Winter Working Accessibility: The Snow Offensive

Authors: David Coyne, Lawrence Eddie, Mary-Kate Jory, Noah Renkema

Course: GNG2101A

ABSTRACT

The following document outlines the steps underwent by design team A9 in the process of creating a design solution for their client. The design process used throughout the semester and shown in this document is that of design thinking. All iterations of the design solution from the brainstorming phase until the final comprehensive prototype have been included. An analysis of the steps taken by the team is included for future improvement.

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INTRODUCTION

We are a team of four driven civil engineering students, who were presented the opportunity to work with, our client, Austin Smith, on the invention of a device that will provide him further mobility in the winter time as well as a source of income by means of shoveling snow. The device must be detachable, durable and easily stored.

PROBLEM REFINEMENT LOOP

In this part of the product development procedure we attempt to define what our product will do, and the specific problem it will solve. To do this we will have interviews with potential clients, in our case one, and see how we can solve the problem that they are having or fulfill a desire that they have.

NEED IDENTIFICATION

After the initial meeting with the client we created the following lists to facilitate further interviews and the problem solving process. Knowing what is unknown aids in creating new questions and narrowing down what further problems we could solve:

Summary of What is Not Known:

- Exact dimensions of the motorized wheelchair
- What the client envisions for the final prototype
- The level of automation the client would like to see in the final solution
- How to attach device to chair
- Which chair is preferable to use for this project
- Operational speed of the chair in winter
- The grip the tires have in the winter
- Dimensions of the attachment

From what is not known, we will take what the client had specifically described as the purpose for the device and make them into translated needs. The translated needs helps us create criteria for the device and find other products on the market that may satisfy our clients needs.

Translated needs:

- A device that clears snow
- A way to increase the wheelchair's mobility in winter conditions
- A way to insure that the snow moved is not impeding the wheelchair's motion
- The device must be compatible with different wheelchairs
- The device must be easy to remove and store
- The device must be durable

Taking our translated needs we create an order of importance of the device that we will create. The needs with top marks on this list will become the priority when creating sketches and prototypes, lower needs will be a feature that we hope to implement but if a constraint does not allow then it will be discarded.

Order of Importance: [5 being most important - 1 being least important]

- The device ensures user safety 5
- Clears snow 5
- Not impeding motion 5
- Attachable and removable (simplicity) 5
- Durability 4
- Improves winter mobility 3
- Storeable 2
- Compatible with multiple chairs 1

From the order of importance we created a statement, that encompasses what we will design the device to do. This statement is also empathetic with the client and reminds us why we are building the device, it's for a person:

Our client desires a device, adaptable to any wheelchair, that will give him further mobility in the winter time as well as a source of income by means of shoveling snow. The device must be detachable, durable and easily stored.

PRODUCT SPECIFICATION PROCESS

The framework for our product is not quite finished, we have a statement describing a device but no visual representation or market example. The next step is benchmarking, finding devices similar to what our customer desires. For this project there weren't any market product but devices that others had create themselves and were not selling. Even these were far and few between. So we found five and compared them with our translated needs and order of importance.



***Image set 1**: Benchmarking Alternatives*

Options (Alternatives)											
Criteria	Weight	Benchmark 1		Benchmark 2		Benchmark 3		Benchmark 4		Benchmark 5	
		Rating	Total	Rating	Total	Rating	Total	Rating	Total	Rating	Total
User Safety	**5**	4	**20**	3	**20**	5	**25**	5	**25**	5	**25**
Clears Snow	**5**	5	**25**	3	**20**	5	**25**	3	**15**	5	**25**
Motion Not Impeded	**5**	3	**15**	2	**10**	4	**20**	3	**15**	5	**25**
Attachable	**5**	2	**10**	3	**15**	1	**5**	2	**10**	5	**25**
Durability	**4**	3	**12**	3	**12**	4	**16**	3	**12**	4	**16**
Improved Mobility	**3**	2	**6**	3	**9**	3	**9**	2	**6**	4	**12**
Storeable	**2**	3	**6**	3	**6**	1	**2**	3	**6**	3	**6**
Compatibility	**1**	3	**3**	2	**2**	1	**1**	1	**1**	4	**4**
Total			**97**		**94**		**103**		**90**		**138**

***Table 1:** Decision Matrix for benchmarking*

After considering what was on the market we created ideal metrics for our criteria and used them later in the design process to determine if our design was up to our standards.

	Metric	**Unit**	**Target**
User Safety	Weight	kg	>200 kg
Clear Snow	Area	m^3	<3 m^3
Motion Not Impeded	Speed	m/s	<10m/s
Attachable	Weight	lbs	<51 lbs
Durability	Time	Years	>5 years
Improved Motion	Speed	m/s	<10m/s
Storable	Area	cm	>100cm
Compatibility	Length	cm	>50cm

***Table 2**: Design Criteria*

After finding these specification we have a very good idea of what we can create and narrows down the ideation process from anything to something that is on the same wavelength that our client desires.

PERSISTENCE LOOP

The persistence loop is the part of the design process where a design or solution is implemented, and another solution is needed due to impurities of the original idea, this loop idea is often come back to, as there is many times where a solution seems right at the time, but another solution comes up and is much more feasible.

Throughout our process of designing and making our product, we ran into many roadblocks where we realized what we were doing was not the best option, and could potentially not work. With that we went through the persistent loop aspect of the design process and came together as a group to decide on what the best option would be going forward.

CONCEPTUAL DESIGNS

The first step was to create concepts that could be evaluated and assessed for compatibility with our criteria. Each team member was tasked with creating three unique ideas that could be created or combined to become the final product.

First was David; his first concept worked for both chairs and attached to the sides of the wheelchair. The attachment was an angled plow. The second concept was for the newer chair, a shovel using the motor of the chair to lift the footrest. The third concept was for both chairs and attached to the sides again but the attachment was a plow that rolled the snow over.

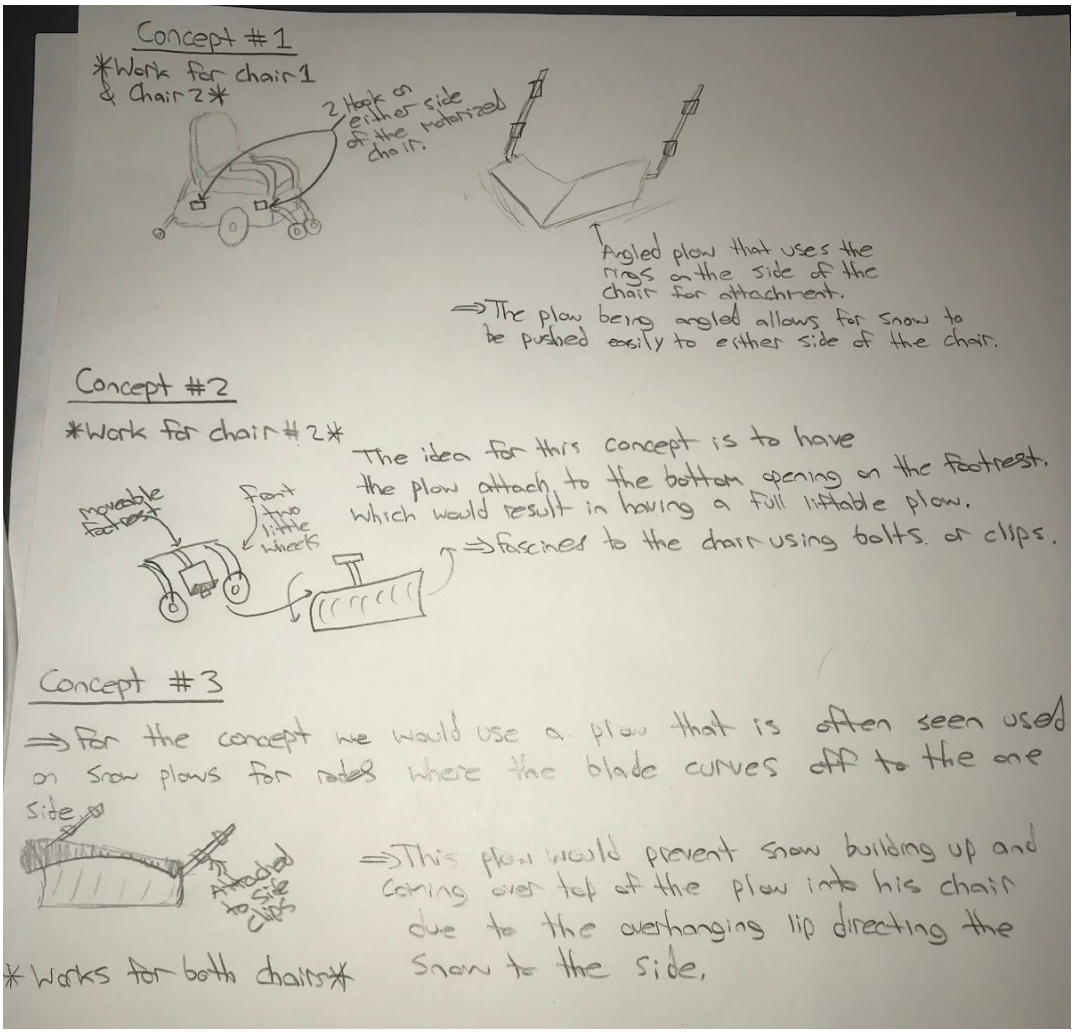


***Image 2**: David's Concepts*

Next was Lawrence; their first concept was a plow that uses the client's newer wheelchair that attaches to his foot rest and utilizes the motor to lift the plow. It has the plow situated in front of the chair and then to the left side at an angle of 45 degrees. The angled part of the plow is

attached at the back of the wheelchair using an extendable arm and a clip. Second concept was plow that is immediately in front of the client with a handle to lift the plow. The plow is attached to the front two clips of the wheelchair and are extendable and have a rotating part on the plow. The third concept was a plow that uses the the snow as a weight to bring itself to a semi upright position. It uses two clips to attach itself to the front of the wheelchair and as a small cart that the plow uses to lever itself on, there is an additional support to hold the plow at angle to start plowing and to prevent it from tilting in the opposite direction.

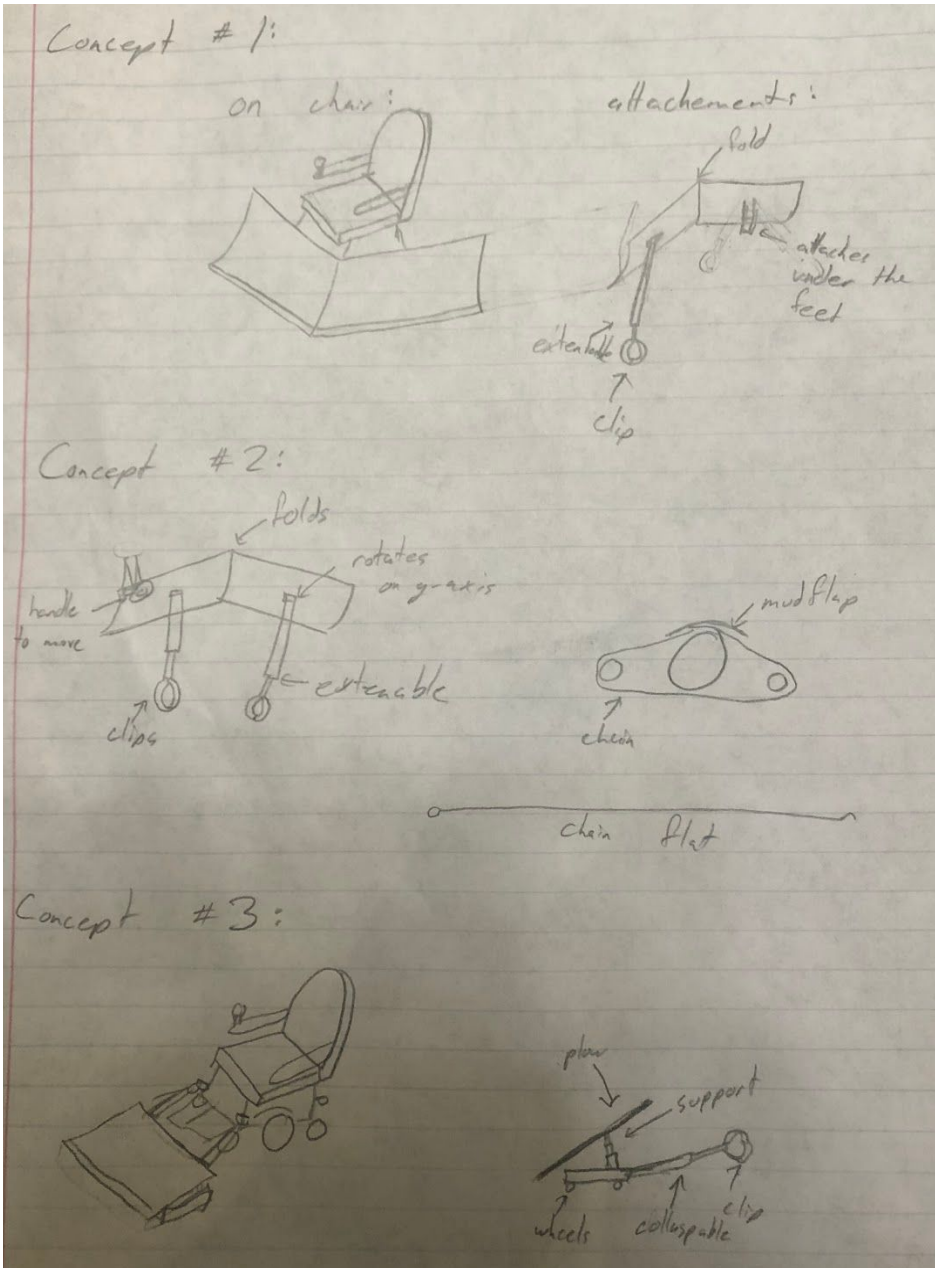
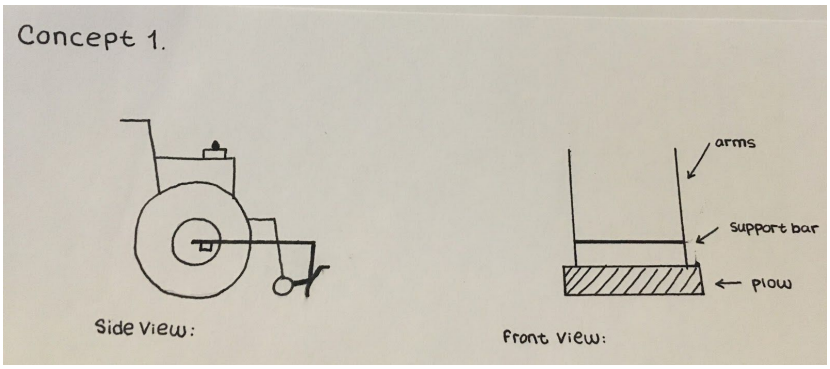
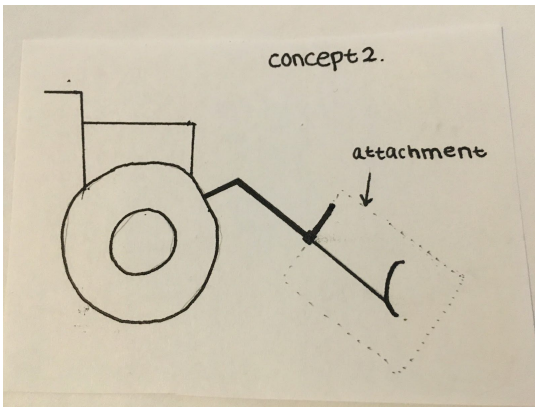


***Image 3**: Lawrence's Concepts*

Noah's concepts were next; first a concept design for Austin's older (less motorized) wheelchair. This design consists of two arms that attach to the sides of the main frame structure of the chair; using industrial heavy duty clamps to clamp the arms to the frame. Attached the arms is a support bar to ensure that the arms does not bend under weighted-pressure. And a slightly curved plow, simply pushes snow out of the extended pathway. The second concept was for Austin's newer (more motorized) wheelchair. This design simply takes advantage of the chairs manufactured design. At the bottom of the chair where the footrest is located is an opening [length 3 inch x width 1.5 inch x height 12 inch]. The free space allows for an attachment to be placed up into the opening and fastened. Austin's chair being motorized allows the footrest to reline. The design invisions the ability to not only remove snow out of the extended pathway, but pick up the snow and move it as well. Thirdly a concept design for the plow shape for Austin's wheelchair. This design is made to ensure maximum use can be made from the plow. The plow is made of plastic, and a thin layer of sheet metal at the bottom (for removing ice and withstanding sidewalk cracks). The arms are made from a light but strong metal. The plow has a inclining shape to ensure snow is move in one direction of the walkway (this design will move all the snow to the right of the walkway).





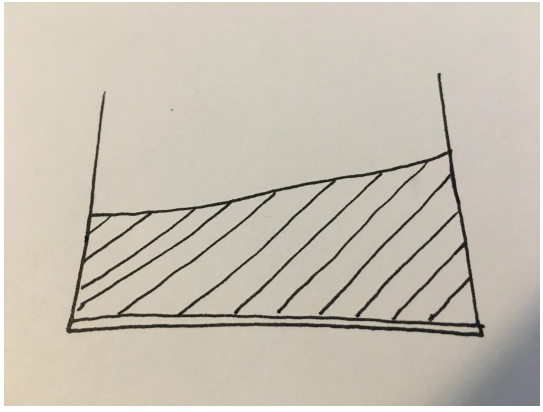
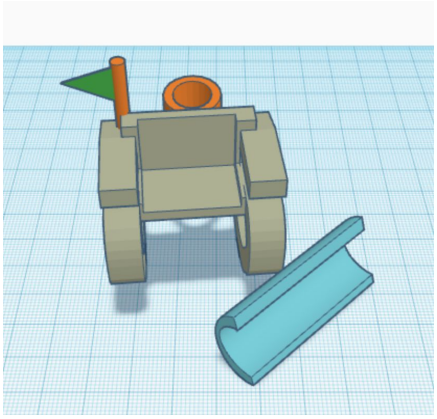
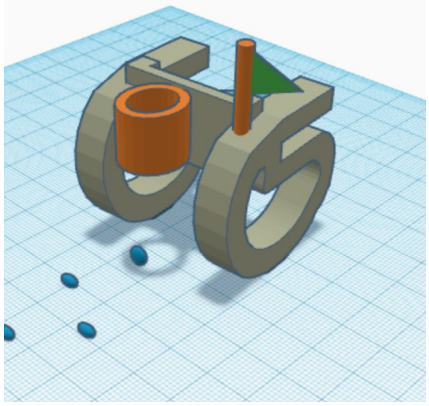
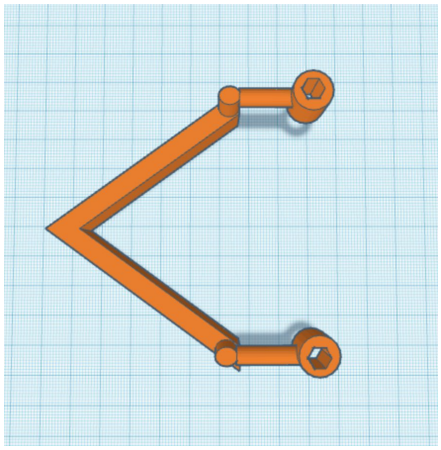


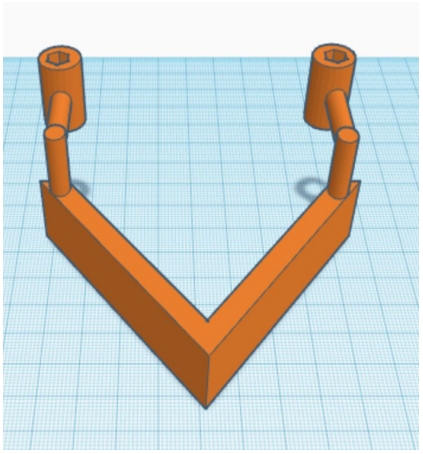
***Image set 4**: Noah's Concepts*

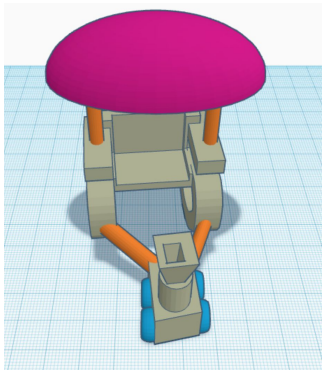
Last but not least Mary-Kate's concepts; the first design features a shovel at an angle that would collect snow and push it to the side as the client drove his wheelchair forward. Attached to the wheelchair would be a device for salt distribution to further remove ice and salt from the area in which the client is working. Additionally there is a flag attached to the wheelchair so that the client would be more readily spotted by the individual who would be supervising him while he worked. The shovel would attach to the front of the left side of the wheelchair. The second design is a plow modeled after the ones traditionally used by steam engines. This design would be attached directly onto the front of the wheelchair, parallel to the wheelchair's front edge. The method through which the plow would be attached to the wheelchair is by two clamps at the ends of the handles of the plow. The third design is a little more out of the box and is comprised of a snowblower and an umbrella. The snow blowers purpose is evident, to remove snow from the area that the client will be working within. The umbrella's purpose is twofold, firstly the umbrella will protect the client from any snow that might otherwise land on them due to the snowblower and secondly it will enable whoever is supervising the client to spot him easily.











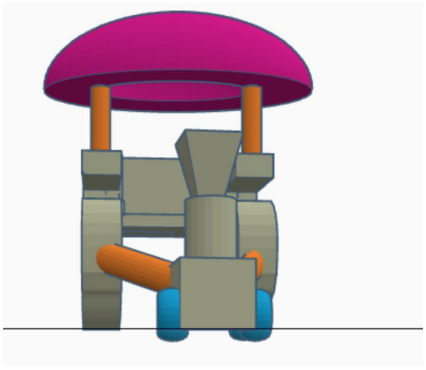


***Image set 5**: Mary-Kate's Concepts*

PROJECT PLANNING AND FEASIBILITY STUDY

Feasibility Study:

Technical: Does your team have enough expertise and technical resources?

As civil engineering students, we are all interested in the discipline centred around design and construction. Each member of our group has had experience in the design process (GNG 1103). The knowledge we have acquired from the courses we have taken thus far in university has provided enough in expertise. For example, civil engineering graphics (GNG 1107) has provided us with drawing skills highly required when trying to create a prototype. From a technical point of view, we each have our own individual skills, which combined makes us a strong resourceful team.

Economic: Can the cost of your project be reasonable?

The cost of our project is limited to $100.00 (provided by the University of Ottawa), which is reasonable if we plan and find the best material for our design. Having a smaller budget, although it might make designing a device more difficult, might actually be beneficial in understanding how the industry works (especially in the private sector). In industry you are employed under contract by a company to complete a project within a defined budget and constrained time. Sometimes having constraints can play a large role in the overall quality and useability of the work. With this understand we are going to use the best of our ability to deliver on quality and useability.

Legal: Are there any legal issues with releasing your solution to the public?

There are no legal issues with releasing our solution to the public. The materials that we have choose are public domain (a patent that has become public usable). Should there be any to arise we will shed light on the issue and resolve it before continuing the design process. However we did find three intellectual properties related to your product:

The first patent that is related to our product, United States Patent 8393096, which is described as "Plow of use with a motorized wheelchair". In the specific description of the device it is mentioned that the plow is in a V shape. However in their claim there is also a handle attached to the plow therefore our products differ enough to create a new patent without asking for permission. (Source: Thomas, Charles A. (Tijeras, NM, US), 2013, Plow for use with a motorized wheelchair,United States, THOMAS CHARLES A. 8393096 http://www.freepatentsonline.com/8393096.html)

The second patent that can be related to our product is Patent 2434908, which is a design for a spring system that connects a plow to a vehicle. This patent is specifically referring to cars as the vehicle attached, even so it is similar to our arms on our plow. (Source: Schultz, Lynn W., Koch, Timothy G., Wendorff, Terry C., 2007, Spring Bracket Design and Method for Snow Plow Blade Trip Mechanism, United States, SNOW-WAY INTERNATIONAL, INC 2434908 http://www.ic.gc.ca/opic-cipo/cpd/eng/patent/2434908/summary.html?query=Plow%2c+motorized+wheelchair&start=1&num=50&type=basic_search)

The third patent that relates to the product our team had produced is United States Patent 9845581, which was described as "Plow for use with automobiles and other vehicles". In the description of the patent it is explained that the plow can be used for any personal use vehicles including ATV's. This patent does not relate to our design as it stands but modifying our plow to be more attractive to larger markets (ie. personal use vehicles) is a logical step for the expansion of our business and this patent will need to consulted in the future. (Source: Anthony, Richard, Sanders, Paulette, 2015, Plow for use with automobiles and other vehicles , United States, Nordic Auto Plow, LLC 9845581 http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&co1=AND&d=PTXT&s1=Plow&s2=Wheelchair&OS=Plow+AND+Wheelchair&RS=Plow+AND+Wheelchair)

Operational: Are there any organizational constraints that will prevent your success?

The main organization constraints currently are time management. It is important that we as a team work together to complete tasks on time and continue to communicate our ideas and plans on a daily basis. We should work towards finishing a quality and informational final report.

Scheduling: What are the deadlines and are they reasonable for your solution?

The final deadline is Design Day which is the 25th of November, by that time our plow must be operational. Additional deadlines include the final report due date. The team must stay on task and organized in order to be ahead of deadlines and more importantly final exams.

With all of the above considered, our project and the timeline has been entirely feasible for our group. The project plan has guided us to success. Our feasibility study has assured us that the project is possible within the limits/constraints created. And by the time this document is sent out we will have complete the project.

ANALYSIS

A lot of time was spent in the persistence loop as the team felt it was crucial to really understand the problem before prototyping to avoid the waste of resources and the team's combined efforts. The team understood that the most important aspects of the design were of course that the device ensures user safety, clears snow and does not impede motion. The team was very conflicted about attempting to make the device compatible to many wheelchairs. The team only had one model of motorized wheelchair with which to work and insisting the attachment be compatible to many wheelchairs would drastically change the design of the attachment mechanism. In the end for our final design solution the team disregarded compatibility and focused on making a design solution suitable for our specific client.

PROTOTYPING, TESTING, AND CUSTOMER VALIDATION

The first idea for the plow was to attach it to the bottom of the client's newer wheelchair so for the first prototype was built to test the rotation for the plow. The second idea for the plow was to attach it on the sides of the older chair where there are tie downs for when the chair is in transportation.

First Prototype

The first prototype will test the ability of the snow plow attachment to be raised and lowered without breaking. The axis of rotation for our proposed design would be below the client's knees. A traditional snow plow with sides at 90 degrees to each other would not be able to rotate about an axis such as the one the team proposed in the last deliverable. The first prototype will determine if there is such an angle that exists that would allow the client to raise and lower the foot platform of his wheelchair as needed without damaging the ends of the snow plow.

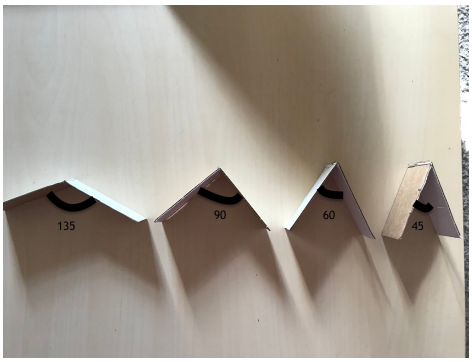


***Image 6**: First Prototype before testing*

The tests for this prototype was moving the cardboard plows in a rotation approximately 9 degrees as described in the owner's manual. The results of this test was that all four angles showed failure, however, the 135^{o} angle was the plow that showed the least amount of failure.

The customer was very excited about the V-shape of the plow and the idea that the plow would be compact (not large and cumbersome). They were concerned with the material and viability of the plow, considering they were not going to be gently with the plow.

Second Prototype

The second prototype focused on the attachment both of the plow arms to the wheelchair as well as the two sides of the plow to each other. Our goal was to find an inexpensive material strong enough to withstand high compressive and tensile forces, in addition corrosion resistance. It was crucial to find a material that could handle both harsh winter conditions and the wheelchairs electric power. We decided to use hollow aluminum rectangular tubes and cut two equal length arms, 2.3 ft. in length. Taking each of the arms and drill pressed holes. These holes are for the arms to attach to; laying the arms on the brackets and fastening the arms to the brackets with nuts and bolts. This design allows for ease of attachment and detachment of the plow.

***Image 7:** Second Prototype*

The test for the second prototype was to see how the arms attached to the wheelchair and how secure the connection is. The result of the test was a creation of a device that would stop the arms from sliding off the clamps. The device was simply two L-shaped brackets that are put on top of the U-brackets.

Third Prototype

The second part of the prototype was to connect the two shovels together with a bracket, forming a 135º angle between them. This was done by taking a piece of steel sheeting and bending it to the 135º angle, then attaching it to the shovels with bolts. The steel sheet metal was 1.58 feet in length and 2 inches in height.

Image 8: *Third Prototype*

The test for this prototype was to test the coverage and the thoroughness of the plow moving snow, the test was performed outside on the sidewalk when there was a thin layer of snow. The result was favourable and the plow cleared snow very well.

FINAL SOLUTION

Image Set 9*: First image the connection to the wheelchair, middle image full device, third image connection of arms to plow*

The final solution was a comprehensive prototype consisting of the second and third prototypes with the addition of a spring mechanism for the plow to allow give as well as attaching the plow to the arms using the springs.

Due to unfortunate timing, the final solution was not road tested as the snow had melted off the sidewalks by design day. The team was able to test the final solution in the lab however and found that all attachment mechanisms functioned as hoped.

BUSINESS MODEL

Chosen Model:

The common business model: "Brick and mortar"/landlord is our chosen model, because it will best improve our product. The landlord model is designed to sell physical products to others in a centralized business place. Our product is physical and will be more easily distributed through a centralized location.

Considering we have such a niche market we would also proceed to the online market. If we build a simple website to provide our product and social media (i.e. youtube, instagram etc.) as our advertising platform we will increase our market size.

Canvas:

<table>
<tr><td rowspan="2">Key Partners
- Austin
- People with disabilities
- Support from other businesses</td><td>Key Activities
- Refining the product</td><td rowspan="2">Value Proposition
- Provide mobility and a means of community involvement for those with disabilities, with help from an attachable snow removal device</td><td>Customer Relationships
- Personal professional relationship</td><td rowspan="2">Customer Segments
- Motorized wheelchair users
- small personal motorized vehicle users</td></tr>
<tr><td>Key Resources
- University funds
- Personal funds
- Raised funds and donations
- Makerspace</td><td>Channel
- Online advertisements
- Hospitals and care centres etc., propose the products benefits
- One-on-one
- Word-of-mouth</td></tr>
<tr><td colspan="3">Cost Structure
- Product development
- Patent</td><td colspan="2">Revenue Stream
- Free/no-profit until there is a large market size</td></tr>
<tr><td colspan="3">Social and Environmental Cost
- Mean of income for people with disabilities</td><td colspan="2">Social and Environmental Benefits
- Encourage outside activities</td></tr>
</table>

***Table 3**: Business Model*

Core Assumptions:

- That there is a significant demand for the product.
- That our target market consists of solely those in motorized wheelchairs.
- That we could find manufactures for this product.
- That we could continue to produce the product without a revenue stream.
- That a large market size for this product will eventually develop.
- That an initial product could be developed with the current resources available to the team.

ECONOMIC

Material	Units Purchased	Price per Unit	Total Price	Place of Purchase
Aluminum Shovels	2	$39.54	$79.08	Canadian Tire
Steel Sheet Metal	38 inches^2	$0.03	$1.14	Brunsfield
Aluminum Rod	60	$0.14	7.14	Brunsfield
Zinc U-Bolt	2	$5.99	$11.98	Lowe's
Gate Hinge	1	$2.11	$2.11	Lowe's
Assorted Bolts and Screws	15 x Bolts 12 x Nuts	$20.95	$20.95	Home Hardware
		Total:	**$122.41**	

***Table 4**: Bill of materials purchased*

Cost of materials:

We had a strict budget of $100.00. Each of the items we have selected were there original sale prices; we were unable to find sales and or discounts when purchasing materials. If we had found sales we would have been able to reduce our costs and stay within budget. Going over budget was totally justifiable because we as a team felt the responsibility to bring our client a viable product.

USER MANUAL

1.Introduction

This User Manual (UM) provides the information necessary for the caregiver of the user to effectively use the *Snow Offensive* wheelchair attachment.

2.Overview

- Included in the *Snow Offensiv*e are 2 “arms”, 1 plow and 2 brackets
- The “arms” consist of a metal rod with a U-bolt on one end, this U-Bolt clamps onto the wheelchair
- The purpose of the brackets are to stabilize the connection of the arm to the wheelchair
- The *Snow Offensive* is meant to be attached to motorized wheelchairs with the purpose of clearing sidewalks
- The *Snow Offensive* has been designed to be easily detachable
- The *Snow Offensive* is meant to be able to be stored, once the arms have been detached from the plow

2.1 Cautions and Warnings

The *Snow Offensive* was not created by professionals as such there are some small precautions that could be considered. Parts of the *Snow Offensive* were created using scrap metal, namely the brackets. Thusly, some caution should be employed when handling them. Be wary of sharp edges that were missed during the filing process.

Additionally, as the *Snow Offensive* is composed of entirely metal components it gets quite cold when it is brought outside. Whomever, is attaching the *Snow Offensive* to the wheelchair of the user should consider using gloves to protect against very cold temperatures.

3. Getting Started

Before using the *Snow Offensive* one must first attach it to the wheelchair. On most motorized wheelchairs one will find two long, flat metal loops extruding from the base of the chair, running parallel to the floor. This is the ideal point for the *Snow Offensive* to be attached to. The arms of the *Snow Offensive* should positioned so that the aluminum tubing lies under the extrusion mentioned above while the U-Bolt lies on top, falling to the front and back of the metal extrusion. The U-Bolt should then be tightened with the use of a wrench. The bracket is then inserted facing down above the U-Bolt, preventing lateral movement of the arms. The set-up is pictured below.

***Image 10**: Set-Up for the Snow Offensive*

4. Using the System

The *Snow Offensive* was designed to improve the mobility of motorized wheelchairs in harsher winter conditions. Once the *Snow Offensive* is attached to the wheelchair, the wheelchair should be driven at slower speeds to avoid the risk of harm occurring to either the user or the *Snow Offensive.* As the motorized wheelchair is driven, the *Snow Offensive* will push snow to either side of the plow.

5. Troubleshooting

If the *Snow Offensive* plow, arms or anything in between come loose, any of the connections can be re-secured through the use of the of a wrench. The primary method of attachment employed by the team to secure all of the components together was using screws and bolts. Therefore, it is quite easy to use a wrench to tighten the bolts and secure the connection.

In the event that the plow encounters some such obstacle, reverse the wheelchair and the *Snow Offensive* will lift up off the sidewalk.

If the brackets do not fit easily into the designated area, try switching the brackets on either side. Due to human error the brackets are not identical and sometimes work better on one side than another.

5.1 Support

If none of the above solutions work to fix the problem encountered please contact one of the members of the design team for improved technical help.

Mary-Kate Jory mjory023@uottawa.ca
David Coyne dcoyn024@uottawa.ca
Lawrence Eddie aeddi019@uottawa.ca
Noah Renkema nrenk048@uottawa.ca

DESIGN FILES

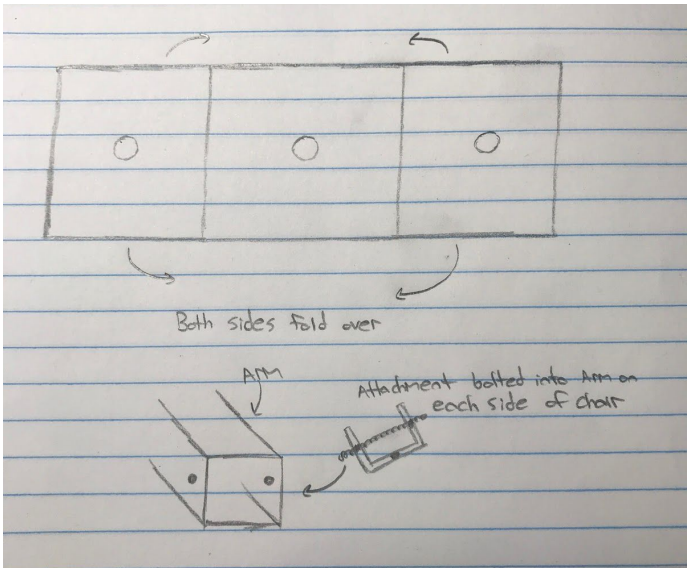


***Image 11**: Connection between the arms and the plow*

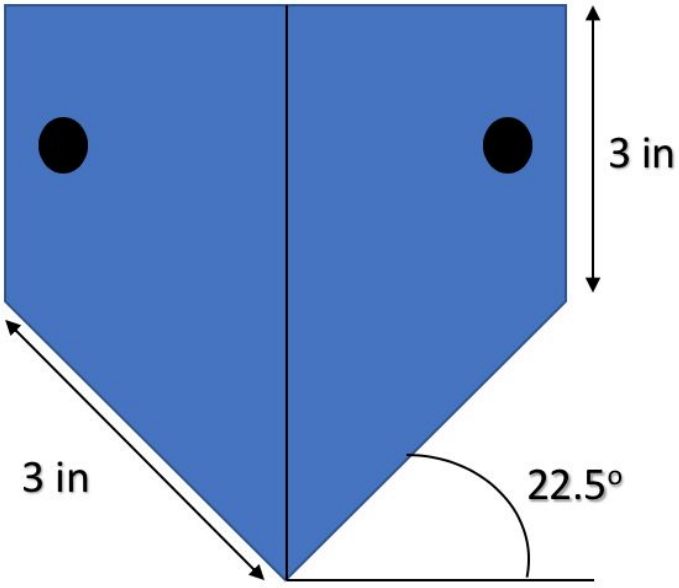


***Image 12**: Connection between the two shovels forming the two sides of the plow*

Project available at makerepo at https://makerepo.com/mjory023/gng2101a9winter-working

CONCLUSION

This process of project initiation and delivery has been an involved learning process for the members of the design team. Skills such as teamwork, time management, problem solving and budgeting had to be developed in order to complete the design solution for design day. Time management was a particularly tough skill for the design team to master as the individuals on this team were running on seemingly opposing schedules. The difficulty in developing time management skills made determining the critical path in the beginning stages of the project exceptionally difficult. Problem solving was complicated as there were many hidden flaws in the design that were initially overlooked, fixing these weak areas later down the road took a great deal of innovation and creativity. The difficulty of working with constraints such as the very limited $100 budget cannot be understated but that too was resolved through out-of-the-box type solutions. Overall a great many skills have been learned this semester both technical and project oriented.

BIBLIOGRAPHY

Source for **Image Set 1**:
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https://www.youtube.com/watch?v=ziEBvVVrNHQ;
https://www.youtube.com/watch?v=5ddMyerXsaM.