GNG 2101

# Design Project User and Product Manual

## Wheelchair Plow
## Bye Bye Snow


Submitted by

**Section B02 Team 24**

Nicolas Beaudoin, 300160333

Juan Pablo Sanchez Garcia, 300173810

Omar Mortaja, 300171089

Uvil Chithruke Dahanayake, 300199138

Zackary Dickinson, 300169324


December 5th, 2021


University of Ottawa

# Table of Contents

## List of Figures

# List of Tables

## List of Acronyms and Glossary

| Term | Acronym | Definition |
|---|---|---|
| Frame | | Rigid square tubing part of the plow |
| U-clamps | | U shaped bolts with 2 nuts and a plate to secure it |
| Connecting arms | | Parallel part of the frame connecting the clamps to the hinges |
| Kinetic energy | | Energy of moving objects |
| Pin and holes system | | Series of holes which house a pin to adjust the angle of the blade |

Table 2. Glossary

# 1 Introduction

For many young adults and teenagers with disabilities, it can often be frustrating to see yourself helpless in situations which may be trivial for others. That is why students taking the Introduction to Product Development for Engineers and Computer Scientists class at the University of Ottawa are dedicating themselves to tackling such problems. The particular challenge for the B24 team involves allowing the user to plow snow while being wheelchair-bound. This should allow the client to contribute to his household and neighbourhood and possibly start a snow removal business.

The client seeks a user-friendly and widely-accessible product that helps their wheelchair-bound sibling displace snow safely, conveniently and reliably while minimising the use of physical mouvements. The product should keep the original functionality of the wheelchair intact and cannot rely on the user's leg mobility.

Provided within the user manual are cautions and warnings, product documentation (covering prototypes and concepts), how the design works, what is required to build it, and how to build the design. The intended audience of this user manual is any potential user, anyone wishing to recreate the product, researchers, and manufacturers.

# 2 Overview

Many medical conditions have the unfortunate result of limiting a person's mobility to the point of being wheelchair bound. For such individuals, many essential tasks can be completely impossible without assistance. Such a task is plowing snow off of circulation outdoor areas. To fix this problem, the user would need a way to plow snow from his wheelchair. The user cannot use his arms to hold a shovel since certain conditions limit arm movement and others will still require the user's arms to move the wheelchair.

The product should be able to offer the full set of plowing features typically found on commercial plow trucks for a fraction of the cost of the competition which does not offer such options. The plow should be able to absorb the shock of obstacles and glide over them with a spring suspension system and the blade should be able to angle left and right. Having a blade spring system not only makes plowing much more efficient, it also helps to maintain the safety of the user which many other products jeopardise. The blade angling system offers a lot more versatility while plowing and is not offered by other manufacturers.

| Question | Client Statement | Interpreted Need |
|---|---|---|
| **Typical Uses** | I want the plow to lift snow | Plow must move upwards |
| | The plow will be used in the driveway (asphalt) | The plow must function normally and not damage or be damaged from contact with asphalt. |
| | I want to move snow | Displace snow |
| **Likes / Regulations** | I really like Power Shovel | Design like Power Shovel |
| | I want it power controlled | Electric or motorized movement |
| | I really like buttons to control it | Ideally uses a button design for control |
| | I do not want to spend 20 minutes putting it together | Conveniently designed to mount easily |
| | Safety (stability) for the user | Provides a safe solution, regardless of supervision. |
| **Dislikes** | Snow blowing in user's face or over electronics | Plow maintains safety of user and equipment |
| | I do not want any permanent changes to the wheelchair | Detachable, no holes, no welding onto chair |

| | | |
|---|---|---|
| **Optional** | There are different speeds that the wheelchair can go, but we have preset profiles already. However, we can program it to go faster. | Plow operates normally regardless of wheel speed and weather condition |
| | We do have a backup wheelchair that is only used for emergencies. | Plow mounts on electric wheelchair |

*Figure 2.1 : Client Statements and Customer Needs*

| Number | Need | Importance (1 least-5 most) | Reasoning |
|---|---|---|---|
| **1** | Durability | 2 | Since the user is not expected to move large amounts of snow. It is not expected that the snowplow will get heavy use. It will be more likely be used to plow small amounts of snow but more frequently |
| **2** | Easy to mount | 3 | 'It is assumed that multiple people will help mount the plow and it is allowed to take time to mount, just not up to 20 minutes.' |
| **3** | Safety | 5 | The client does not want any of the electronic equipment on the wheelchair to be damaged. Preventing any snow of colliding with her brother |
| **4** | Functionality | 5 | The user should feel involved helping around the house. |
| **5** | Compactness | 1 | Functionality is the priority. Ease of storage is a luxury. |
| **6** | Physical ease of operation | 5 | User can move his hands, but occasionally needs a break (it cannot be constant hand usage), so it is important to have an easy way to control the plow. |

*Figure 2.2 : Customer Needs Matrix*

*Figure 2.3 : Isometric View of SnowPlow*

## 2.1 Cautions & Warnings

Plowing snow exposes the user to slippery ground surfaces which may lead to a loss of traction or the wheelchair while plowing. This loss of control may lead to injury or even death of the user and others. Always make sure the wheelchair can navigate safely on the surface to be plowed. Avoid constantly holding up the plow blade as that could lead to strained/sore arm muscles. Avoid putting fingers under hinges and inside the pin and hole concept to prevent pinching, cutting, or other possible injuries. Do not stay out in the winter cold too long as the user could get hypothermia or mild illness (ex. common cold). Be cautious of surroundings to prevent damage to people or property (ex: cars).

# 3 Getting started

To use the snow plow the user should have somebody to help them with the installation. After the user is seated in their wheelchair, the helper may attach the snow plow using the U-clamps. After the U-clamps are secured, the plow blade can be rotated horizontally to push snow at an angle. After plowing snow, the snow plow can be removed by unsecuring the U-clamps.

## 3.1 Set-up Considerations

When setting up the snow plow, the user must have an adjustable crescent wrench to secure the clamps and a helper with full body mobility to aid in the installation.

## 3.2 User Access Considerations

The snow plow should be installed after the user is seated in the wheelchair and should be installed by the helper.

## 3.3 Accessing the System

On each of the connecting arms are two holes. Align the holes so that the attachment location is situated by the holes on either side.

*Figure 3.3.1: Holes on Connecting Arms*

The U-clamp should be inserted so the attachment location is on the inside and should have the plate inserted on it. The U-clamp can then be secured in place by tightening a nut on the prongs that come out of the mounting bars.

*Figure 3.3.2: Connecting arms with U-clamps secured in place*

The frame of the plow should be approximately parallel to the ground.

## 3.4 System Organization & Navigation

To adjust the angle of the snow plow, the farthest pin from the plow on the rotating piece can be removed. After removing the pin, the angle of the plow can be adjusted. Once the desired angle is chosen and the holes are properly aligned, the pin can be reinserted to hold the angle in place.

## 3.5 Exiting the System

To detach the snow plow, a helper can unscrew the nuts to take off the cover and the U-clamps. Once the U-clamps are removed the snow plow can be removed.

# 4 Using the System

Our snow plow has 3 main systems, the Pin & Holes angling system, the rope lift, and the tension spring. The pin & holes concept is used to rotate the snow plow horizontally and hold it in place. The rope lift is used to raise and lower the snow plow should the need arise. The tensions spring allows the snow plow to

## 4.1 Pin & Holes Angling System

The pin and holes system is used to rotate the plow blade horizontally and hold the angled position. The pin marked in red in the image below can be removed and repositioned.

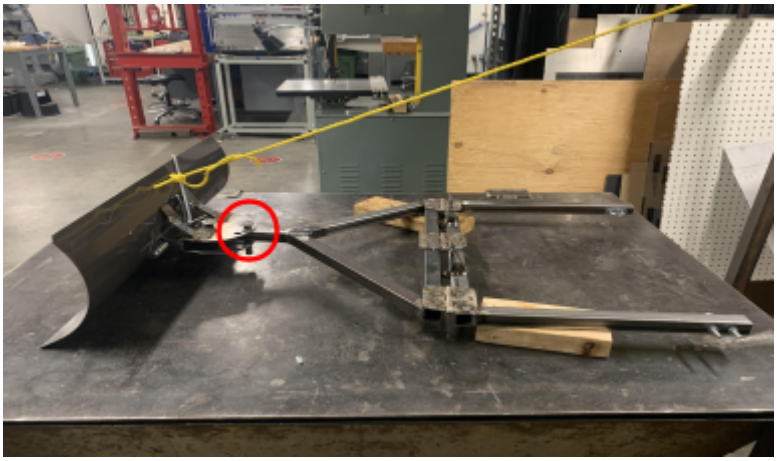


*Figure 4.1.1 : Focused View of Pin and Holes System*

The plow blade can then be rotated to several angles. There are three different angles that can be used. The blade can be angled to the right, facing straight forward, or angled to the right. To secure an angle, all the holes must line up with the desired position.

*Figure 4.1.2: Pin & holes angled right with holes aligned*

The pin removed earlier can now be reinserted to hold the plow blade in place and prevent it from further rotating.

*Figure 4.1.3: Pin & holes angled right with pin inserted*

## 4.2 Rope Lift

To lift the plow blade, the user can pull on the rope attached to the plow blade as seen in the picture below

*Figure 4.2.1 : View of Rope in use*

By pulling on the rope, the user can lift the plow blade when it rotates vertically around the hinges marked in the picture.

*Figure 4.2.2 : Elevated Blade*

## 4.3 Tension Spring

The two springs in the picture below are the tension springs.

*Figure 4.3 : Focused View of Tension Springs*

When the plow goes over a crack or a chunk of ice, the plow blade will tip downwards to glide over it. The springs will tilt with the blade, but the tension will allow the blade to tilt back towards its neutral position.

*Figure 4.3.1 : Blade Simulation over crack or debris*

# 5 Troubleshooting & Support

| Problem | Solution |
|---|---|
| Unable to securely mount the plow to the wheelchair. | - Clean mounting points are clean from debris |
| Clamps damage the wheelchair | - Add a rubber layer between the clamps and the wheelchair.<br>- Tighten the clamps with less torque. |
| Plow blade gets caught on ground defects while plowing | - Inspect the blade as it can pivot as intended.<br>- May require plastic bushing see, support for more information. |
| Pin does not want to enter fully in hole of the rotating point. | - Align top and bottom holes.<br>- Light bending of the sheet metal may be required to straighten sheet metal. |
| Hinges become stuck | - Add lubricant to the hinges and remove ice or debris from hinge |
| Blade rusts | - Locate chips in the paint, sand down area, reapply paint to location and follow instructions on spray can.<br>- After use, wipe down excess snow |
| Rotating rod does not want to leave the mold | - Slightly hit the rod with a hammer back into its location, then rotate the head of the rod to another location and try again. |

*Table 5.0 : TroubleShooting and Support*

## 5.1 Error Messages or Behaviors

| Incorrect Behavior of Parts | Cause | Resolution |
|---|---|---|
| Bent Metal | - Mishandling in Shipping<br>- Excessive Force<br>- Rust | - Contact support for additional information |
| Blade rotates more than intended | - Spring over extended<br>- Hinges broken or over extended<br>- Entire snow plow is upside down | - Contact support for additional information<br>- Assure that the blade is correctly oriented. Blade is correctly orientated when the springs are on the top of the blade. |
| Springs over extend | - Mishandling in Shipping<br>- Excessive Force<br>- Rust | - Contact support for additional information |
| Hinges break or unable to move | - Mishandling in Shipping<br>- Lack of lubrication<br>- Rust<br>- Excessive Force | - Contact support for additional information |

*Table 5.1 : Error Messages or Behaviours*

**For all resolutions indicating "Contact support for additional information" see section 5.4 support.**

## 5.2 Special Considerations

| Exceptions | Resolution |
|---|---|
| Broken Metal | - Contact support for additional information |
| Broken Clamps | - Contact support for additional information |
| Broken Blade | - Contact support for additional information |

*Table 5.2 : Special Considerations*

**For all resolutions indicating "Contact support for additional information" see section 5.4 support.**

## 5.3 Maintenance

| Seasonal Maintenance | Use Maintenance | Storage Maintenance |
|---|---|---|
| Description: Maintenance before the start of the season | Description: | Description: |
| Lubricate hinges and pivot location<br><br>Inspect frame for integrity<br><br>Inspect paint for cracks or chips in the paint, refer to troubleshooting for a solution<br><br>Inspect cast mold for any cracks or tears | Secure the slack on the rope<br><br>Inspect all points of rotation for appropriate use cases<br><br>Inspect all mounting points to be mounted correctly<br><br>Inspect pin and holes to be inserted fully before commencing | Disassemble frame from pin and holes and store together<br><br>Keep all bots and clamps together in a small bag<br><br>Store blade in a non highly moisture area and remove all water contents on the blade |

*Figure 5.3 : Maintenance*

## 5.4 Support

If any assistance is needed for operating or repairing the products, users may contact Mana Azarm, the professor of the team who developed this product in an engineering class. The contact can be reached either by email at mazarm@uottawa.ca.

In case of an emergency threatening the safety of individuals or damage to property, contact the appropriate local emergency number for law enforcement, the fire department or an ambulance.

# 6 Product Documentation

The final prototype was built by dividing the products in 3 sub-assemblies. The first one was the frame, which involved cutting square tubing to length and with the proper angle and then welding the individual pieces of tubing into one with a MIG, TIG, or stick welder. The frame also required drilling ½ inch holes to host the pin of the pin and holes system and the clamp screws. The hinges can simply be welded on at the desired place. Ideally a rustproofing coat of paint and primer would be added to the frame although this was not done for the prototype.

The second component is the pin and holes system. The sheet metal part was manufactured by cutting around the printed template with an angle grinder and drilling holes in the right locations. Then, the sheet steel can be bent to the appropriate shape. The pins are made by turning down ½ inch round stock to 7/16 inch on the lathe and by welding a washer to one end to act as the stop. The other end should have a ¼ inch hole to house the lock pin.
The final sub-assembly is the blade. The blade is simply acquired from a supplier and modified to fit the frame. The modifications include welding a square tubing to the back of the blade and 3D printing a plastic bushing to fit between the ½ inch pin and the tubing. Injection molding is a better alternative if made at mass scale. A hole may also be drilled at the top of the blade to mount the spring.
Ideally, the plow should be made all in aluminum if possible for the materials natural rust resistance and for its better strength to weight ratio. The was decided at 1 inch since it gave the best strength to weight ratio for our needs while still being standard square tubing. The sidewall thickness chosen at 0.065 inch can vary within that form factor since the frame has a large safety factor. The sheet metal thickness was arbitrarily chosen at 16 gauge, but it can vary based on tool capacity and if the product is made with aluminum instead. Having access to larger diameter drill bits would allow them to simply use the ½ round stock as the pins without first turning them on the lathe.

| Bill of Materials | Dimensions (if Applicable) | Links | Unit Cost |
|---|---|---|---|
| Steel Square Tubing | 1" * 1" * 1/8" | https://makerstore.ca/shop/ols/products/square-tube-steel-per-inch/v/BF001-1X1-8 | $34.56 |
| Cutting Service | | https://makerstore.ca/shop/ols/products/cutting-service-brunsfield-centre | $3.00 |
| Sheet Metal | | https://www.homedepot.ca/product/paulin-12-x-24-inch-16-gauge-steel-sheet/1000861862?rrec=true | $18.27 |
| Steel Round Tubing | 1" D * 6" | https://makerstore.ca/shop/ols/products/round-tube-steel-per-inch/v/BF008-D1-X3 | $1.14 |
| Shovel/blade | | Facebook Marketplace | $30.00 |
| Springs | | https://www.homedepot.ca/product/paulin-11-32-od-x-3-inch-extension-utility-spring/1000127093 | $2.21 |
| Pins | | https://makerstore.ca/shop/ols/products/round-bar-steel-per-inch/v/BF012-D1-2 | $2.55 |
| Total Cost Including Tax | | | $98.27 |

*Table 6.0 : Bill of Materials*

## 6.1 <Subsystem 1 of prototype>

### 6.1.1 BOM (Bill of Materials)

| Bill of Materials | Dimensions (if Applicable) | Links | Unit Cost |
|---|---|---|---|
| Sheet Metal | | https://www.homedepot.ca/product/paulin-12-x-24-inch-16-gauge-steel-sheet/1000861862?rrec=true | $18.27 |
| Pins | | https://makerstore.ca/shop/ols/products/round-bar-steel-per-inch/v/BF012-D1-2 | $2.55 |
| Total Cost Including Tax | | | $20.82 |

*Table 6.1 : Bill of Materials of Subsystem 1*

### 6.1.2 Equipment list

- Bend Brake
- Drill Press
- Band Saw
- File

### 6.1.3 Instructions

First, print out the solidworks model drawing. Second, using a bandsaw, cut sheet metal into the outline from solidworks drawing. Third, drill holes in desired locations. Finally, using the bend brake, bend the design into a c (taco shape). Optional, using spare sheet metal, cut pieces using bandsaw and weld on top side of design to support blade.

## 6.2 <Subsystem 2 of prototype>

### 6.2.1 Equipment list

- Hand drill
- File

### 6.2.3 Instructions

Depending on the width and size of spring chosen, drill 1 hole on the upper half of the blade and another hole on the pin and hole concept support piece. Then using nuts and bolts secure the spring to the blade and pin and hole concept holes previously drilled.

## 6.3 <Subsystem 3 of prototype>

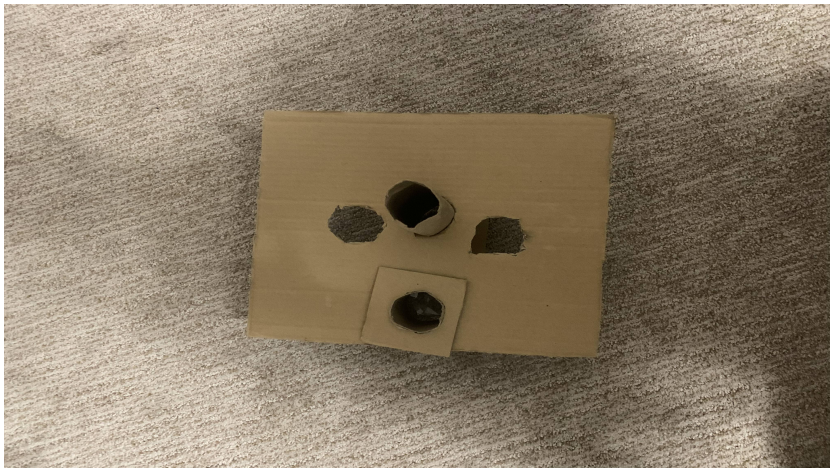
### 6.3.1 Equipment list

- Hand drill
- File

### 6.3.2 Instructions

Depending on the width of rope and method chosen, drill 1 or 2 hole(s) through the upper half of the blade, then thread the rope through the hole(s) and tie as many knots as desired.

## 6.4 Testing & Validation



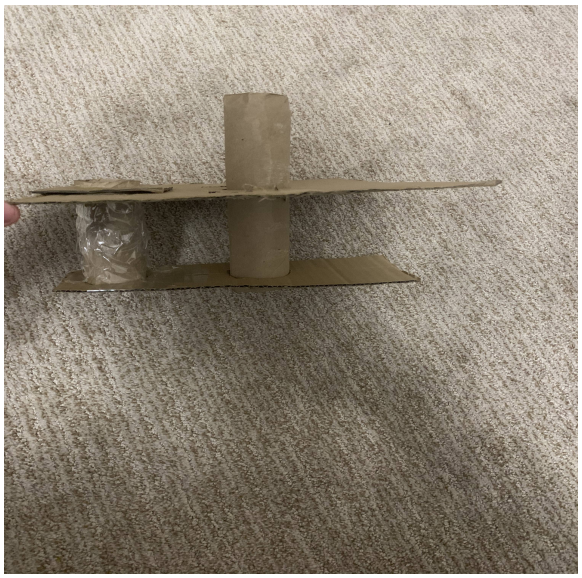


Table 2: Test results for various angles and displacement

| Concept | Distance between pivot joint and Pin | Angle of holes |
|---|---|---|
| 1 | ~30cm | ~17.5° |
| 2 | ~15cm | ~40.0° |

The conclusion was that the further away the pivot joint and pin are apart the narrower the angle gets, thus reducing the radius of plowing. Subsequently, a closer distance between the pivot joint and pin allowed for a much steeper angle of plow, making the mechanism more effective.

Table 1: Test results for the holding capacity of the plow blade

| Blade types | Predicted holding capacity | Holding capacity results | Dimensions Length * Height (uncurved) |
|---|---|---|---|
| 1. Low curve | -Hold less snow (paper)<br>-take less material | Hold less snow (10 paper balls) | 20 ¾" * 10 ½" |
| 2. High curve | Hold more snow (paper) | Hold more snow (16 paper balls) | 19" * 20" |

Test 2 was the blade curve test for the prototype 1 blade (cardboard) with paper balls used to represent snow. This testing was done to find what curve would hold the most snow. The result was that the high curve blade holds more snow (paperballs).

**Table 1: Snow load capacity**

| | Weight | Weight of snow | Minimum force Required to lift |
|---|---|---|---|
| Expected | 10.0 lbs | 1.912 lbs | 53.005 N |
| Actual | 9.21 lbs | 1.912 lbs | 49.490 N |

Test 3 was a weight test for the prototype 2 (solidworks) frame. The test was done using the solidworks evaluate section to determine the weight of a steel design. A good thing that was found is that the weight and thereby force required to lift was lower than expected.

# 7 Conclusions and Recommendations for Future Work

Time Management, Backup plans, Improvising, and Adapting are all lessons learned throughout the semester.

With more time and money, the first thing the group would do is rustproof the design with either a spray or a paint coating to ensure a longer lasting design. Furthermore to aid the user an improved blade lift design would be created by including a grip to the lift rope, adding a pulley system, or even by motorizing it. With much more time and resources, the design would be redone

with lighter materials, possibly aluminum.

# APPENDICES

## 8 APPENDIX I: Design Files

For other documents (solidworks designs) please see Maker Repo page (https://makerepo.com/omarmortaja/985.gng2101b24detachable-snowplow-)

**Table 3. Referenced Documents**

| Document Name | Document Location and/or URL | Issuance Date |
|---|---|---|
| Deliverable C | https://docs.google.com/document/d/1_yhiykdAqTPvFcd0UfjgxDhoCt8fQvkpbs1GyaMcjJg/edit | |
| Deliverable D | https://docs.google.com/document/d/13mT5zPnrsCE_Dnj-CsMYKVnvi8fIzlqxb6BfivtMNGg/edit | |
| Deliverable F | https://docs.google.com/document/d/1ZmN3IhK7ZK4pH7Z6EWMAt4hwfvu_Bg64OpRvkAnMxbY/edit | |