GNG 2101

Product Development and Management for Engineers

Dr. Hanan Anis

Wheelchair Assist Final Report

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Abstract

The objective of this project was to provide a cost-effective, functional and comfortable one-sided lever to the LIFE Program for our client Abass. This lever had to safe, effective, easy-to-use, adjustable, reliable and sufficient, while also be relatively cheap and one of a kind. To accomplish this task, a group was created; the wheelchair assist group. As a group, our task was to use design this solution using the design model subsequently taught in the lectures. Starting with using a beginner's mindset to empathize with client, define the exact problems and issues faced by the client, generate ideas for a solution then create a viable solution that satisfied all the necessary specifications during the span of three months. This report documents the steps, challenges, ideas, and solutions that we encountered throughout the design process.

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Introduction

Motion is something we as living, breathing human beings were blessed with and is thought to be available by all, why shouldn't it be? It's just moving two legs alternatively to get to any particular destination. We walk, we run, we engage in sports and other physical activities because we can move the way we are capable of. However, there are some who do not get this opportunity and have spinal damage or parts of their bodies that they are unable to move, thus hindering their motion and confining them to wheelchairs, needing people to help them move through the smallest distances. While these issues are well known all over the world and solutions are present, not everyone can afford these solutions and one such person exists much closer to home; our client, Abass, whom we met while working with the Life Program.

The Life Program is an organization in the Ottawa region that works with developers to help and support people, especially those who cannot help themselves, and they are facing an ongoing struggle to find people who can provide a design that could help people confined to wheelchairs to be more self-reliant. In order to provide such solutions for our client, the GNG2101 Wheelchair Assist team was tasked to provide a functional and self-sufficient attachment that was safe and capable of propelling the user forward without major discomfort. In addition to solving the problem of limited mobility that our client faces, this solution would be made to give the user the freedom to move wherever he wants, whenever he wants.

In order to accomplish this task, we employed the design-thinking model that was presented during the course. This model had two main loops: the Problem Refinement and the Persistence loops. The main steps involved in the former being; 'empathize' and 'define'. That is, we began by meeting with the client to understand and feel what he was experiencing and properly identify the needs, fully understand the problem and grasp the sense of urgency in the situation he was in. Then the persistence loops having the following steps; 'ideate', 'prototype' and 'test'. After getting a fitter idea of the resources available to the client and his needs, we did considerable research and benchmarking of available products and started proposing different designs for the attachment. We then brainstormed, thinking of the different constraints, metrics and specifications that had to be considered for the design. We also determined that a retracting lever would be the best form of attachment to relieve stress on our client. Many of our design choices were dictated by the cost of the materials purchased, as a $100 budget was given for the entire system.

The final prototype of the assist system was completed for Design Day (November 29, 2018). Our system worked quite effectively, with the only issue being low product life as materials used will not be strong enough for continuous use. Overall, we are satisfied with the final design and are without a doubt sure, that our client will be too.

2 - Design Process

2.1- The Client and the User

The client, Abass, is a young man in his early twenties who unfortunately is confined to a wheelchair, in constant need of aid when he attempts to move from place to place. He's under the care of the Life Program, who has a guide assigned to him to help him get around and communicate every day. His only way of motion is using his right arm to rotate the rim of his right wheel along with a right leg shuffle due to an inability of effective left sided movement. He does not possess the ability to grip or pull with his left hand but however, has some push capabilities, which is all our product will need from him to function properly.

2.2 - The Problem Statement

The main goal of this project is to provide a cost-effective and one-sided wheelchair attachment for our client, Abass, who unfortunately is only able to move himself and his chair with just one of his legs and arms. Hopefully, this attachment will be sufficient in assisting and further enhancing his motion.

Having a set budget, we needed to prioritize comfortability and ease of use when he used his left hand. The parents of our client prioritized his need to move on his own so that he gets some physical activity done every day. Moreover, stress on the client is also a main concern as the product is meant to reduce strain on the client when moving and not increase it further. We can condense our task as the wheelchair assist group into a single problem statement, which is:

Abass requires a one-sided, functional and reliable wheelchair attachment that will be efficient and self-sufficient in assisting him and further enhancing his motion.

2.3 - Benchmarking

The design process is an intricate process that must be carried out to provide the best results for the client. A crucial aspect of the design process stems from the work of others and the hurdles they have encountered during similar projects. Our group was able to search the web and converse with students working on similar projects. This was extremely helpful, giving us ideas as to how the lever would be attached, sizes of gear, etc. Despite how helpful the information was, we found that our project possessed a unique characteristic that other projects similar to it have lacked, notably the issue where our client can only properly use one side of their body. Meanwhile, most of the products benchmarked are only operable by fully, able-bodied people.

Once the problem was fully defined, it was decided that research must be conducted to see what was currently on the market, to see how improvements can be made and to keep the project away from plagiarism claims.

It was found that there were 3 wheelchair levers on the market and their specs are as follows:

	Hand Drive	**NuDrive Air**	**The Wijit Wheelchair Lever Driving and Braking System**
Cost	$40	$1995	$4995
Weight	1 kg	3.4 kg	Unknown
Dimensions	76 cm	63.5 cm	Unknown (roughly 60cm)

Description	Easy to put together, 3D printable, works for different wheelchair models	Lever-driven propulsion accessory for manual wheelchairs.	Lever drive with forward, neutral, reverse and braking system for manual wheelchairs

Table 1: Benchmarking

Hand Drive NuDrive Wijit

Figure 1: Benchmarked Lever Images

It was clear, that the lead competitor to the lever the group planned to create would be the Hand Drive, due to cost and usability.

2.4 - Metrics and Target Specifications

The metrics for the project are as follows:

Number	Metric	Unit	Need
1	Product Cost	$	Cost-effective (5)
2	Weight	Kilograms (Kg)	Not too heavy and easy to use. (10)
3	Dimensions (Height)	Centimeters (Cm)	To be above the arm rest (40)

Table 2: Metrics

The target specifications for the project are as follows:

Design Specification	Relation	Value	Units
Product Life Span	≥	3	Years

Quantity	=	1	N/A (Model)
Cost	<	100	Dollars
Ease of Use	=	Yes	N/A
Reliability and Comfort	=	Yes	N/A
Aesthetic	=	Yes	N/A
Self- Sufficient	=	Yes	N/A

Table 3: Target Specifications

For the clients utmost use out of the lever, some training for use will have to be conducted to make sure that the full potential of the lever is used, however the training will be very straightforward for use and attaching. The lever is to be easy to use, easy to reach and push oriented to ensure client comfort.

2.5 - Conceptual Designs

The wheelchair assist system needed to be comfortable, efficient and unhindering in use during normal daily routine procedures. The final solution must be easy to use, adjustable and adaptable to various kinds of wheelchair models as he was to be getting a new wheelchair we were and still are, yet to see. It should last for a long period of time, at least a year preferably and be self sufficient, being able to return to its original position so as not to force our client into a pull rather than push motion. It had to be cost-effective and ought to not be too heavy to avoid strain and client strain/dissatisfaction. It should be one of a kind and used specially to help assist and further enhance our client’s motion.

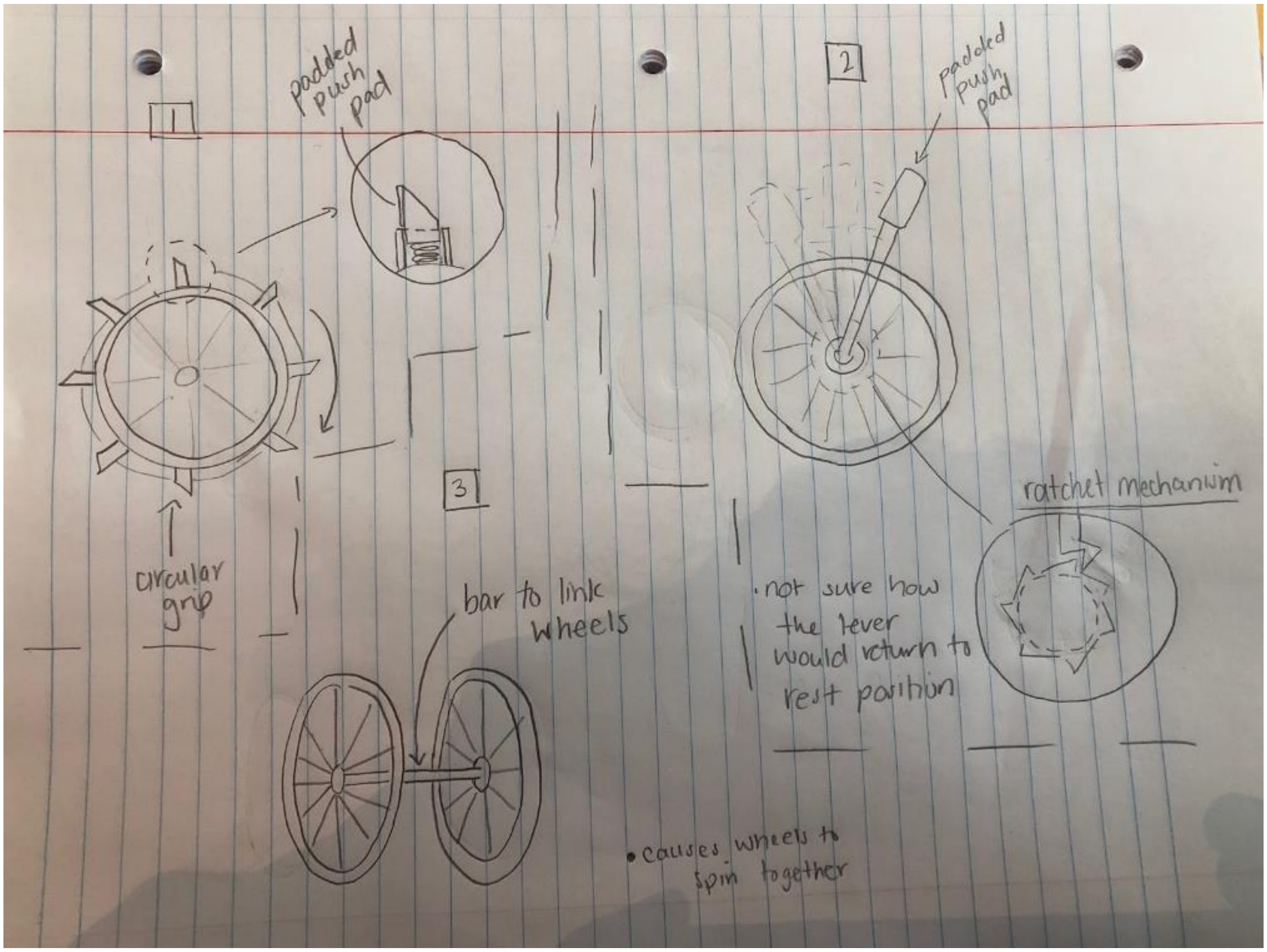


Figure 2: Initial Designs 1

Design 1:

A attachment of rubber stoppers that would allow for an easier way to push the rim of the wheelchair wheel.

Design 2:

A one-sided push lever that attaches to the hub of the left wheel. When the user pushes the lever, the ratchet mechanism would allow forward motion while also let the lever be brought back to its resting position with little effort.

Design 3:

A bar that would attach to the hubs of both wheels. This would link the motion of the wheels meaning when one is spun, the other moves with it. This would help increases the clients motion since he only has full strength in one arm.

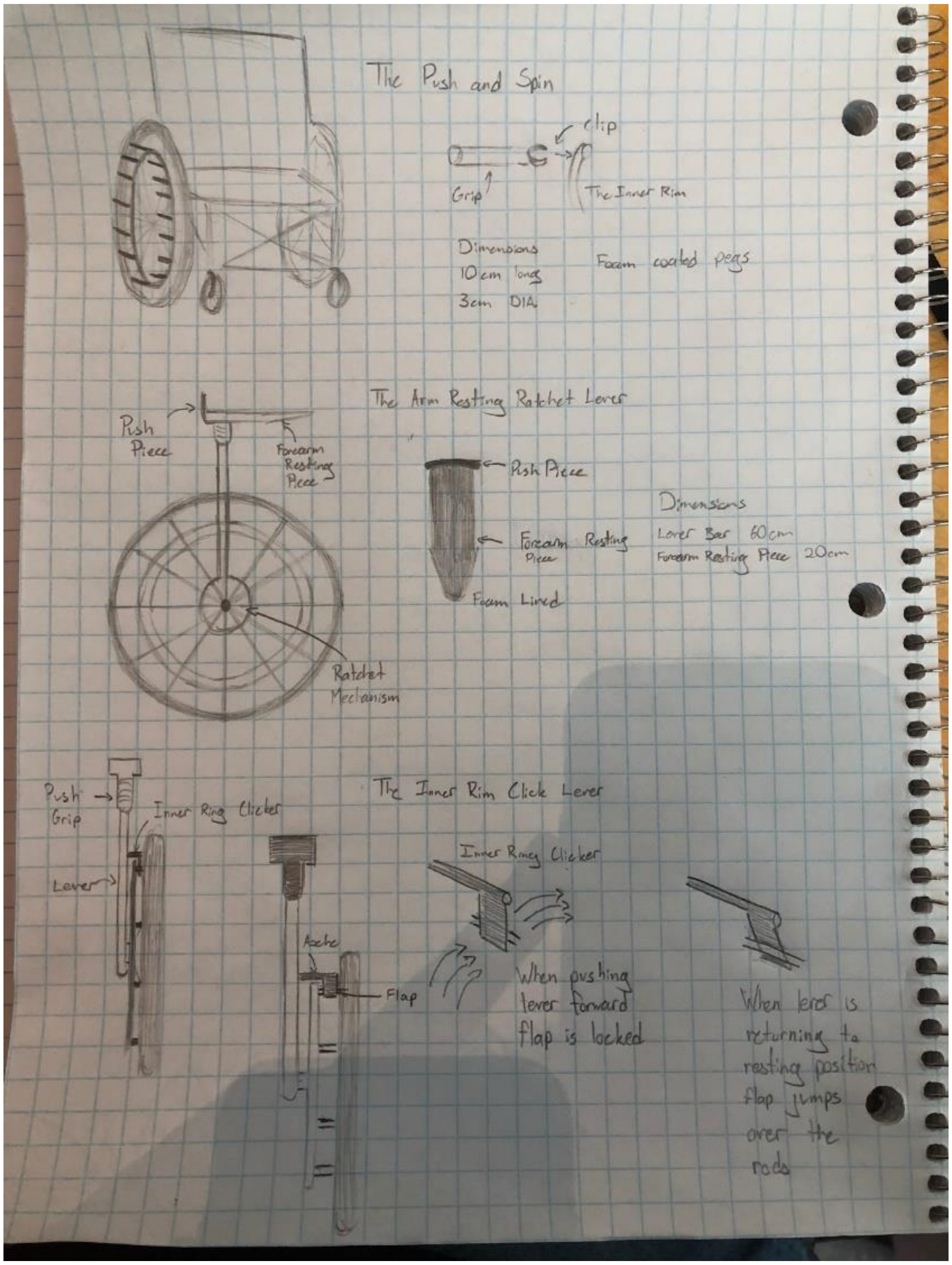


Figure 3: Initial Design 2

Design 2: (The Arm Resting Ratchet Lever)

This design is a lever that would be attached at the wheel axle. The lever would go up to the arm rest level to allow the client a comfortable height of arm motion. The lever would be using a ratchet mechanism, which would allow for effective forward motion, and a non-problematic return to rest position for the lever. The push piece is composed of two parts, the part that the client would exert force on, and the piece that would allow the client to rest/guide their forearm.

2.6 Project Planning and Feasibility Study

Here, we addressed the tasks to be completed and logistics that remained for the wheelchair assist. Although both materials and designs had been proposed, certain details remained that had to be confirmed before beginning the final construction. To eliminate possible oversights or errors in the design, we consulted with the teaching assistants, professors and our client, so as to ensure the right design was made before the final construction, and extensive testing of our proposed design system was performed. A lot of these tasks below greatly depend on our client Abass, who is supposed to be getting a new wheelchair by our next client meet, therefore new ideas and dimensions would be found. The following table outlined the remaining tasks as of October 14th, as well as the group member(s) responsible for their completion:

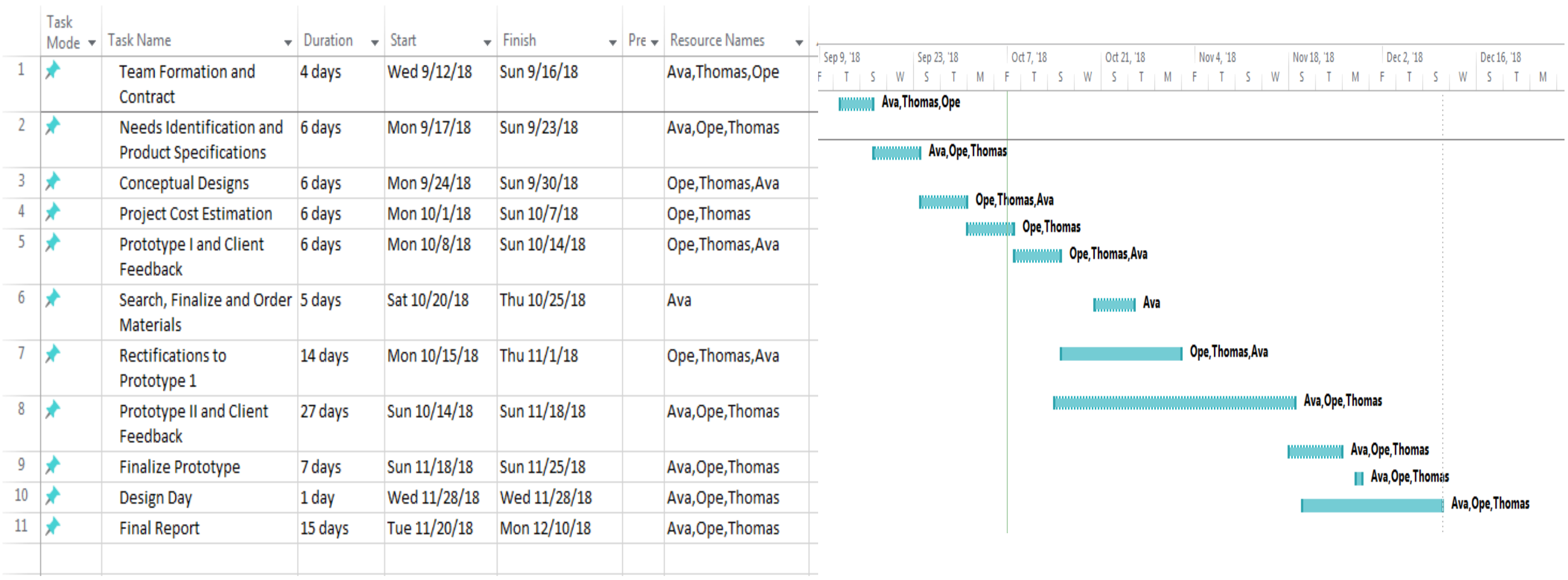
Project Plan

Task	Task Description	Group Members Responsible for Task
Finalize Design	Finalize the design of the assist system and confirm the design with both TAs, professor and client	Thomas, Ope, Ava
Creating and finalizing materials list for the design.	Once the design has been finalized, the materials list (with quantities) must be confirmed and completed.	Thomas, Ope
Order Materials for Project	Confirm which materials can be provided by the MakerSpace and Brunsfield Centre, and which must be purchased externally.	Ava
Create Prototypes	Prototypes are to be made to get a general idea of our final design.	Ava, Thomas, Ope
Inaugurate Prototype Testing Procedures	Two prototypes will be made and tested using a series of procedures that we must define.	Ava, Thomas [next deliverable (E)]
Create 3D Models	3D models with accurate dimensions would be created as a visual representation as well as prototypes.	Thomas, Ope, Ava
Final Design	The final design would be created here after confirmation that the final prototype suits clients needs.	Thomas, Ope, Ava
Installing Components	Here, the assist systems are connected and installed to the clients wheelchair and testing can be performed.	Ope, Thomas, Ava

Testing	Subject the design to the tests outlined in our procedure.	Ope, Ava, Thomas
Troubleshooting	Make alterations and rectifications to the design based on the results of the testing process.	Ope, Thomas, Ava

Table 4: Project Plan

The Gantt Chart



	Task Mode	Task Name	Duration	Start	Finish	Pre	Resource Names
1		Team Formation and Contract	4 days	Wed 9/12/18	Sun 9/16/18		Ava,Thomas,Ope
2		Needs Identification and Product Specifications	6 days	Mon 9/17/18	Sun 9/23/18		Ava,Ope,Thomas
3		Conceptual Designs	6 days	Mon 9/24/18	Sun 9/30/18		Ope,Thomas,Ava
4		Project Cost Estimation	6 days	Mon 10/1/18	Sun 10/7/18		Ope,Thomas
5		Prototype I and Client Feedback	6 days	Mon 10/8/18	Sun 10/14/18		Ope,Thomas,Ava
6		Search, Finalize and Order Materials	5 days	Sat 10/20/18	Thu 10/25/18		Ava
7		Rectifications to Prototype 1	14 days	Mon 10/15/18	Thu 11/1/18		Ope,Thomas,Ava
8		Prototype II and Client Feedback	27 days	Sun 10/14/18	Sun 11/18/18		Ava,Ope,Thomas
9		Finalize Prototype	7 days	Sun 11/18/18	Sun 11/25/18		Ava,Ope,Thomas
10		Design Day	1 day	Wed 11/28/18	Wed 11/28/18		Ava,Ope,Thomas
11		Final Report	15 days	Tue 11/20/18	Mon 12/10/18		Ava,Ope,Thomas

Figure 4: Gantt Chart

Feasibility Study Factors

Technical

Each member of the group was familiar with working hands on, with tools, following blueprints, etc. Our expertise was limited due to the fact that we have little real work experience, but the basic knowledge we did have sufficed for the work at hand. As for resources, our group had the Makerspace, the Brunsfield Centre, computer labs, TA's, and the internet at our disposal. The university offers very useful resources which were all be used in the creation of the final product.

Economic

The cost of the project was slightly above budget, above 100 dollars. The components of the mechanisms we created were made of easily accessible materials, such as 3D printed materials and things accessible from hardware stores.

Legal

There should not be any legal issues with releasing our solution to the general public, however if any arise, they are most likely to be that our final product has some similarities to designs made by NuDrive and their permission wasn't requested. This is because our solution is to add mobility to someone who struggles to move easily in a wheelchair due to a single sided disability. Our design does not affect the chair in any way, included the standing brakes and the original breaking system of the wheelchair, which would consist of grabbing hold of the outer rim of the wheel firmly enough to stop wheel rotation. The design is strictly to assist, with little to no implications of safety.

Operational

The group does face one quite large constraint at the moment which could play in a significant amount on the final product, this constraint being with the wheelchair of our client. Currently our client is in an older wheelchair that he plans to upgrade shortly. The issue we face is that neither the client nor the supervisor from the LIFE program know when this new wheelchair will be purchased. They also do not know any specifics about the chair yet, this would include, wheel diameter, armrest height from axle, size of chair (height and width), outer rim location (distance to the wheel), braking system location, and possible axle connections. There is also a communication barrier with our client which results in an inability to confirm client preferences. Other than those, the other constraints present could be schedule oriented amongst the group members, conflicting exam dates, sickness, absence, etc. If our client gets his new chair upon our next meeting, then the constraint will be gone, however if he does not, we will have to construct a prototype that is adaptable in size and in connection points.

Scheduling

The main deadlines of our project were:

- Prototype 1: October 14, 2018
- Prototype 2: November 18, 2018
- Class Presentations: November 25, 2018
- Design Day: November 28, 2018
- Final Project Report: December 10, 2018

The deadlines for our solution was reasonable. Prototype 1 was a fast approaching deadline; however it was still doable, this deliverable ended up being a physical adaption of the final idea we decided upon, and was made using items easily found around the house. Prototype 2 was over a month away, so we thought that will give our client the time to purchase the new chair, but he hadn't yet. As for the class presentations, design day, and the final project report these were all meetable, seeing how there were no pressing conflicts for these then, later dates.

2.7 - Final Design Idea

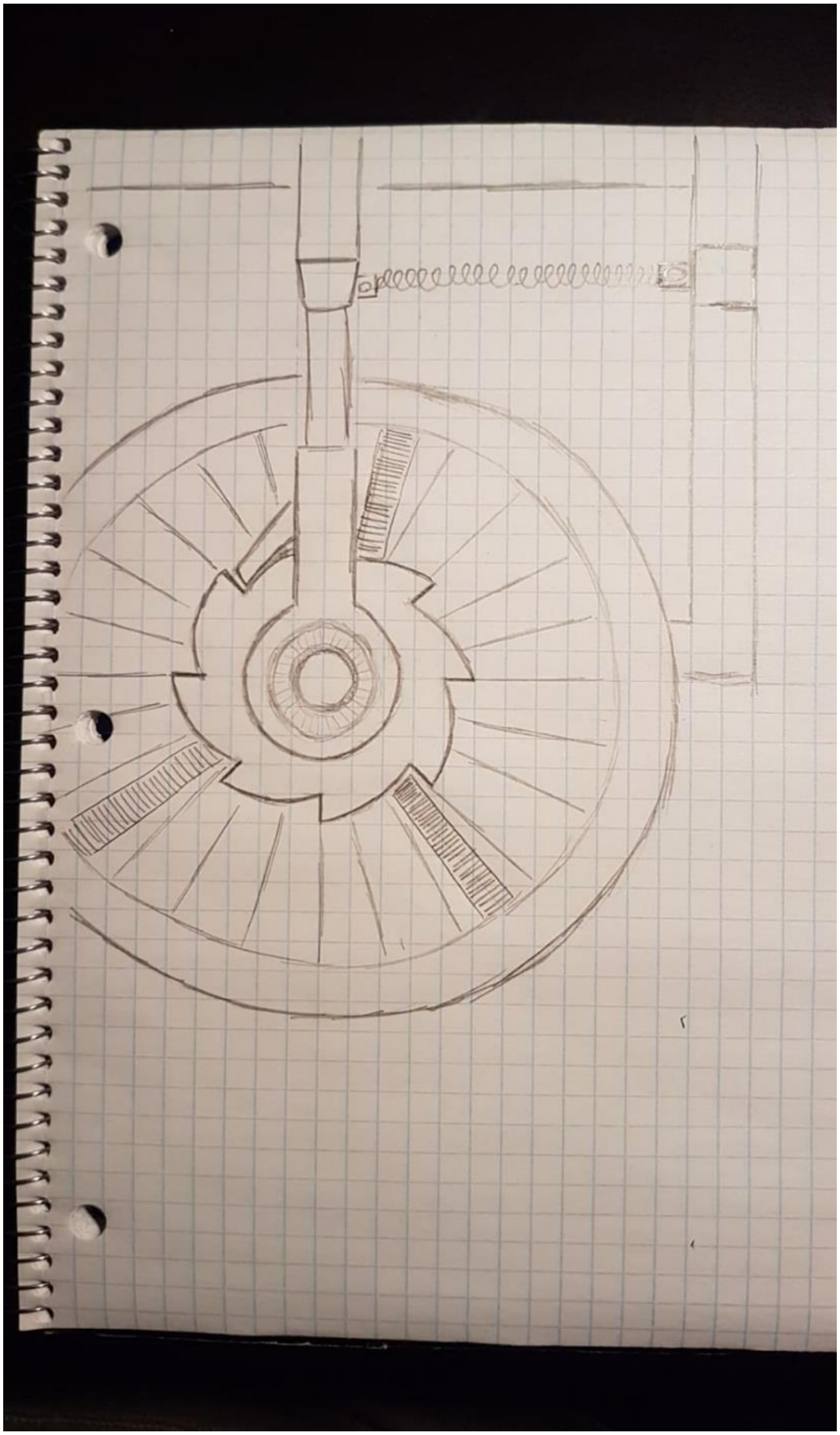


Figure 5: Final Design

2.8 - Prototyping and Testing

Prototyping is a long and tedious process; however, it is the most important in the design process. This is what allows for investments into the final product to payoff because there is an understanding how the product will function thanks to testing and constant tweaking of the design.

The wheelchair assist system includes a lever rod with a hand-rest as its handle that will promote comfort upon use. The rod is then connected to a lever attachment centered at the hub of the left wheel of the wheelchair, as a main objective of this design is to promote our client's motion on his left side. Within and alongside this attachment are ball bearings, gears, holders, pawls as well as a series of bolts, nuts and metallic strings that will hold it all together. The testing of our ideas is essential as it ensures the wheelchair assist system will work correctly. Testing will help to minimize and ultimately eliminate the design flaws and the potential oversights within our assist system design. The testing process is critical to ensure no major oversights or design flaws are overlooked. The general objective was to learn the type of materials and design that would work the best for the system but also fulfill the budget constraints, yet still leave a sufficient amount in case of last-minute important changes.

2.8.1 - Testing Criteria

Most of the testing conducted was in the sense of if pieces come together and fit into one another. We put pieces together and checked to see if they rotated freely the way they were supposed to, or stayed firm together as necessary. We came across a lot of problems in this phase, and materials needed to be either filed or completely sawed off to solve these challenges.

2.8.2 - Initial Prototypes

First Prototype: a low fidelity prototype meant for inner group communication and to give a body to the final design idea mentioned and illustrated above.

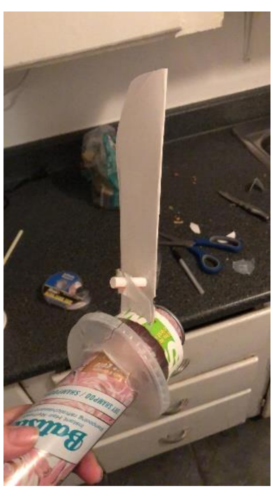


Figure 6: 1st Prototype

Second Prototype: a low cost prototype seeing if the bearing axle system as well at the lever attachment fit well with each other, and minor sizing issues were fixed in the coming prototype.

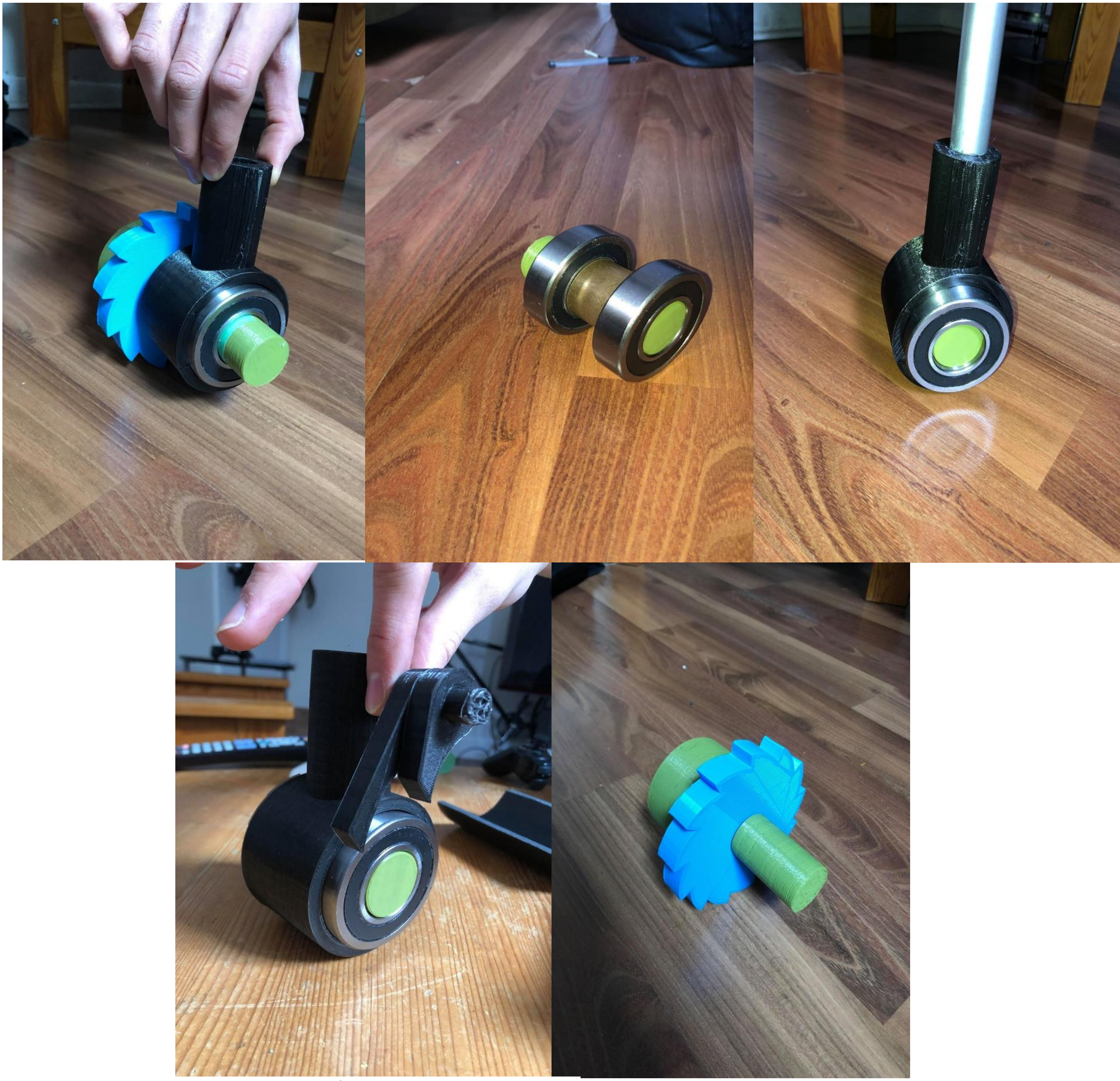


Figure 7: A collection of 2nd Prototype systems

2.8.3 - Final Prototypes

The third (final) prototype attached to a wheelchair (taken on design day)

Figure 8: Final Prototype

Design Day was the day of presenting the project. It was the day that the three-month long production of the wheelchair assist design was flaunted, shown to, and explained to anyone and everyone, ranging from fellow students and teachers which we see on a daily basis, all the way to esteemed guests of honour such as judges, potential users and most importantly, our client. We ensured our final prototype was fully functioning and capable of performing on design day, which it was, and had a wheelchair system given to us capable of showing off the capabilities of our project. Our progress was be mapped out by a power point presentation and poster board. Our aim was to explain the concept of our project as well as its significance in the life of our client. We were able to couple this working prototype with the wheelchair mentioned earlier and people got to see exactly how the project was to work. This was our verification method to show and explain, with evidence just how the design would work, real-time, with our real client.

Our project, including all CAD files, can be found on MakerRepo at:
GNG2101 - A20 - Wheelchair Assist
https://makerepo.com/awagstaff/gng2101a20wheelchairassist

2.9 - Creating a Business

Business Model Canvas

<table>
<tr>
<td rowspan="2">Key Partners

Material Supply Company

Volunteer Programs

Nudrive</td>
<td>Key Activities

3D Printing

Metal Work</td>
<td rowspan="2">Value Propositions

Limited Mobility

Delivery & Installment

Better Movement</td>
<td>Customer Relationships

Professional & Caring

Free of Charge</td>
<td rowspan="2">Customer Segments

People with Disabilities

Help Centres for Handicap People</td>
</tr>
<tr>
<td>Key Resources

A Customer Base</td>
<td>Channels
In person meetings

Advertisements (in Hospitals, PT centres, etc.)</td>
</tr>
<tr>
<td colspan="3">Cost Structure

Advertisement

Materials

Wages</td>
<td colspan="2">Revenue Streams

The device/product

Product priced ~$300 (cost for us, $100)</td>
</tr>
</table>

Table 5: Business Model Canvas

Economic Analysis

Costs of the Business
Selling Price per unit = $350
Units sold per year = 1080
Cost Price per Unit = $100

Variable Costs
- Materials - $54000
- Labour - $40000 x (2 employees) [Semi-Variable]
- Advertisements - $5000
- Average Product Shipping - $36

Fixed Costs
- Rent for Unit (Office/Warehouse) - $43800, 2677 square foot, $16.36/square foot per month
- Utilities - Included in rent
- Equipment & Machinery (steel,) - $50000
- Web Domain - $10
- Website Maintenance - $1000

Direct Costs
- Direct Materials
- Direct Labours

Indirect Costs
- Quality Control - $30000
- Insurance - $1000
- Web Domain - $10
- Website Maintenance - $1000
- Product Shipping

Net Present Value Analysis

The Net Present Value is the difference in value of cash inflows (revenue) and cash outflows (costs) over a period of time . The Break Even Analysis is a graph showing and comparing all major costs for designing a product with the sales for that product and is used to determine how much profit or loss there will be in that product's market. It is made with sales on the y-axis and number of units sold on the x-axis. Then plotting the linear values for the total cost and total revenue on this axis. The Break Even Point is the intersection point of the total revenue and total costs. It is the sales amount in either sales or units that is required to cover all costs of the business. Before this point on the graph, there is just loss and after this point, the business profits. At the break even point however, profits equal zero.

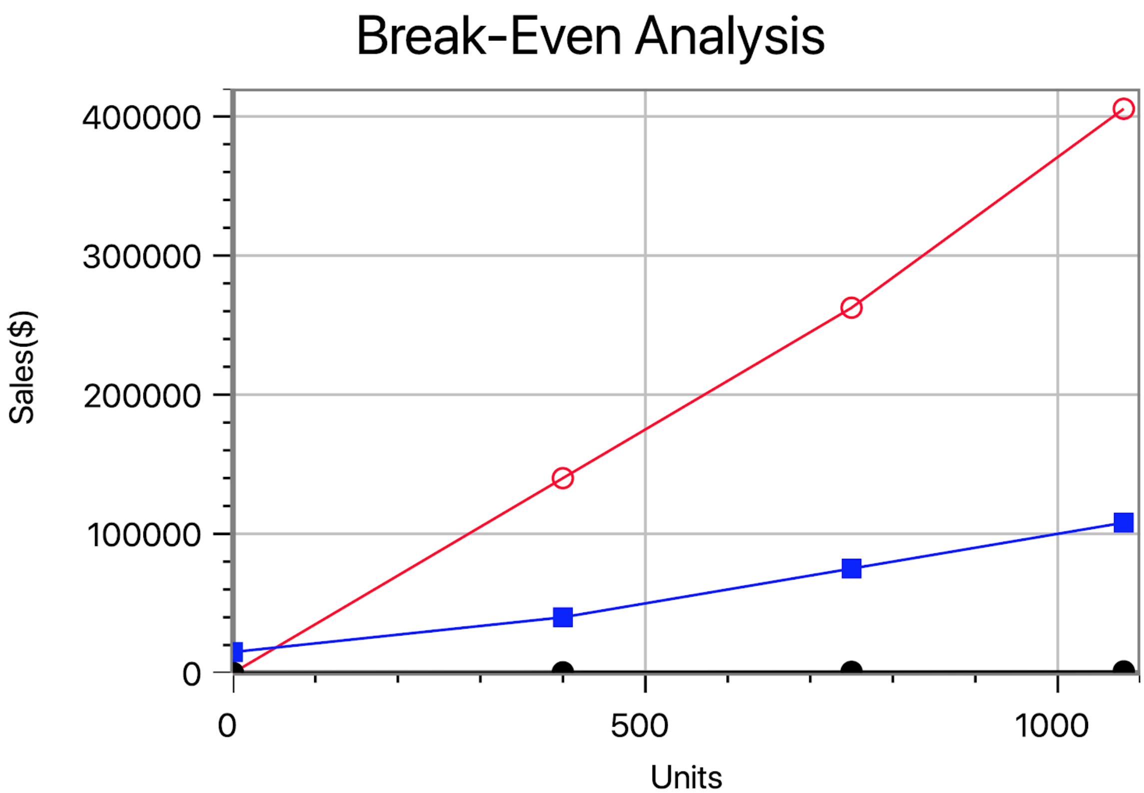


Figure 9: Break Even Analysis

The Red line in this graph represents the Total Revenue and the blue line represents total costs. The Break-Even Point is recorded at 53 units and 18,000 in sales.

Assumptions

- Sufficient labour is acquired and steadily expands with increase in revenue.
- Customer base will be steadily expanding.
- Cost of materials does not change in the next three years. (No depreciation)
- We will be able to increase our sales on a yearly basis, to ensure company growth. (i.e. more customers therefore more sales).
- Company expansion will be gradual.
- Assuming that 400 sales were made in the first year, 750 in the second and 1080 in the third.
- That the cost to start up the business with no units sold is $15,000.

3 - Conclusion and Recommendations for Future Work

Throughout our report, our team has outlined the progression of our project, as well as all relevant information to help the reader understand our process. We set out to create a cost effective solution to our client's mobility limitations, and we hope our work will pave the path for future improvements. Our goal is for our design to bring positive results and improvements to more people outside our client. With this report, we give detailed specifications on materials and methods used, issues we had with our design process, and many other pieces of information that will be useful for future teams, if our group does not decide to continue with this project.

We have learned many lessons about time management, effective team leading, and proper task distribution. In the future, our team would create a much more detailed task list with deadlines and assigned work. This would ensure we stayed on track and did not fall behind our schedule. It would also give us an abundant amount of time to ideate and spend more time on perfecting our design, especially concerning the strength of our materials. Some future steps we hope to take, are to investigate the cost and time that would be required to create a final and long-lasting product for our client. This would include researching the cost of certain metals and carbon fiber 3D printing, and taking a welding training course.

At first we found ourselves behind when it came time to developing our first prototype and presenting our project progress, with respect to our original project plan. After a constructive third client meeting and more time spent ideating and researching, we were back on track towards developing a functioning final product. With the help of Makerspace, our TAs' input, and skills learned in labs such as 3D printing and basic training, our group was able to develop a physical, comprehensive prototype that brought our concept design to life, helping us eliminate design flaws and visualize each element as a unit. Producing a successful final design that we used in our presentation on Design Day to full effect and most importantly, we hope will help our client improve his mobility and ultimately bring positive change to his life.