GNG2101 Final Report

Wheelchair Skis

Submitted by

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Abstract

Wheelchair skis are our solution to the problem that our wheelchair bound client raised. This problem was that of winter mobility being hindered by the snow buildup on the sidewalks. We used the Iterative Engineering Design Process taught to us in class in conjunction with client meetings to design, build and test an add-on for manual wheelchairs that would allow the user to travel over both snow and sidewalk thus giving the client back the mobility they lost during the winter.

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List of Acronyms

Acronym	Definition
IEDP	Iterative Engineering Design Process
BOM	Bill of Materials

1 Introduction

1.1 Problems faced by wheelchair users in Canada

According to Statistics Canada, there are just shy of 200,000 manual wheelchair users in Canada. From meeting with our client, we came to learn that many of the users face mobility problems in the winter due to snow. When a sidewalk isn't plowed in a timely fashion, as is often the case in many places, the front wheels get bogged down making it much more difficult to get from place to place. As a result of this many users find themselves trapped indoors during the winter. We were contracted to design and produce a solution to this that would give back mobility to a user in a manual wheelchair.

1.2 Potential solution and user requirements

We met with our client to gather user requirements and discuss potential solutions for their problem. The user requirements that were set for the project came directly from the need statements of our client. It was important to make sure that we focused our project on the specific needs of our client rather than the general needs of the public. Although we would have liked to create a universal solution that could be used by many wheelchair users, we first had to satisfy our client's needs. Namely targeted at manual wheelchair users with full time caretakers like our client.

After the first meeting with our client, we were able to form a general understanding of the issues that our client faced on a daily basis. From these issues we were able to form a set of requirements that our wheelchair skis would have to meet before they could be deemed suitable. Below is a list of the requirements that were generated from our clients need statements and daily issues:

- The skis must be durable, detachable, lightweight/compact, safe, and weather resistant.
- When the skis are not being used, they should be stored on a pouch, attached to the back of the wheelchair.
- The skis must be able to traverse deep snow
- The skis must not obstruct the backpack hooks on the back of the wheelchair
- Extreme mobility is not must, but a nice-to-have.

1.3 Comparison with Competition

When conducting our benchmarking research we came across another product, Wheelblades by Epical Solutions. This product is an attachment to the two front wheels of the user's wheelchair to improve winter mobility.

Figure 1: Wheelblades by Epical Solutions

This product allows the wheelchair user to travel with ease over snow and ice, but it does not allow movement over concrete, whilst our product allows ease of movement over snow and pavement/concrete. It also is priced at around $300 CAD, which is much higher than our product (around $100 CAD). These differences come from a core design goal that is different to ours, namely that Wheelblades are targeted at the recreational market while our product is designed for everyday use in primarily city environments.

2 Engineering Design Process

We followed the Iterative Engineering Design Process (as it was taught in our class). This design process gave our project the firm structure that it required while at the same time allowing for a great deal of flexibility to accommodate for changes in our solution's requirements and the discovery of new concepts that could be incorporated in our solution.

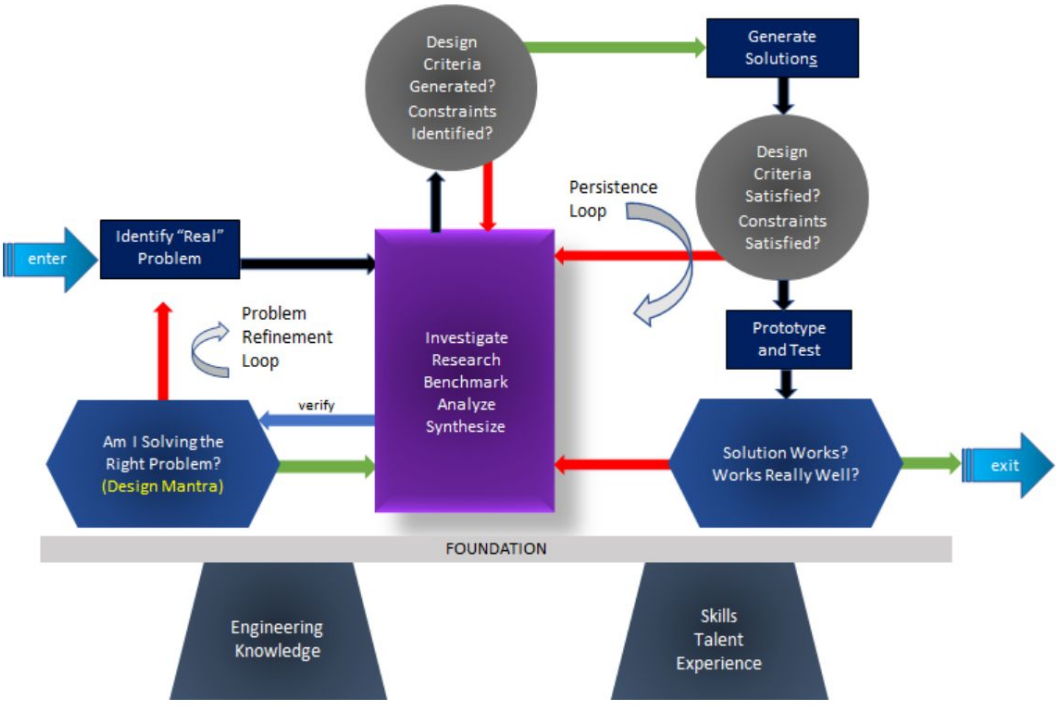

Figure 2: Flow Chart Depicting the Iterative Engineering Design Process

3 Need Identification and Product Specification Process

This section summarizes the important client needs that were identified recorded during our first interview. We first formulate needs and prioritize them. With these needs a problem statement is formed which encompases the requirements and contraints for the product being developed. Next, we benchmarked with respect to various products that fulfill a similar goal as our problem statement expresses. Finally, we create metrics that correspond to the needs formulated and target specifications that our future prototypes will strive to satisfy.

3.1 Need Statements

From the client statements we compiled all of our client's needs, and their corresponding priority, in the table below.

#	Need	Importance
1	The product lasts many years of constant use.	8
2	*The product has a universal design so it can be implemented on any wheelchair.	2
3	The product ensures the safety of the user.	3
4	*The product can travel through snow, ice and other winter conditions.	1
5	*There is an easy to attach and detach mechanism for fixing the product to the wheelchair.	4
6	*The product is lightweight.	6

7	The product is compact for storage.	7
8	The product has a colourful design.	9
9	The product is connected to the frame or wheels.	5

Table 1: Needs and Prioritization

3.2 Problem Statement

With these needs in mind, we were able to determine what the problem statement of this project should be:

Our client would like a durable and safe attachment to his wheelchair that allows him to travel on unplowed sidewalks in the winter, his wheels often sink in the snow. This product has a budget of $100 and is detachable and lightweight and could be in the form of a set of skis or sled.

3.3 Benchmarks

Below is an evaluation of two different products that have been able to solve specific problems similar to the problem that we are trying to solve. The products that were evaluated were Wheel Blades by Epic Solutions and the Grit Freedom Chair by GoGrit. Both of these products strive to increase the mobility of wheelchairs in winter weather (for recreational and/or everyday purposes). By examining these products, we can identify how they were able to accomplish what they did and where the areas of improvement are in their solutions.

Rankings in descending order: **Green = 3**, **Yellow = 2**, **Red = 1**

Specification	Wheel Blades*	Grit Freedom Chair 3.0**
Cost	$159-$295	$2,995
Mass	N/A	N/A
Installation ease	Easy and quick	Assembly of whole wheelchair
Size	258mm long x 110mm wide	406.4mm wide x 660.4mm high
Travels through snow	Yes	Yes
Total	8	6

Table 2: Benchmarking against another wheelchair ski attachment

3.4 Metrics and Target Specifications

Once having made a list of metrics, we had to set target specifications that our product would need to adhere to.

#	Metrics	Importance	Units
1	Size of skis (width, length, height)	3	inches
2	Weight of skis	2	kgs
3	Braking distance	1	metres
4	Installation time	4	seconds
5	Temperature of environment	5	°C

Table 3 Metrics

#	Design Specifications	Relation (=, < or >)	Value	Units	Verification Method:
-	**Functional Requirements**	-	-	-	-
1	Travels through snow	=	Yes	N/A	Test
2	Travels on ice	=	Yes	N/A	Test
3	Brakes distance	≤	2	m	Test
4	Breaks on release	=	Yes	N/A	Test
-	**Constraints**	-	-	-	-
1	Mass	=	3-5	kg	Design
2	Cost	≤	100	Canadian Dollars	Budget
3	Operating Conditions: Winter weather	=	Yes	N/A	Test
-	**Non-Functional Requirements**	-	-	-	-
1	Aesthetically pleasing	=	Yes	N/A	Client Review
2	Ease of installation	≤	15	seconds	Test
3	Safety	=	Yes	N/A	Test
4	Product Life	≥	3	Years	Test

Table 4: Target Specifications

4 Conceptual Designs

We came up with three designs to solve the problem. We used 3D CAD models as well as physical models.

The first design consisted of a long ski for each wheel. The wheelchair would roll up from behind the skis and rest along a groove so the wheelchair would not rock side to side. Finally, the wheels would be fixed to the skis by a strap and buckle. We used a small, physical and comprehensive to model our design.

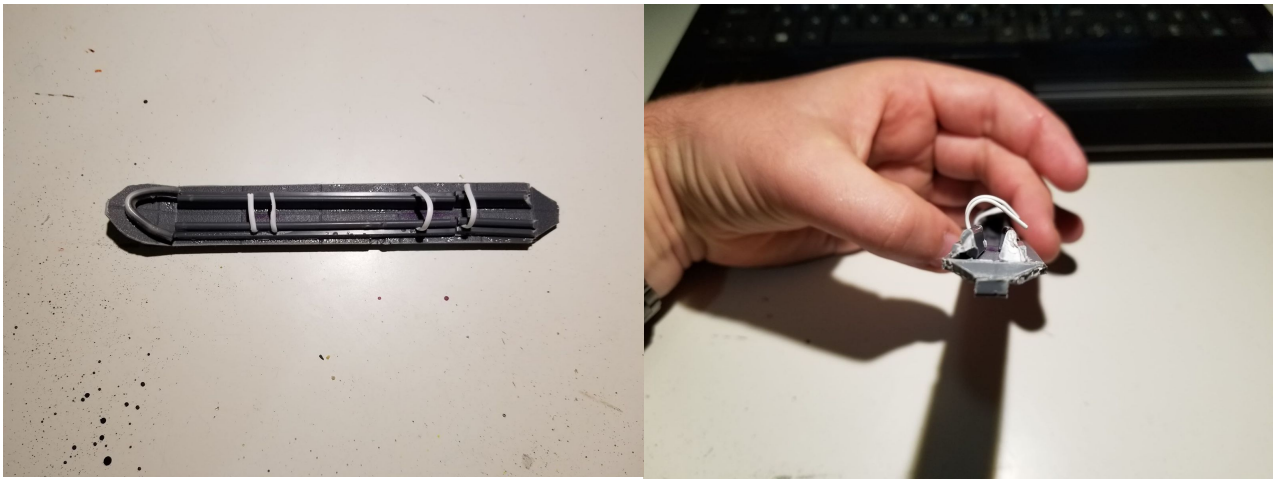

Figure 3: First design

Our second design consisted of a wider ski or snowboard with a hole cut in the middle for the wheels to fit in. Also, only the front wheels would be attached to the ski and the rear wheels will be completely free. There was also a clamp which is hand tightened to replace the buckles.

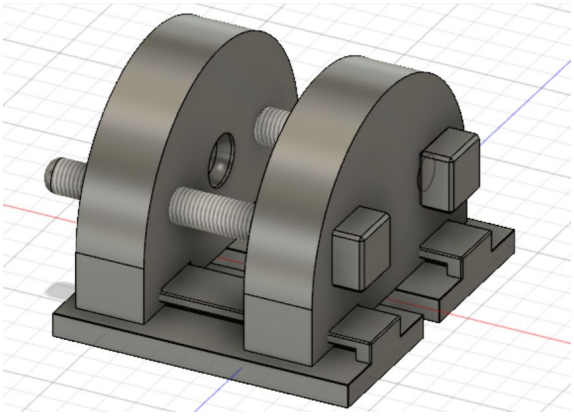

Figure 4: Second design

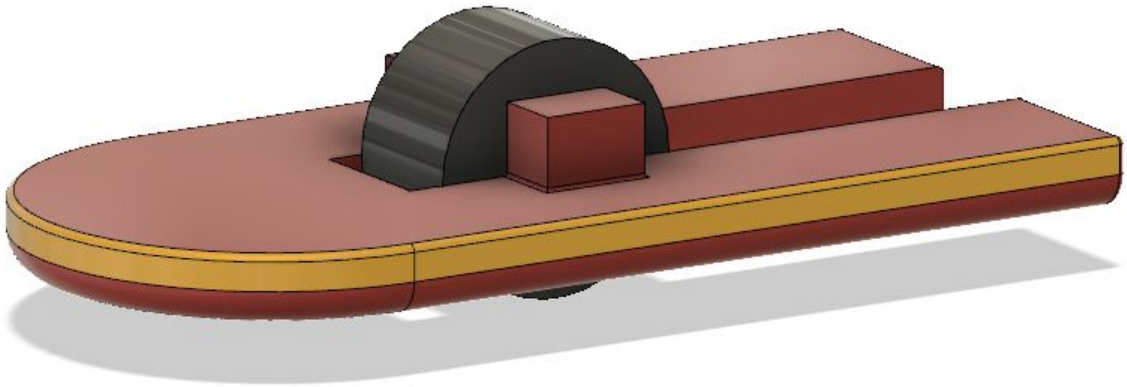

Figure 5: Second design - with ski

The final design still applies a snowboard with a hole for the wheel but with no cut all the way to the back. The attachment now consists of a bracket that will hold the skis to the axel and fastened with wing nuts.

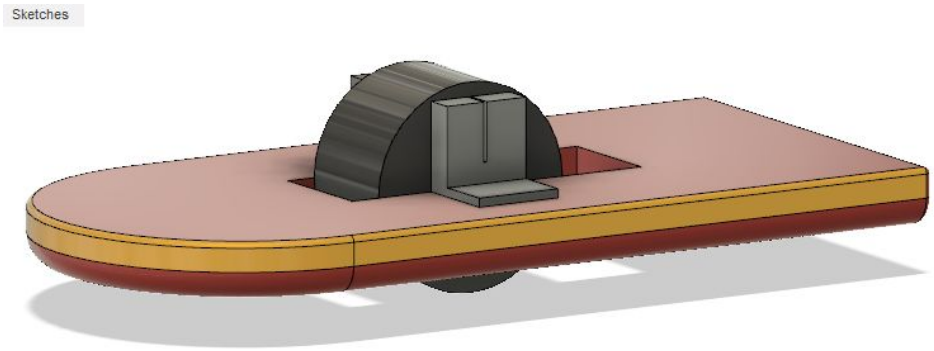

Figure 6: Final design

5 Project Planning and Feasibility Study

5.1 Project Plan:

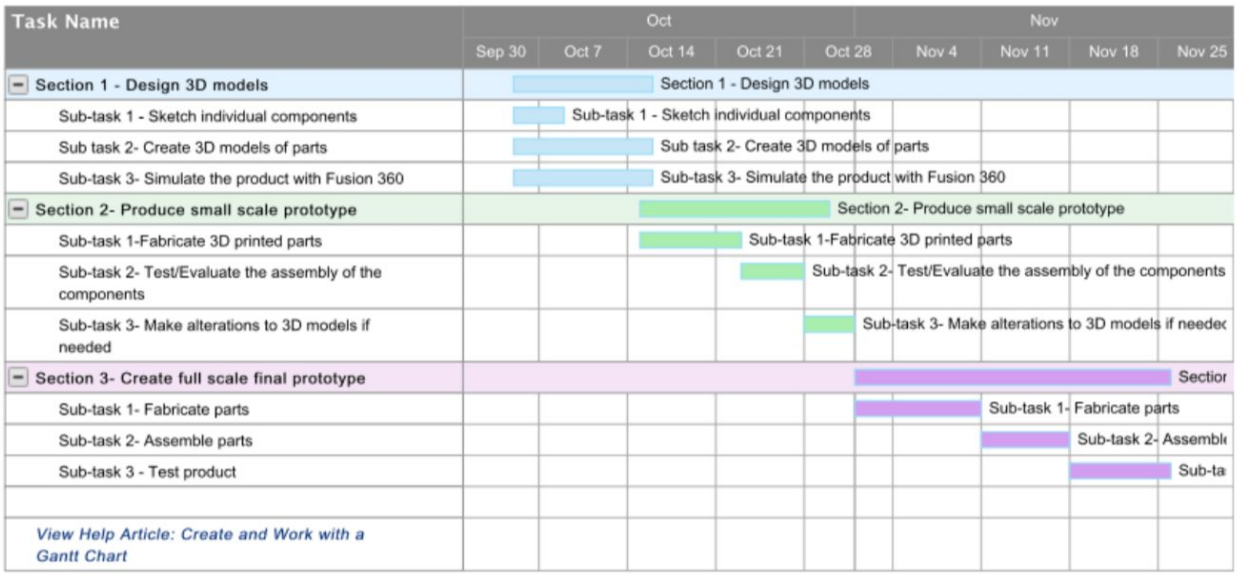

Figure 7: Gantt chart

We were mostly able to keep track on our tasks during the project, although there were a couple delays such as waiting for parts to arrive, 3D printing problems, we were able to showcase our working final prototype during Design Day.

5.2 Feasibility Study:

1. Technical:

In terms of fabrication/manufacturing skills, our team has a deficit. None of our team

members are mechanical engineers. However we actively worked to remedy this and filled our knowledge gaps, thanks to the trainings during the laboratories. In terms of resources, all the machines and tools that we need to fabricate our product are available at the university (at Makerspace and Brunsfield)

2. Economic:

Based on the prices of the parts that we use to build our product, we determined that the cost of our project is at $96. This cost includes the snowboard ($60), screws and bolts ($15), insulating foam ($13), and metal parts ($12)

3. Legal:

There are a few legal constraints that would affect our product. Our product would need to adhere to canadian health and safety standards set by Health Canada.

Another legal concern regarding our product would be the protection of our intellectual property, namely our prototype designs.

4. Operational:

There are a few operational issues might affect our product and prevent success. Such as setting up time to meet, due to our hectic schedules it was hard to find a time where each team member was available.

5. Scheduling:

The deadlines for each task of our project plan are detailed in the gantt chart in figure 6. Design day is the final deadline. We were able to deliver a successful product using this schedule.

6 Analysis:

There were no calculations required in this design process but we did constantly check our design criteria to ensure that we are solving the right problem.

The first criterion is “allow mobility on snow and pavement.” Our final prototype me this when we tested on both snow and pavement and the wheelchair moved well on both.

Next, we ensured that the product does not in affect the safety. The product does not change the structural soundness at all and is lightweight so there is no added difficulty in the handling. Therefore, we concluded that this product met this criterion.

Thirdly, The client wanted to ensure that the product can be placed and removed easily. To achieve this we include wing nuts that allow for easier fastening of the ski attachment to the wheel. This criterion was mostly met as there is bit of awkwardness when placing the ski before fastening it.

Also, the product is lightweight. We did this by using aluminum for the brackets and a snowboard made out of plastic.

Finally, we kept the budget below the required $100. In the end it cost $96 to manufacture.

7 Prototyping, Testing and Customer Validation.

After the completion of the final prototype we were able to run a number of tests on the product in order to determine if it met all the required criteria. At the time we were running the tests there was a small (1-2in) layer of snow on the ground that we were able to benchmark the product.

The tests we ran involved indoor testing with the product installed and a team member on the chair in order to make sure it functioned normally in a standard wheelchair environment which as long as the pace was kept to walking speed it did perfectly. When nearing running speed the extra length and weight of the skis on the front wheel would cause speed wobbling which presents a potential control issue.

With the snow outside we were able to run tests both with a team member on the chair and off the chair in order to make certain that the skis functioned properly both on snow and in transitioning from snow to sidewalk and back again. In this testing the skis performed perfectly without any issues, due to the lack of a thick layer of snow the exact performance in deep snow was not able to be tested.

Unfortunately, the client was not able to schedule a meeting in order to see the final prototype in person. However it has been built to their requirements and according to the design they have seen and approved of.

8 Final Solution

Our final prototype was a physical comprehensive prototype. It was as close to our final design as possible. Our final design goal was to have a set of skis that attach to our client's wheelchair that allow him to travel over unplowed snow and also over clear pavement. On Design Day we mounted our prototype on a wheelchair and demonstrated how to install and remove the skis.

Figure 8 shows the skis from our final solution. The main bases of each ski were made from a plastic snowboard that was cut in half. Each ski has two metal (aluminum) 'L' shaped brackets on them that contain a singular channel designed to hold the axil of the wheel. In between the two brackets, there is a hole that was cut in to the base of ski that allows for the wheel to sit through. The reason why the wheel was exposed at the bottom of the ski was to ensure that the if the wheelchair needed to traverse any plowed surface the wheel would still be able to function normally. This feature was one of the most prominent differences between our design and that of the Wheel Blade product that we had found during the benchmarking. The last prominent feature of our skis was the foam filling that was used inside each ski to prevent snow and water build up within the ski.

Figure 8: Final Solution

9 Business model

In order to turn our project into a business, we adopted the Manufacturer business model. We intend to make a finished product from raw materials and sell it either online (using the Shopify platform) or in store (specializing in winter/general sports gear).

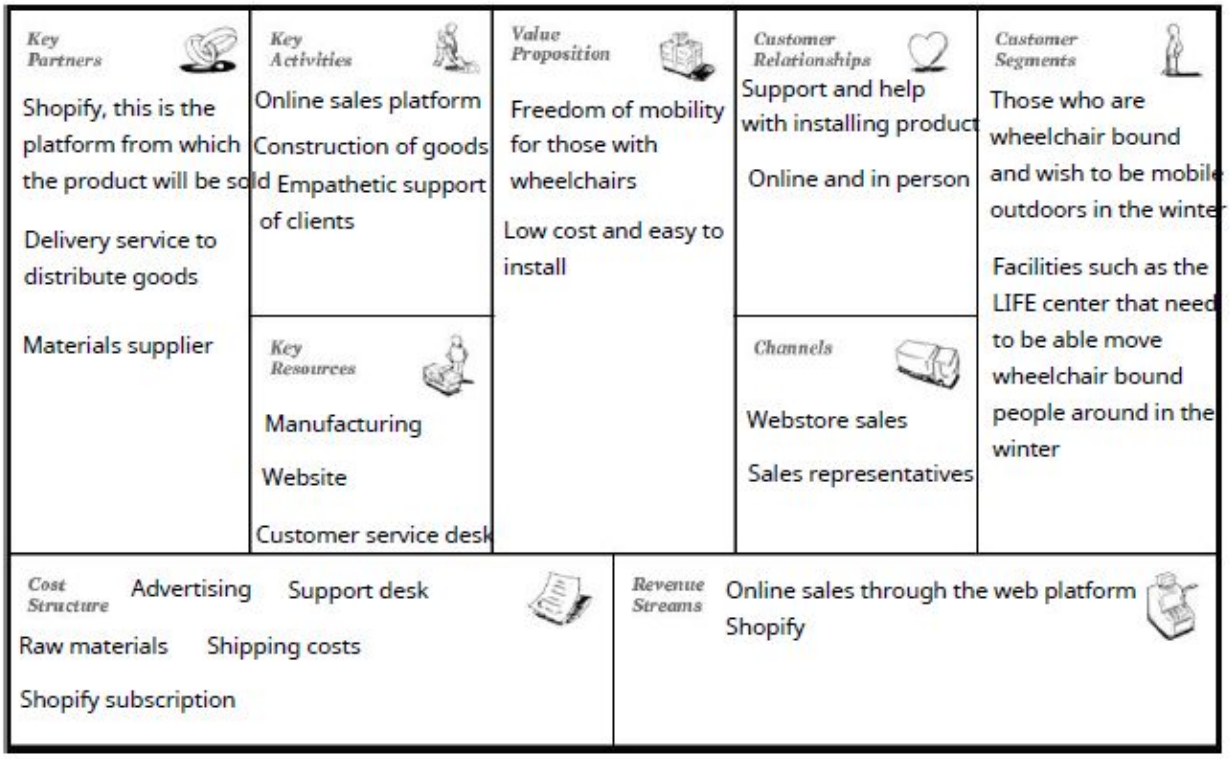

Figure 9: The Snow Gliders' Business Model Canvas

10 Economic Analysis

10.1 Bill of Materials (BOM)

This is a compilation of all of the costs of the various components used over the span of the project.

Part	**Cost (CAD$)**
Snowboard	63
3D Filament (PLA)	Free
Nuts, Bolts, Washers	20
Spray Foam	13
Square Aluminium Pipe	Free (Was offcuts from Brunsfield)

Table 5: Bill of Materials

10.2 Future Project Costs

If we turned this project in to a business, these are some of the costs that we might expect to encounter while attempting to manufacture and sell our product.

Table 6: Future project costs

Variable Costs:	Cost of labour to manufacture product: $72 per set (4 man hours at $18/hour) Cost of Materials: $32 per set (Plastic to mold into ski: 1kg at $1/kg, Aluminium plate 10lb at $3/lb: $30, Misc screws, bolts, paint, etc:$1) Shipping: $20 for inside Canada

Fixed Costs:	Cost of Shopify Subscription: $79 per month,
Direct Costs:	Cost of parts

11 Conclusions and Recommendations for Future Work

Lessons learned:

One lesson we learned was the effectiveness of choosing the correct design process. Choosing the right design process for your project can strongly impact its outcome, as well as the effectiveness of your final solution. As mentioned before, the design process we used (IEDP) allowed us to iterate multiple times, improving our design along the way due to changing requirements. This would not have been possible, if we had used the Waterfall design process,

Prototyping skills. We learned how to create a variety of prototypes to achieve different goals such as communicating designs, and test functionality.

Anyone can create, as long as they are willing to try. When we started this project, none of us knew the skills that we needed to manufacture the prototype, but given enough effort, we were able to learn the skills we needed to accomplish the tasks.

Future work:

- Provide support for electric wheelchairs
- Fabricate our own ski base
- Allow the user to install the product themselves. perhaps with some type of ramp
- Improve the mounting bracket for easier installation

12 Bibliography

Needs for mobility devices, home modifications and personal assistance among Canadians with disabilities

*”Wheel Blades.” Epical Solutions,
https://www.epicalsolutions.com/shop/mobility/wheel-blades-skis-for-wheelchairs-or-strollers/
https://wheelblades.ch/en/index.php

**”Grit Freedom Chair 3.0”, GoGrit
https://shop.gogrit.us/

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.

Product Functions and Features:

The Snow Glider wheelchair skis were designed to increase the mobility of wheelchair-bound citizens in winter weather. They allow the user to traverse deep snow and ice with ease. Since the front wheels of the wheelchair are always exposed, the user will never need to remove the skis before traveling on surfaces that have already been plowed. Overall, The Snow Gliders will restore the freedom of mobility to any wheelchair users that find it difficult to move on unplowed or icy terrain.

The main bases of each ski were made from a plastic snowboard that was cut in half. Each ski has two metal ‘L’ shaped brackets on them that contain a singular channel designed to hold the axil of the wheel. In between the two brackets, there is a hole that was cut in to the base of the ski that allows for the wheel to sit through the ski. The last prominent feature of our skis was the foam filling that was used inside each ski to prevent snow and water build up within it.

Installation Instructions:

- Firstly replace the front wheel axles with the provided threaded rod and wing nuts, make sure to put the spring washers on before the wing nuts
- Loosen the nuts so that there is 1 inch of room on either end of the yoke
- Raise up the front of the chair and slide the brackets of the skis under it so that the grooves on the brackets line up with the axles
- Lower the chair onto the brackets so that the axle slides down the groove
- Lift the ski so that the axle is at the bottom of the groove with the spring washers on the outside and then tighten the wing nuts till hand tight.
- If properly installed the skis will not slide down the groove when released with the wheel protruding through the slot on the bottom allowing the wheel to work normally without the ski contacting the ground.
- Product is now ready for use

Removal of Product:

- Loosen the wing nuts till the skis drop loose
- Raise front of chair and slide skis out from under it
- Lower chair back to the ground and tighten the wing nuts till snug against the yoke

Safety Precautions:

When using the product care must be taken to not exceed a normal walking speed due to the increased length and weight of the skis on the front wheel. Excessive speeds will cause the skis to wobble. This could cause difficulty in steering the chair and discomfort for the passenger.

In addition care must be taken to properly attach the product otherwise the skis won't function properly.

Lastly always ensure the wing nuts are on the axle when using the chair. Without them, the axle can fall out, causing the front wheel to detach from the chair leading to a danger to the user.

APPENDIX II: Design Files

MakerRepo Link: https://makerepo.com/Techman120/gng-2101-the-snow-gliders-group-b2b

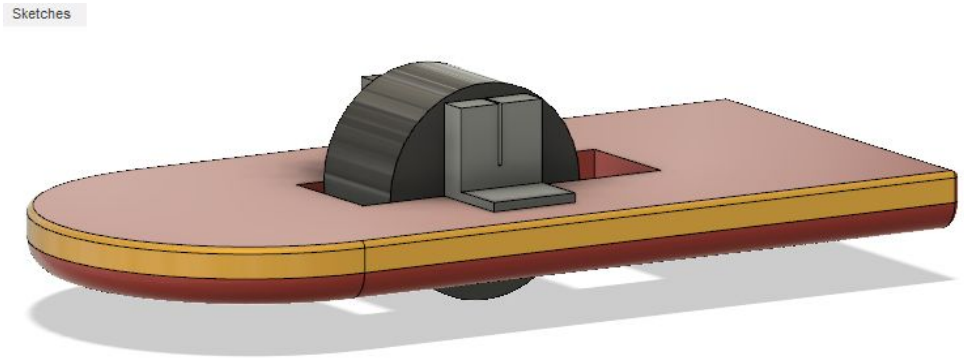

Figure 10: 3D Model of Our Final Design

APPENDIX III: Other Appendices

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