy and is in an electrical wheelchair.
- Wants to shovel snow during the winter season as he is bored; looking for this product to help him pursue a shoveling contract.
- Has wrist limitation with both hands, however his right hand is significantly stronger than the left.
    - Can't turn his wrists
    - Lever motion can be easier for him
- Expects to shovel approximately 6-8 inches of snow.
- It was always his dream to be able to move snow.
- Currently using a adult electric wheelchair, but has a spare children’s wheelchair in which he also fits.

2 Engineering Design Process

The following figure presents the design process used by our team to solve our client's need. The first step is problem identification, via empathizing and speaking with the client. Then we enter the problem refinement loop, where we researched existing solutions, benchmarked, and started dissecting the problem into more specific statements. Once we were satisfied with the result, we entered the persistence loop, which consisted of brainstorming creative solutions to the project, building and prototyping. This loop also included research, and these steps were repeated until we ended up with a feasible solution.

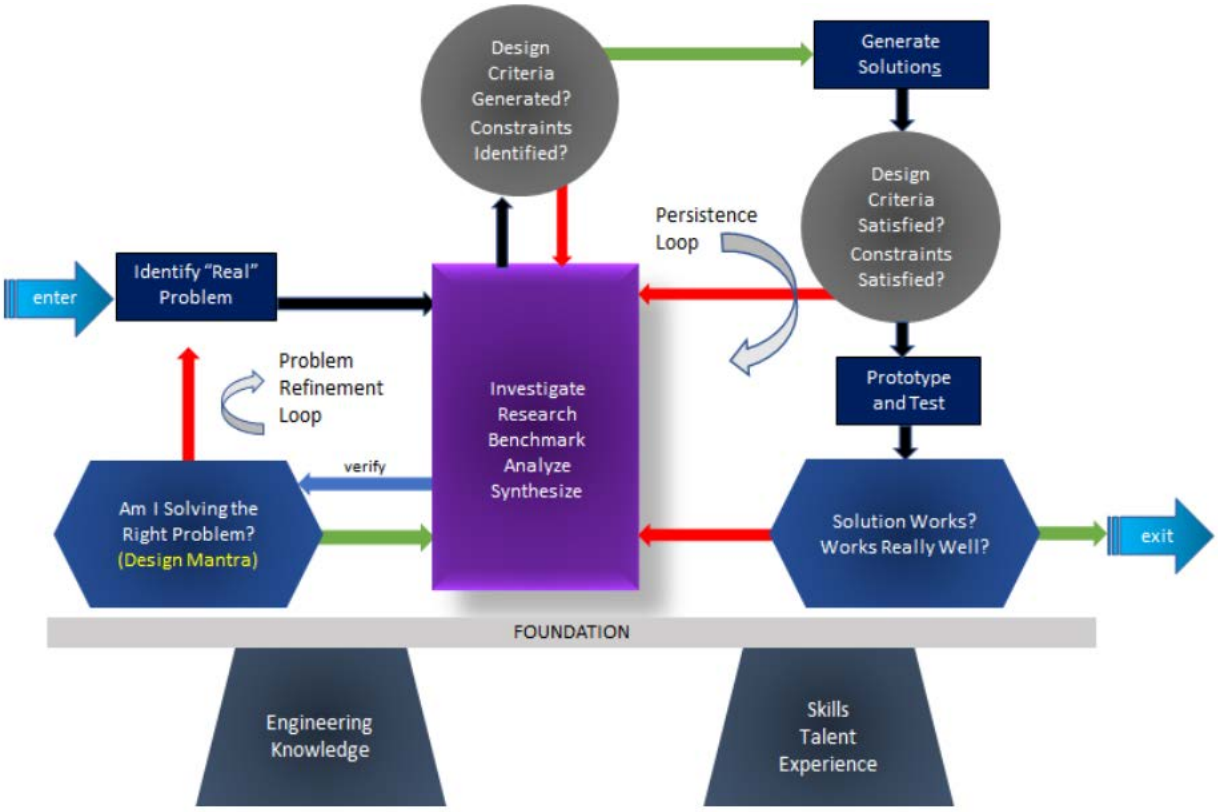

Figure 1. Design process

3 Need Identification and Product Specification Process

3.1 Problem Statement and client needs

The problem statement is innovating an interchangeable, lightweight product, that allows the client to plow snow while remaining in his wheelchair without any need of assistance. The specific customer needs were derived from the client interviews and are as follows:

1. The wheelchair plow is interchangeable from one electric wheelchair to another.
2. The wheelchair plow is portable (carriable by 1 person).
3. The wheelchair plow operates with a little angle to easily push snow away
4. The wheelchair plow has a raise function, so it will be able to raise when not plowing.
5. The wheelchair plow is rigid and waterproof
6. The wheelchair plow can fit through the front door.
7. The wheelchair plow is easy to install.
8. The wheelchair plow uses winter tires.
9. The wheelchair plow operates with safety lights (can be blinkers).
10. The wheelchair plow is aesthetically pleasing.

3.2 Benchmarking

For benchmarking, we researched on the internet and found some interesting products already found in the market. In figure (2), we can see a product that satisfies majority of needs required by the client. This includes the angle the product has, interchangeable and portable, and a raise function. However, this product runs on a advanced and more powerful wheelchair motor as well as it does not include safety lights. This attachment can be found on wheelchair.com under their products section.

Figure 2: Product on wheelchair.com

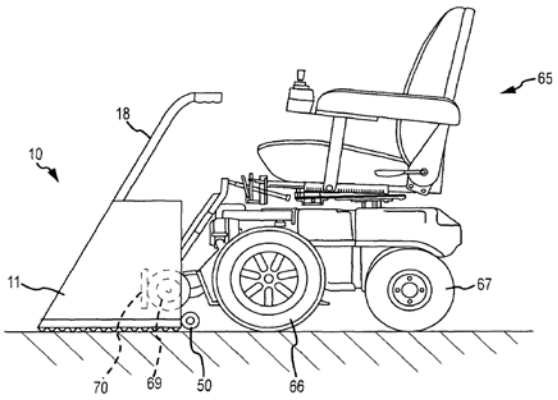

Figure 3. Wheelchair plow patent

We also encountered an interesting patent on Google Patents[1] that utilizes a V-shaped plow to push snow on both sides, using front wheels as well for leverage. A drawing of this design can be seen on figure (3).

3.3 Metrics:

#	Need #	Metric	Imp.	Units
1	6	Plow width	5	in.
2	5	Rigidness	4	GPa
3	2	Plow total mass	5	kg
4	8	Wheel traction	5	N
5	8	Wheel size	4	cm
6	7	Time to assemble plow	3	s
7	3	Motor torque	5	N-m
8	3	Plow angle	5	degree
9	4	Raised distance to ground	2	cm

[1] Us8393096b2 - Plow For Use with a Motorized Wheelchair. https://patents.google.com/patent/US8393096B2/en

10	1	Plow component dimensions	2	cm
11	10	Aesthetics	1	rel.
12	9	Blinker light brightness	1	cd
13	5	Corrosion resistance	5	material

Figure 4. Table of metrics based on client's specifications

3.4 Target Specifications:

#	Need #	Metric	Units	Marg. value	Ideal value
1	6	Plow width	in.	> 33	< 30
2	5	Rigidness	GPa	> 150	> 200
3	2	Plow total mass	kg	< 30	< 20
4	8	Wheel traction	N	< 26	< 29
5	8	Wheel size	cm	<45.72	<61
6	7	Time to assemble plow	s	< 500	> 300
7	3	Motor torque	N-m	4.45-0.3048	4.45-0.3048
8	3	Plow angle	degree	<55	>65
9	4	Raised distance to ground	cm	<1	<1
10	1	Plow component dimensions	cm	<45.75	<53.34
11	10	Aesthetics	rel.		
12	9	Blinker light brightness	cd	< 400	< 600
13	5	Corrosion resistance	material	Steel	Poly

Figure 5. Target specifications based on metrics

4 Conceptual Designs

Based on our project metrics and target specifications already defined, we set out to specify design criteria in two categories: musts and wants. Musts are criteria necessary for the client to have our product. Wants refer to criteria that are not that important but would still increase the value of our product.

Musts: The most important design specifics we will be looking for in our design criteria is, first, its ability to plow snow. Other necessary design criteria include low weight for portability, ability to raise from ground, and small width, to be able to fit through Austin's door. We will also analyze the cost of building each concept.

Wants: Other design criteria that we can also consider include the ability to plow snow on both sides, maneuverability or ease of use, durability, ease of installation, and an aesthetic design (this includes the addition of blinker lights for safety).

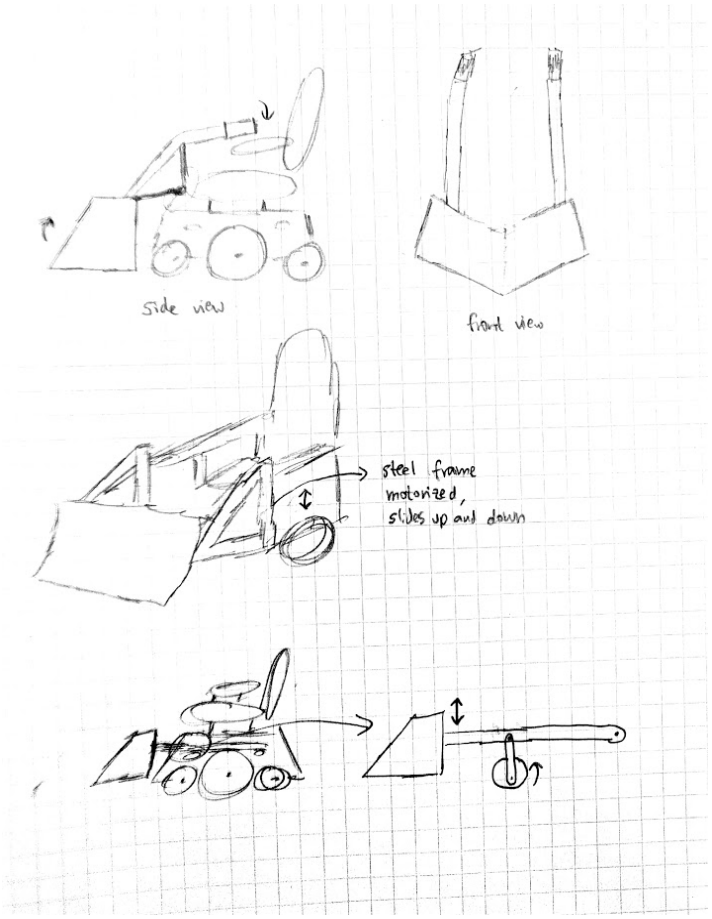

Figure 6. Some design concepts

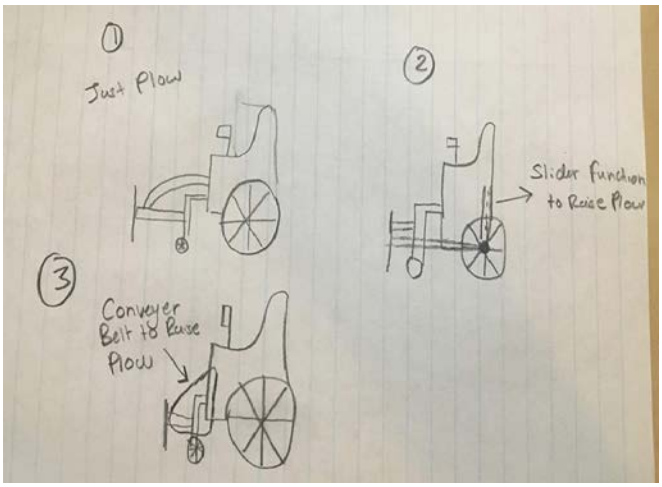

Figure 7. More design concepts

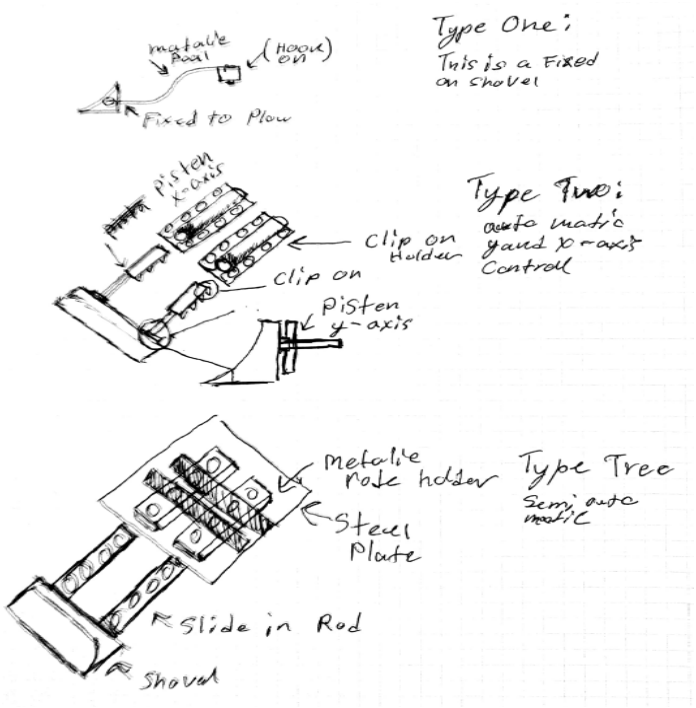

Figure 8. More design concepts

Based on all our preliminary designs, we set focus on a design that uses purely mechanical components, and a lever mechanism to lift the plow (we would later deem this design unfeasible because our client was not able to lift it manually).

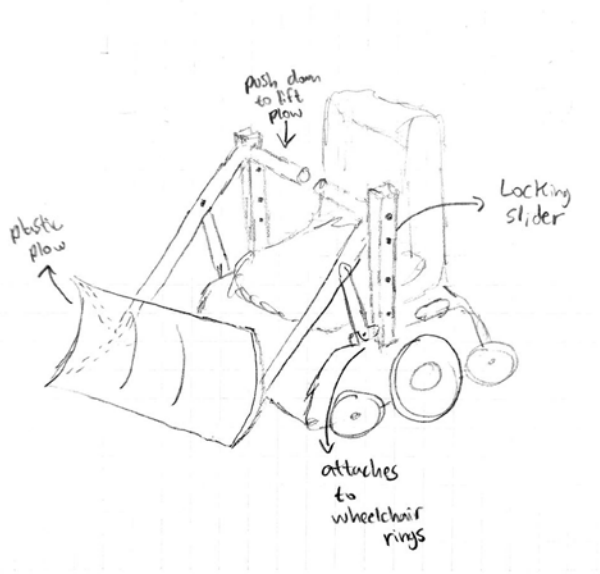

Figure 9. Drawing of first prototype design

5 Project Planning and Feasibility Study

5.1 Project Planning Gant Chart:

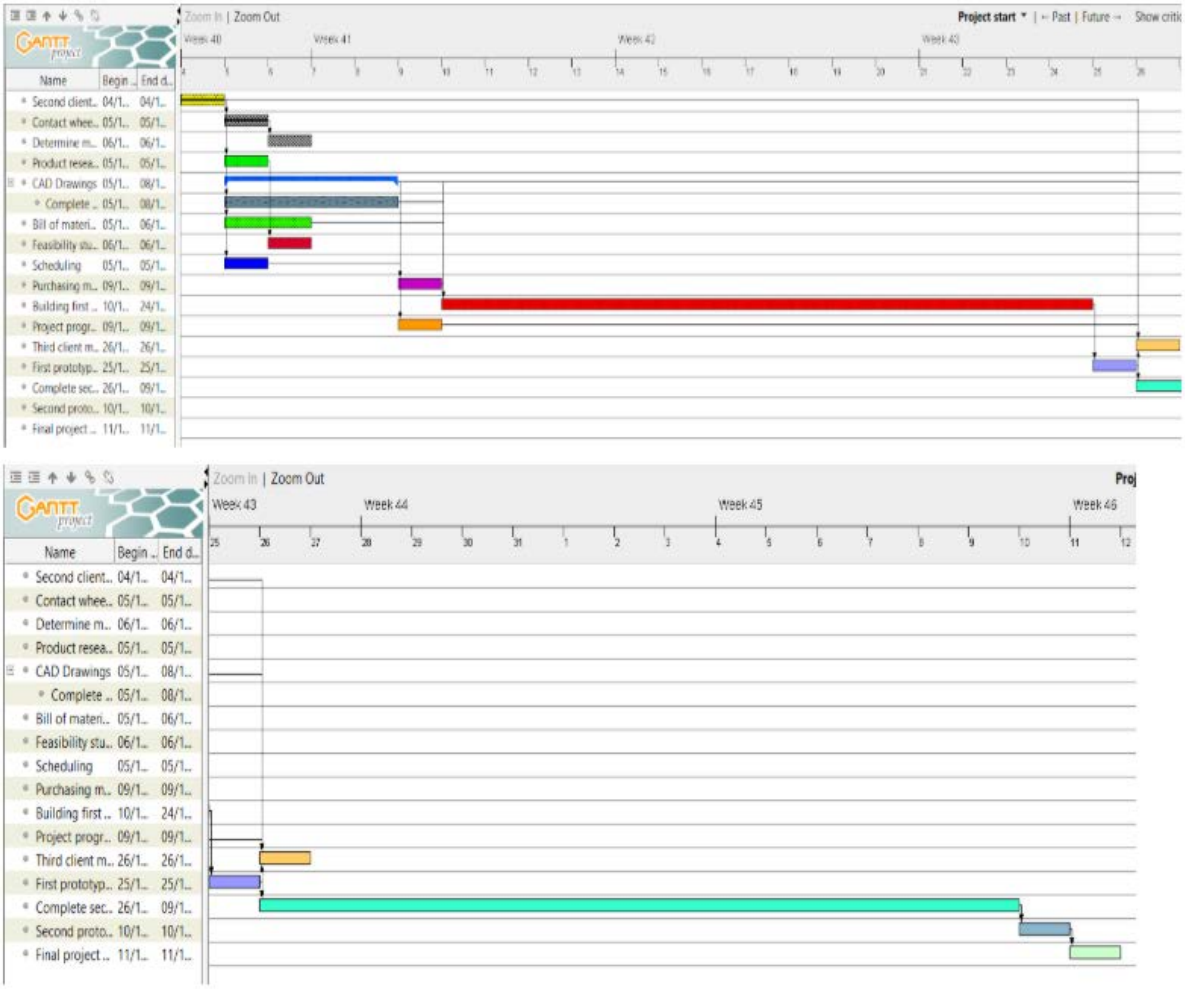

Figure 10. Project Gantt Chart

5.2 Feasibility Study:

The following is our feasibility study presented before the completion of our project:

Our team believes we have enough expertise and technical resources to complete the project given by the client. With the training sessions in the STEM building as well as additional training sessions that can be taught to us from the Brunsfield centre, we believe that this can be within our grasp of building the wheelchair plow. Some examples of mechanical processes the STEM lab taught us was to use the mill, the lathe as well as the drill. This will come essential to us when we need to perform a face cut, drill holes into our metal, or even to create a smooth finish on one of our products.

This project requires minimal parts; however, the parts may be over our one hundred dollars budget. For example, we must get custom metal to support our plow, which will certainly cost a good portion of our budget. Another reason it may be over our budget is that, upon our second client meeting, we settled on using a V-shaped plow, and not a normal plow. This request is upwards of a hundred dollars, which we simply cannot put all of our budget into. To fix this, we compromised, and have settled for a cheaper plow (which is not V shaped, but we believe it can serve its purpose) for our first prototype. If the client is not satisfied, however, our one-hundred-dollar budget may need to be increased, but this can be determined after our main products are purchased.

Our design is a custom-made design, and although it is based on a patented design, the changes are so broad that legally there will be no issues.

With every project, there is always an organizational factor that comes into play which determines the outcome of the result. One of the main one is keeping the group organized. This is a key part to the group's success, because if we were aren't organized, this will lead to the product not being complete or even complete to our full potential. This can be easily avoided by constantly communicating with the members to always keep them in the loop of when things are due or if we had to work on a side assembly for the project. Little things like that will keep the group organized and be able to finish the project with success.

The main deadlines that we need to consider is Building first prototype (October 14, 2018) , Project progress presentation(October 18th, 2018), Third client meeting (October 25th, 2018), First prototype testing (November 15th, 2018) and Final project presentation (November 28th, 2018). We believe that the dates are reasonable, as long as the group can meet at least for 4 hours a week to work on the project and at least get some hands-on work with the wheelchair every week moving on forward. Our Gantt chart schedule will help us stay on track for completing these deadlines

6 Analysis:

Part of our analysis consisted of researching the best way to build our prototypes with our limited budget. Because of this, we resorted to 3D modelling of our prototypes, in a software called Siemens NX. The following figures show the models used. In the appendix section one can be referenced to the original modelling files.

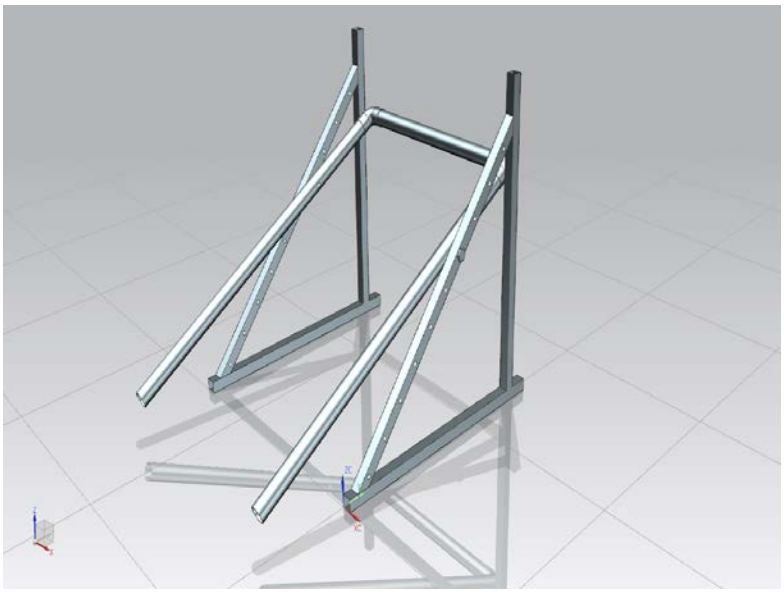

Figure 11. CAD model of first prototype

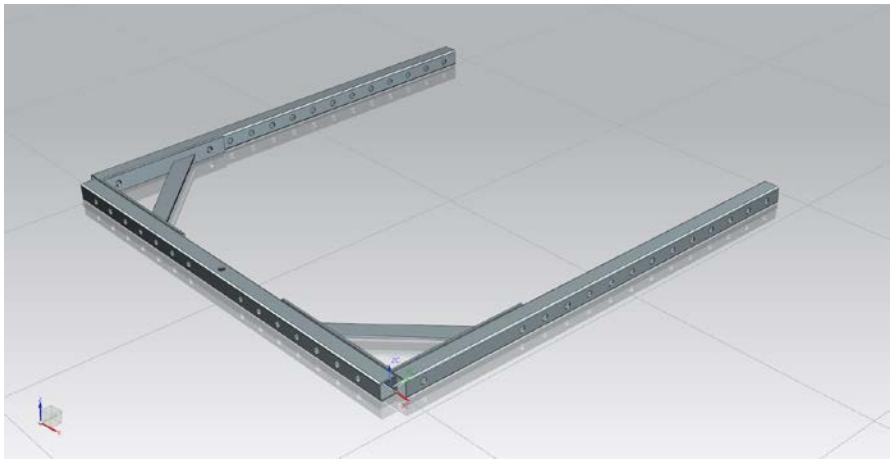

Figure 12. CAD drawing of second prototype

7 Prototyping, Testing and Customer Validation.

Our first prototype consisted of a cardboard mockup with accurate dimensions to test maneuverability and design aspects. This is shown in the following figure.

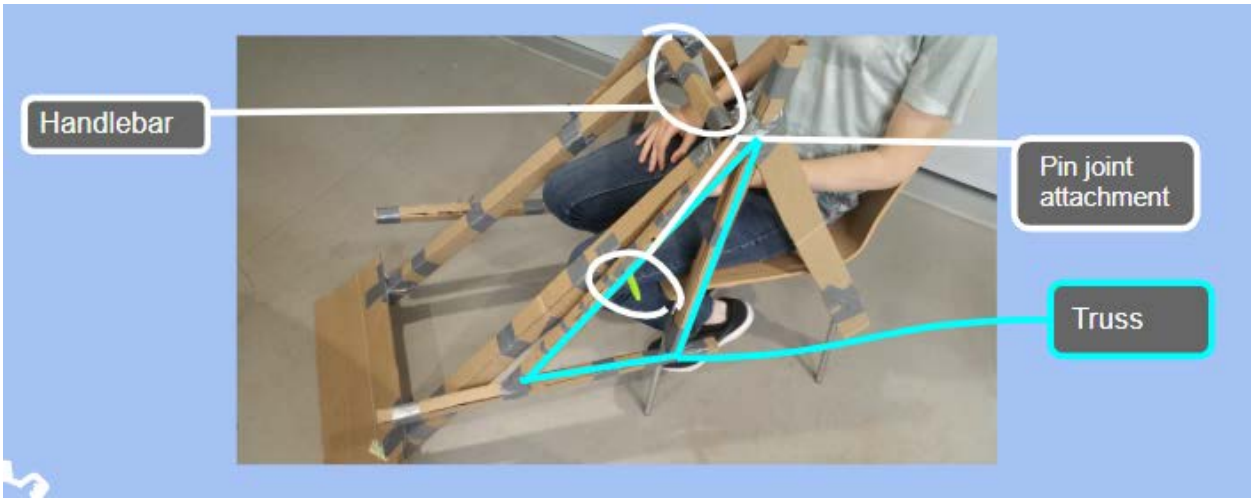

Figure 13. First protoype

After meeting with Jill and Austin Downs on November 8th, our initial prototype (figure 1) was presented and tested. Upon testing, it was clear that Austin would be unable to use this prototype as he could not push down on the bar that raises the plow, which is the main customer need. This meant that the second build had to either include hydraulics to raise the plow or create pivots on the side so that it can move freely and still be able to push. After looking at prices, it was determined that hydraulics would not be an option, as it was too expensive for the $100 dollar budget. This led to the second prototype having a pin-pivot on the sides so that the plow would raise on its own if contacted with an obstacle. The final modification we had to include in our second prototype was to have the shovel tilted on a angle, rather than a straight shape. This was requested by the client.

After that, we built our second prototype.

<u>Design changes between prototype I and prototype II:</u>

- PT II has much more room for Austin get into and while seated
- PT II is interchangeable in the front rather than PT I where the shovel would be permanently installed on the front.
- PT II has no push bar, which was requested by the client. This takes away stress for austin to raise the shovel.
- PT II is tilted on a angle to push snow to the side
- PT II uses less steel, which is much more affordable and compact for the builder and the client.

- PT II is highly modular. The metal frame can be reattached at different lengths, to potentially attach to differently sized wheelchairs.

Figure 14. Second prototype build

Figure 15. Close-up of frame

8 Final Solution

Our final solution was a polishing of our second prototype, as can be seen in the following figure.

Figure 16. Final prototype build

This solution is lightweight (small parts, light plastic shovel), interchangeable (There are holes on front and side for changing sizes, so that it can be adjusted for different wheelchairs), and able to use without the user exerting any force, as there are no levers or pulling mechanisms.
Also, it is rigid, as it is made of steel, coated with rust-proof paint, and looks pleasing to the eye.

9 Business model

Business Model Canvas. What's Your Business: Wheelchair attachable snow-plow

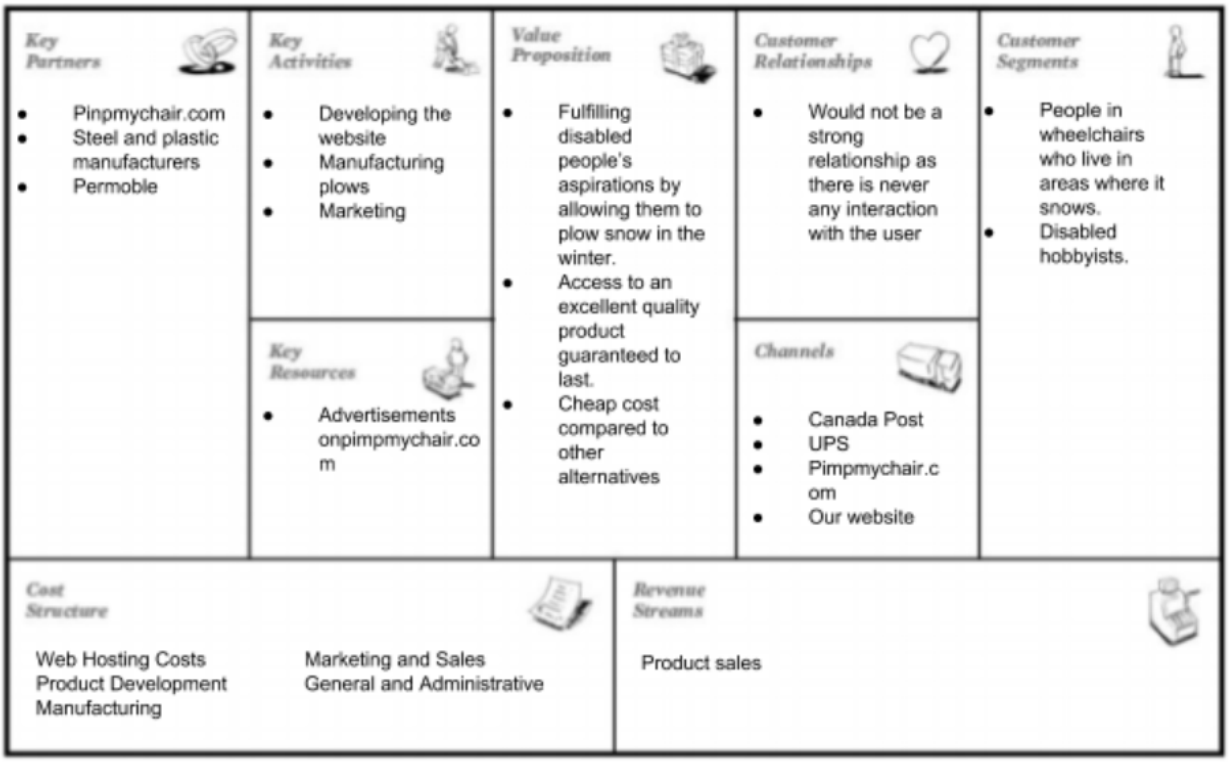

Figure 17. Business model canvas

10 Economic Analysis

For our economic analysis, we made several assumptions:

Disability impacts the lives of many Ontarians, and the numbers of people with disabilities is increasing as the population ages. Today, over 15% of Ontario's population has a disability, including more than 40% of people over age 65. About 1.85 million people in Ontario are in a wheelchair because of a disability.

- The selling price for our product: $399.99
- Cost of goods sold per product:
  - Materials: $100
  - Manufacturing: $75 (using specialized machinery)
- Selling expenses:
  - Marketing: $500 P.A.
  - Website hosting: $2.95 per month
- Administrative expenses:
  - Salaries and wages: Payment by commission, $70 for every product sold
    - The only employees would be ourselves on the first years
  - Rent (including power and gas): $600 a month
- Sales goals:
  - First year: 60 units
  - Second year: 90 units
  - Third year: 130 units.
- We did not include taxes and interest in our cost calculations.

With this data we can predict and income statement for the following three years, as shown on the following table.

	2019	**2020**	**2021**
Sales Revenue	24000 (60 units)	36000 (90 units)	52000 (130 units)
Cost of Good sold	10500	15750	22750
Gross Profit	= 13500	= 20250	=29250
Selling expenses	536	536	536
Administrative expenses	13200	19500	27900
Operating Income	**-236**	**214**	**814**

Figure 18. 3 year income statement

Also, a final Bill of Materials for our finished product is shown on the following figure:

Item no.	Description	Supplier	Quantity	Unit price	Net price
1	Snow Joe Edge 26" snow shovel	Amazon.ca	1	$30.99	$30.99
2	Steel square tube 1" x 1/16" x 120"	Metal spmkts	1	$23.23	$23.23
3	6" zinc plated corner brace	Home Depot	2	$3.20	$6.40
4	zinc-plated U-bolt	Lowes	2	$5.99	$11.98
5	5/16" x 2" hex bolt	Home Depot	8	$0.49	$3.92
6	5/16" hex nut	Home Depot	8	$0.15	$1.20
7	5/16" locking washer	Home Depot	8	$0.50	$4.00
8	1/2" x 2" hex bolt	Home Depot	1	$1.05	$1.05
9	1/2" flat washer	Home Depot	1	$0.39	$0.39
10	1/2" hex nut	Home Depot	1	$0.43	$0.43
11	1/4" hex nut	Home Depot	12	$0.12	1.44
12	1/4" Round head screw	Home Depot	12	$0.57	$6.84
13	1/4"Flat head screw	Home Depot	4	$0.81	$3.24
14	Steel Coat Paint	Home Depot	1	$8.47	$8.47
15	1*1*0.12 HR Steel tube	Brunsfield	1	$3.86	$3.86
16	1/8" x 2" x 4" CR steel bar	Brunsfield	0.33	2.83	$0.93

Figure 19. Bill of Materials

11 Conclusions and Recommendations for Future Work

From this project, we learned that working around limitations is a big challenge but yields the most creative results. Also, just building prototypes and testing was often the fastest solutions, and the one that gets more results. When in doubt, just build it and test it.

Finally, small-scale manufacturing is expensive, and in these types of projects where budget and time is limited, good communication (team and client) is key.

For our next steps, we would like to get our client to test our prototype, and get feedback, continue improving our design, and maybe turning the concept into a small-scale business.

12 Bibliography

Us8393096b2 - Plow For Use with a Motorized Wheelchair.
https://patents.google.com/patent/US8393096B2/en

Bounder Power Wheelchair with Snow Plow

Inc. SCIENTIFIC - https://www.youtube.com/watch?v=5ddMyerXsaM

APPENDICES

APPENDIX I: User Manual

The SpeedPlow is a modular and reattachable accessory that allows the user to safely and easily plow snow away.

For installation, a variable-size wrench is needed.

Steps for installation:

1. Mount the two small pivot attachments to the left and right hook rings of your wheelchair, as shown in the following figure. Tighten bolts with wrench.

Figure 20. Pivot attachment

2. Grab frame and place in front of pivot attachments. If size is not adequate, use wrench to remove bolts and readjust side and front square tubing until frame fits on wheelchair properly.
3. Insert long bolts onto each side, making sure that they cross both the side tubing and the pivot attachments. Tighten nuts with wrench.

Once installed, user does not need to do any further action. The plow can operate just by moving the wheelchair forward.

If shovel breaks: Replace shovel with SnowJoe Snow shovel, found in the following link.[2] Reattachment only needs a standard screwdriver.

[2] https://www.amazon.ca/Snow-Joe-SJEG24-24-Inch-Chopper/dp/B00AYEQZSI/ref=sr_1_77?ie=UTF8&qid=1539286618&sr=8-77&keywords=snow+shovel

APPENDIX II: Design Files

Consult MakerRepo for CAD drawing files, project presentation, and technical documents.