Robot Plows

Team I

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Executive Summary

Group I aims to create a detachable plow to clear the slush in sidewalks and increase the efficiency of delivery in order to improve the quality of life of students in colleges that have snow in winter across the United States. After conducting a multitude of research and surveying college students, Team I decided to mainly focus on delivery efficiency, effectiveness and durability of the plow and expenses when designing the plow that is more efficient than other competitors in the current market.

To satisfy the requirements of the users, Team I brainstormed, made multiple designs and voted on the one they thought would be the most efficient. Team I decided to create a medium functioning prototype of the plow that has curved edges, pointed in the middle, extends out past the wheels, and has a cut out of the middle of the plow. They created the design for the plow with Solidworks and then actually made a model to test their design requirements using cardboard, which is cheaper and more environmentally friendly than 3D printing. Overall, Team I's plow was incredibly successful and meant the ideal range for all of the design requirements that they were able to test.

If Team I were to design the plow again sometime in the future, they would have made the edges of the plow thicker to strengthen it and make the plow beagle to be used for a longer period of time. They would also change the attachment piece to save money and use less material in order to be more environmentally friendly and profitable.

R1-Problem Definition Review

1. Introduction and Value Proposition

Team I wanted to find a way to make life more enjoyable for college students across the United States during the winter. In order to do so they had to do a deep dive into what college students do daily and how snow and unsatisfactory winter weather affects those activities. After conducting a multitude of research, interviews, and surveys, they realized that college students cannot simply drop everything due to bad weather. They still need to leave their dorm or off campus housing whether it's to go to class or get food. In order to make leaving their place of residence more enjoyable for all college students, Team I decided that adding a detachable plow to the Grubhub rovers that are on 250 college campuses would get the job done.

2. Problem Definition

Task: Getting food delivered or traveling across college campuses in the winter.

End User: College students across the United States.

User Experience Chart:

Table 2: User Experience Chart

	Grubhub robots getting stuck in the snow	Slush getting in shoes	Sidewalks aren't fully plowed	Snow is pretty	College students need to eat	College students need to get to class	It's cold	Delivery and walking take a long time
++					**x**	**x**		
+				**x**				
0								
-	**x**		**x**				**x**	
–		**x**						**x**

Pains:

- Grubhub robots get stuck in the snow while attempting to make their deliveries.
- Slush gets stuck in students' shoes as they walk across campus.
- Sidewalks aren't fully plowed and after it snows there is a layer of slush.
- Deliveries in unideal weather conditions talk longer than normal.

Gains:

- A new solution to the robots getting stuck in the snow would be adding a plow in front of them so they do not get stuck.
- A new solution to the slush on sidewalks would be adding a plow to the front of grubhub robots and possibly adding an ice dispenser, so that the plow pushes slush off the sidewalk and the ice prevents the formation of slush.
- A new solution to the sidewalks not being fully plowed would be adding a plow to the grubhub robots so that the last little bit of slush is no longer on the sidewalks.
- A new solution to extended delivery times would be adding a plow to the front of the rovers in order to clear the sidewalks and make the conditions more ideal.

3. Research Plan

Team I plans to conduct research about the food delivery robots on many college campuses, but mainly The Ohio State University. The goal of the research that will be conducted is to learn more about the Grubhub robots and college student's views on them.

Research Question:	Qualitative Data Collection	Quantitative Data Collection
1. How many college students will this impact? Will this only impact OSU students?	Find online articles stating where grubhub robots are. [3]	Find online articles stating the amount of colleges across the US with food delivery robots. [1][10]
2. Do students enjoy using robots to avoid going out in the snow?	Interview students at The Ohio State University who are self proclaimed robot enthusiasts. [2]	
3. Will adding a plow to the robots mean requiring less rescue runs for students who work for the dining services?	Interview students at The Ohio State University who are dining service employees. [5]	
4. Will adding a plow to the robots make college students have an easier time getting around campus, since there will no longer be any slush?	Interview older students in mechanical engineering.[9]	Conduct a randomized ethical survey of students who attend college campuses with robots used for delivery. [8]
5. Do students enjoy having robots on campus in general?	Find a article online including a quote about students opinion.[6]	
6. Can the robots be used to plow the sidewalks for the students all the time?	Find an article stating when students are able to use the robots and when the robots would be operating in order to find out when the sidewalks would get plowed.[4]	
7. Are food delivery robots convenient to the students or do they create too much of a hassle for them?	Find an article stating how the robots are convenient to college students.[10]	

In order to conduct the research Team I will do a deep dive into the internet to find as much information as they could. They will also conduct an extremely ethical survey of random college students who will be informed of exactly what the project is and will be given the option to opt out at any time. They also plan to interview grubhub enthusiasts along with grubhub employees.

4. Research Results

Team I conducted research about the food delivery robots on many college campuses, but mainly The Ohio State University. The goal of the research conducted was to learn more about the Grubhub robots and college student's views on them. In order to conduct the research Team I did a deep dive into the internet to find as much information as they could.

Research Question:	Qualitative Data Collection	Quantitative Data Collection
1. How many college students will this impact? Will this only impact OSU students?	The robots are not just limited to Ohio let alone Ohio State, there's many campuses across the country with food delivery robots. [3]	There are over 250 college campuses in the US that have a partnership with grubhub and use the delivery robots. [1][10]
2. Do students enjoy using robots to avoid going out in the snow?	First year Sara stated, "I really like using the robots, but I think I saw rust in a wheel well of a nearby robot due to the snow so I'm worried if they'll be okay."[2] First year Delany said "I love using the robots, but I'm scared the robots aren't well equipped for winter weather. Adding a plow could possibly help protect them from the elements."[7]	
3. Will adding a plow to the robots mean requiring less rescue runs for students who work for the dining services?	Group I spoke to a curl Market employee about his thoughts on the rovers in the snow and the possibility of adding a plow. "I personally haven't had to save any robots, but a few of my coworkers have and it was very inconvenient and they were very annoyed. I think adding a plow would make the amount of rescue runs virtually none."[5]	
4. Will adding a plow to the robots make college students have an easier time getting around campus, since there will no longer be any slush?	Third year mechanical engineering students stated "That is such a good idea. Honestly I wish my group would have thought of that freshmen year. That's going to help everyone during their day to day lives all	Out of the 302 students that Team I surveyed 188 of them have used a grubhub robot to get food delivered to them. Out of those 188 students about 40% of them have had a delay in their order being delivered due to winter weather possibly causing a rover to get

	winter long."[9]	stuck. Out of the 302 students surveyed the vast majority has experienced slush causing them to be miserable. Out of everyone surveyed only 3.3% believed that adding a plow onto the robots would not have any benefit in solving the listed problems for students in the winter.[8]
5. Do students enjoy having robots on campus in general?	"...the students we have spoken with love this idea and they continue our heritage of being an innovative campus…"[6]	
6. Can the robots be used to plow the sidewalks for the students all the time?	The robots at OSU's main campus only operate from 9-9. If a student or faculty member places an order outside that time period then the order will be delivered by a person. [4]Since they only operate during those hours they can only plow the sidewalks during those hours.	
7.Are food delivery robots convenient to the students or do they create too much of a hassle for them?	The food delivery robots are very convenient for college students. They reach areas of campuses that aren't easily accessible by car, operate in the day, night, rain and snow, and do not add extra fees if the order is small. There is a delivery fee but there is not any extra fee if the order is small.[10]	

They learned that OSU is not the only college campus with robots (Q1) and that student opinion of robots is very high (Q2 and Q5) Through an extremely ethical survey of random college students who were informed exactly what the project was for and given the option to opt out at any time, they learned that most of the students surveyed believe that adding a plow to the front of a grubhub robot will make life more enjoyable for college students everywhere (Q4). Through interviews with grubhub enthusiasts and dining employees they learned that adding a plow could possibly protect the robots from the elements and would make rescue runs very rare (Q2 and Q3). At the conclusion of their research Team I has decided that making a detachable plow for the food delivery robots on The Ohio State University's campus will greatly benefit not only the student body, but also the mechanics for the robots and dining employees.

a. End Users

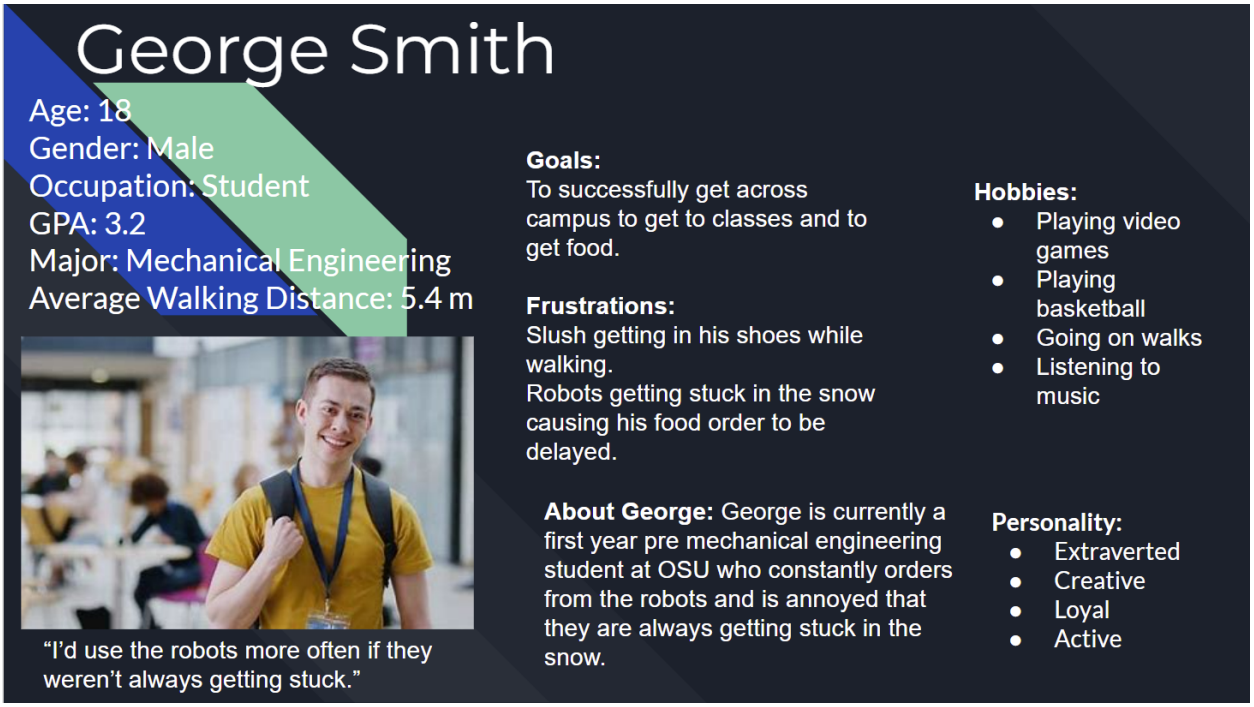


Figure 2. Fictional persona representing the needs, pains, and traits of a target user.

The end user for Team I's research is any college student who attends a university that uses robots to deliver food. An example is an undergraduate student whose major is pre-mechanical engineering and has a high preference to use robots to order food on campus, especially in winter, but has experienced problems with them.

Table 3. Top 7 user needs and descriptions for at-home diagnostic tests.

User Needs (Robots)	Score (1-5)
Easy to attach	2
Effective in plowing the sidewalks	5
Prevent the robots from getting stuck	4
Long term	5
Aesthetically pleasing	1
Cheap	3
Delivery efficiency	3

Seven user needs for robots are presented, and as the End User Need Chart shows,the users pay more attention to the effectiveness and durability of plowing first. Certain needs that were valued as less important included aesthetics and if the plow was easy to attach.

Table 4. Pairwise Comparison Chart

	Easy to attach	Effective Plow	Keeps robots from getting stuck	Long term	cheap	Aesthetically pleasing	Delivery Efficiency				Total	Normalized	Original
Easy to attach		0	0	0	0	1	0				1	1	2
Effective Plow	1		1	0	1	1	0				4	4	5
Keeps the Robots from getting stuck	1	0		0	1	1	0				3	2	4
Long Term	1	1	1		0	1	0				4	4	5
Cheap	1	1	0	1		1	0				4	3	3
Aesthetically pleasing	0	0	0	0	0		0				0	1	1
Delivery Efficiency	1	1	0	1	1	1					5	5	3

The Pairwise Comparison Chart shows that delivery efficiency is the prime need, which is different from the importance in the End User Need Chart. Then, the effectiveness and durability of plow and expense are the secondary important needs for users because the improvement for plow would indirectly increase the speed of delivery. But surprisingly, the importances of keeping robots from getting stuck and easy to attain food in the Pairwise Comparison Chart are less than the ones in the End User Need Chart.

b. Market Character

Team I product's current stakeholders include but are not limited to faculty are the colleges with robots, dining service employee's at the colleges with robots, and grubhub/yandex employees.

Faculty who are employed by one of the 250 colleges with food delivery robots. While the faculty at the colleges with robots are not our specific end user, they are also affected. The sidewalks will be cleared which will make the walk from their car to their classroom more enjoyable due to less slush they must walk through.

Dining service employees at the 250 colleges with food delivery robots. While the dining service employees at the colleges with robots are not our specific end user, they are also affected. If the robots have a plow, they will get stuck in the snow less often requiring less rescue runs for the employees.

Grubhub/Yandex employees are a stakeholder. While the Grubhub and Yandex employees at the colleges with robots are not our specific end user, they are also affected. The plows could affect the maintenance levels for the robots. They could cause the robots to require less maintenance due to being better protected from snow and ice, however, they could also cause the robots to require more maintenance due to attaching the plow.

The current market size for grubhub robots that can plow sidewalks is college students at the 250 colleges with food delivery robots. Team I found that the current market size of the grubhub plows would be students at the 250+ college campuses from researching how many college campuses across the United States have food delivery robots. Once they found an answer they decided to cross reference with multiple other sources in order to ensure that the answer they found was correct. An article by The Verge about grubhub robots stated that Grubhub"...has partnerships with over 250 college campuses in the US"[1]. An article by the Columbus Dispatch stated that "Grubhub hopes to launch the service on campuses across the country…" [3]. An article by Restaurant Dive about the grubhub robots stated that Grubhub "...currently partners with 250-plus college campuses, has increasingly focuses on college students…"[10]. After cross referencing these three separate sources Team I came to the conclusion that their product would be helpful for college students who attend over 250 different colleges across the United States. Team I's current market size has the potential to grow, not only to others at colleges that currently have food delivery robots, but also other colleges if they decide to implement food delivery robots as a part of their campuses.

The following chart explains what the current competition is for plowing sidewalks at colleges with food delivery services. The chart also compares which alternatives meet the needs of college students the best.

Table 5 Current alternatives

User Need	Golf cart plow	Snow shovel	Robots without a plow	Cooking spray	Snow Blower
Easy to attach/use	X	*	*	*	*
Effective in plowing the sidewalks	X (leaves slush)	X (takes forever)	X	X (takes forever)	X (hard to remove ice)
Prevent the robots from getting stuck	*	*	X	X	*
Long term	*	*	*	X	*
Aesthetically pleasing	X	X	*	X	X
Cheap	X	*	X	*	X
Delivery efficiency	X	X	*	X	X

As the chart shows, none of the competitors are very effective whether it's due to the time required to complete the task, left over slush, or left over ice. Adding a plow to the grubhub robots will be more efficient than all the existing competitors because it will be easy to attach, requires no human effort to use, will be effective in plowing the sidewalks, will keep the robots from getting stuck, keep deliveries efficient, and will be designed so that the plow is both cheap but also a long term solution to the sidewalks being covered in slush and the robots getting stuck.

5. Design Focus

Due to the recent winter weather, Team I had to think of a way to make life for college students during the winter more enjoyable, causing them to decide on adding a detachable plow to the food delivery robots that are all over campus. In order to construct the plow Team I will be getting the measurements of the Grubhub rovers that currently deliver food on The Ohio State University's campus. Once measurements are gathered they will design the plow in Solidworks, so that the plow will not be tall enough to cover the robots' sensors, will be extended in front of the robot to ensure that it does not block the wheels of the robots and will be angled in order to push snow out of the way instead of simply pushing it forward.

R2- Conceptual Definition Review

Conceptual Development

a. Process description.

In order for Team I to create their detachable plow for food delivery rovers a lot of brainstorming was done. They needed to design a model that was guaranteed to solve problems that college students who attend colleges with food delivery robots face all winter long. In order to do that they first narrowed down the needs of college students to decide which were the most important so that their prototype fulfilled them. Once the design requirements were figured out they began to work on their design. First they made a mockup of their plow out of cardboard. After doing some tests with the mockup they began making the prototype on Solidworks in order to get a final design. After testing multiple designs with solidworks they began building their medium level of functionality prototype out of cardboard. They then tested their design requirements to ensure that their prototype met all their needs.

b. Brainstorming results.

Each member of Team I was tasked with creating a design so that they would have multiple designs to choose. Figure 1.1 Design 1 (shown directly below) was created by looking at other methods of clearing sidewalks and comparing them. The most beneficial methods all included a curved shovel that was also angled in the middle. As long as the plow is cured and angled at the center then it should still be beneficial for the primary end user, college students.

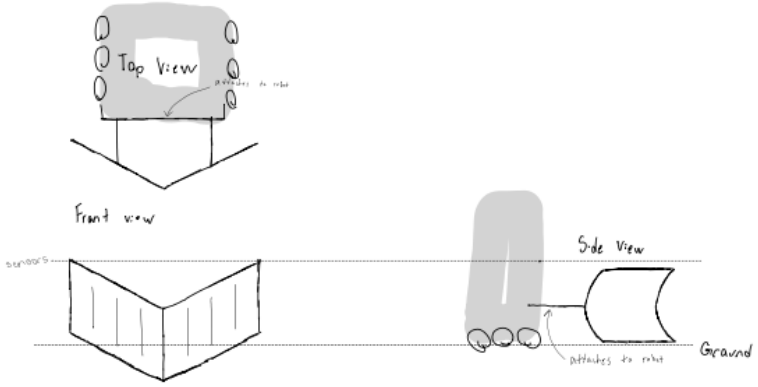


Figure 1.1 Design 1

Figure 1.2 Design 2 (shown directly below) was designed so the robot has a plow attached to it in the front to move snow out of the way.The height of the shovel is a bit lower than the height of the robot to allow the robot to use its sensors in the front.

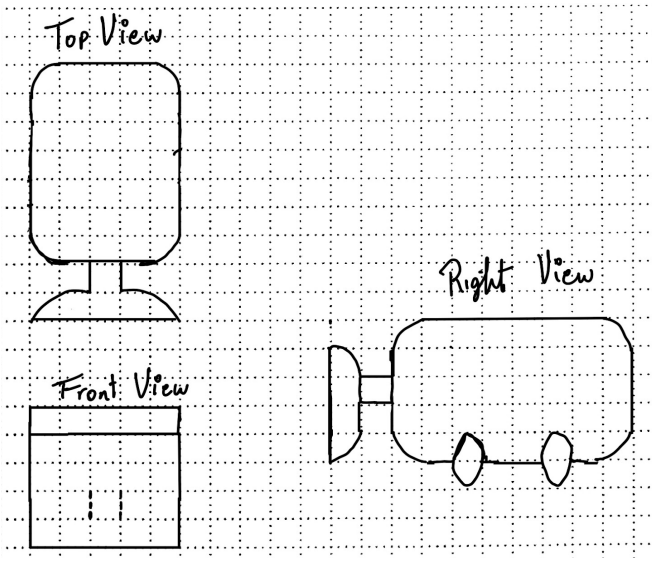


Figure 1.2 Design 2

ADD CHENGXI WANG'S Description-**CHENGXI WANG**

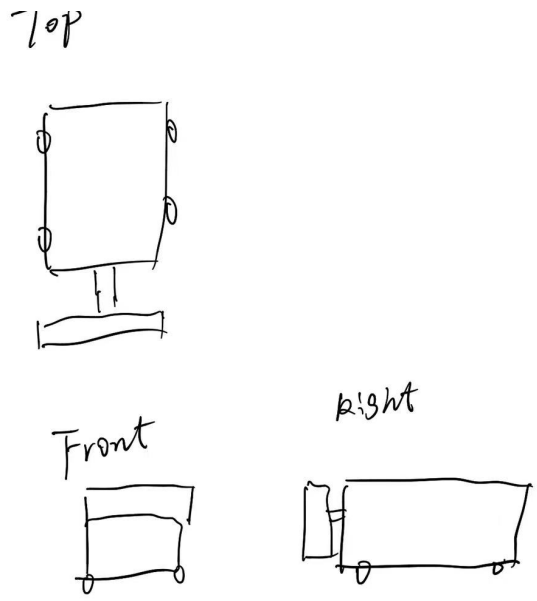


Figure 1.3 Design 3

Figure 1.4 Design 4 (shown directly below) was designed so The plow is attached in the front of the robot with several distances, and the height of the plow would be from the medium of the robot to 15cm above the horizontal ground. The plow can be separated into two parts. If there is too much snow in the plow, the plow would be separated from the middle part and throw the snow into two sides.

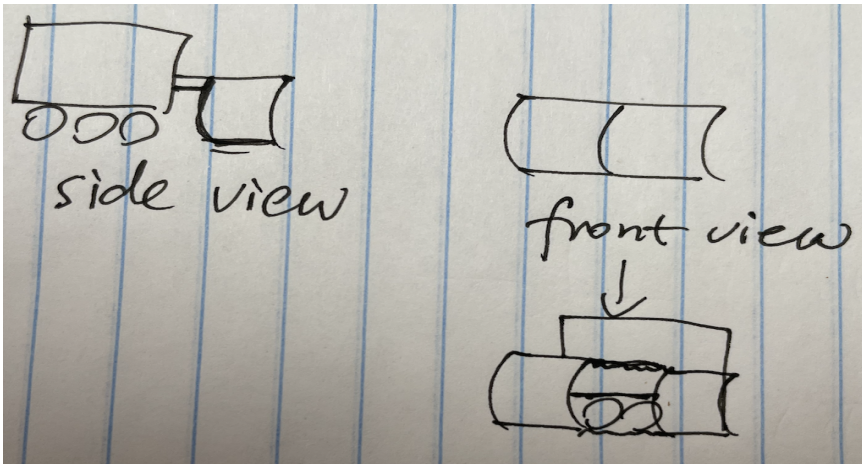
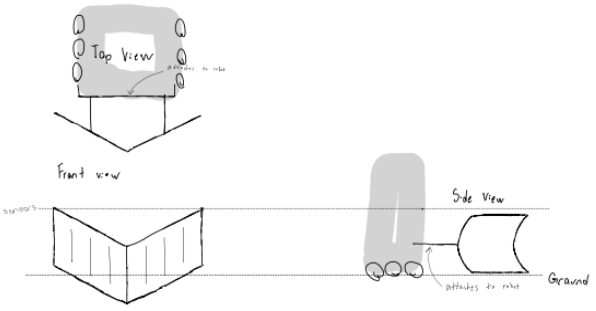


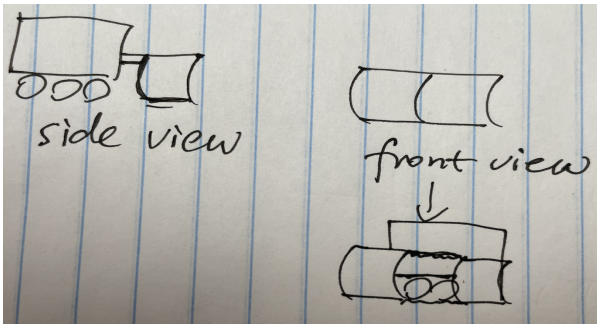
Figure 1.4 Design 4

Concept Selection Design

. a. Selecting Two Concepts

After coming up with four separate sketches that could be possible designs, Team I compared all four of them, deciding that Figure 1.1 Design 1 (shown on the left) and Figure 1.4 Design 4 (shown on the right) would be the most effective in fulfilling all of the user's needs. The main difference between the two designs is the fact that Design 4 separates in the middle, while Design 1 is only angled in the middle.





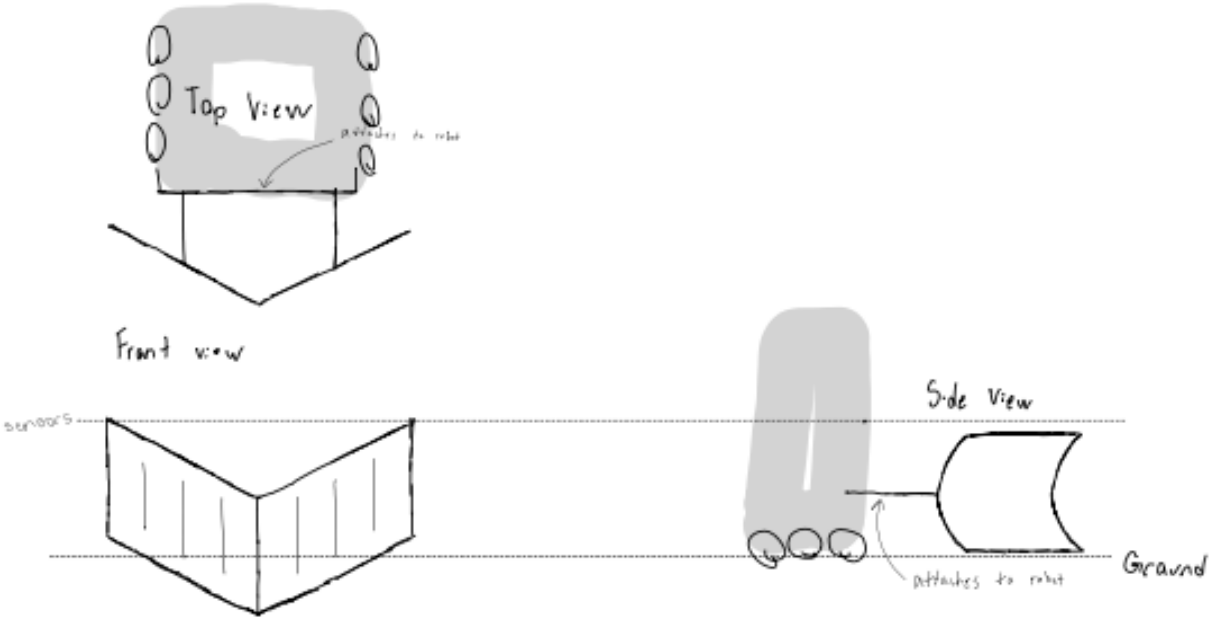
b. Pugh Scoring Matrix

Table 2. Pugh Scoring Matrix

		Golf Cart Plows		Drawing 1		Drawing 4	
Need	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to attach	1	4	4	5	5	3	3
Effective in plowing the sidewalks	4	4	16	4	16	5	20
Prevents robots from getting stuck	2	2	4	5	10	5	10
Long term	4	5	20	4	16	3	12
Asthetically pleasing	3	1	3	4	12	4	12
Cheap	1	1	1	5	5	4	4
Delivery efficentcy	5	1	5	5	25	5	25
			0		0		0
			0		0		0
			0		0		0
TOTAL			53		89		86

The Pugh Scoring Matrix (shown above) compares Team I's two final designs along with one of their competitors. The matrix takes into consideration the seven user needs of college students, easy to attach/use, effective in plowing the sidewalks, prevents the robots from getting stuck, being a long term solution to the problems college students face, aesthetics, being cheap, and maintaining delivery efficiency. Team I ranked each option on how well they satisfy each need and then the matrix weighed the options resulting in a final design.

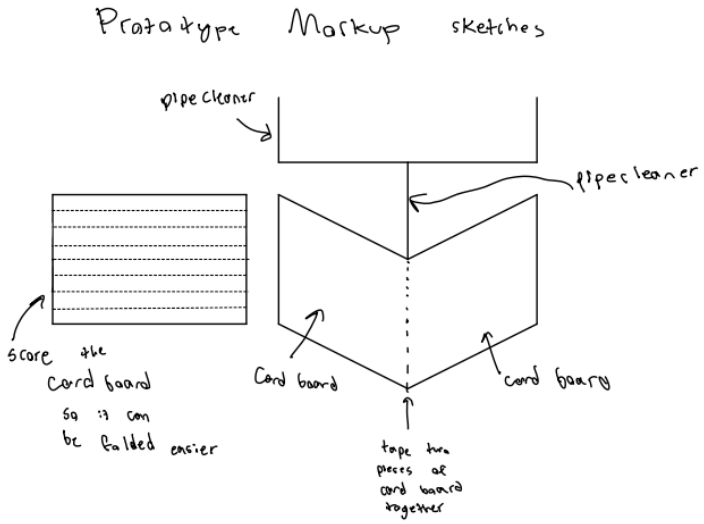
c. Final Concept Selection

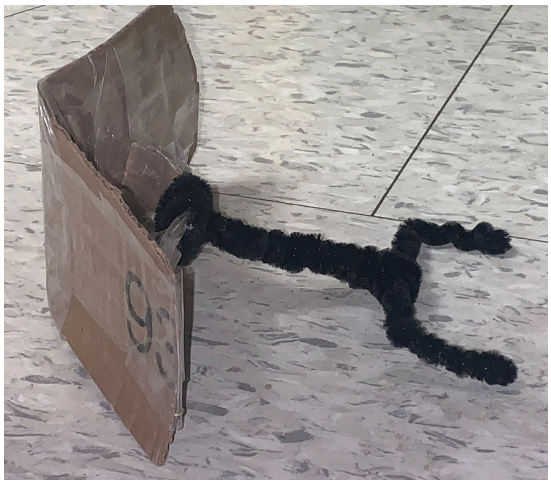


Team I chose to use Design 1 (shown above) as their sketch because it is the most efficient in solving all of the needs of their end users. Since the plow is only one piece it is the easiest to attach, relatively cheaper than designs with multiple parts, and should last relatively longer than other designs. Since the plow is curved and angled it will effectively plow the snow off the sidewalks which also helps prevent the robots from getting stuck. Sinche the plow is designed in a way that it does not cover any sensors then the delivery efficiency should be equal to that of a rover without a plow in nice weather.

Grand Concept Design

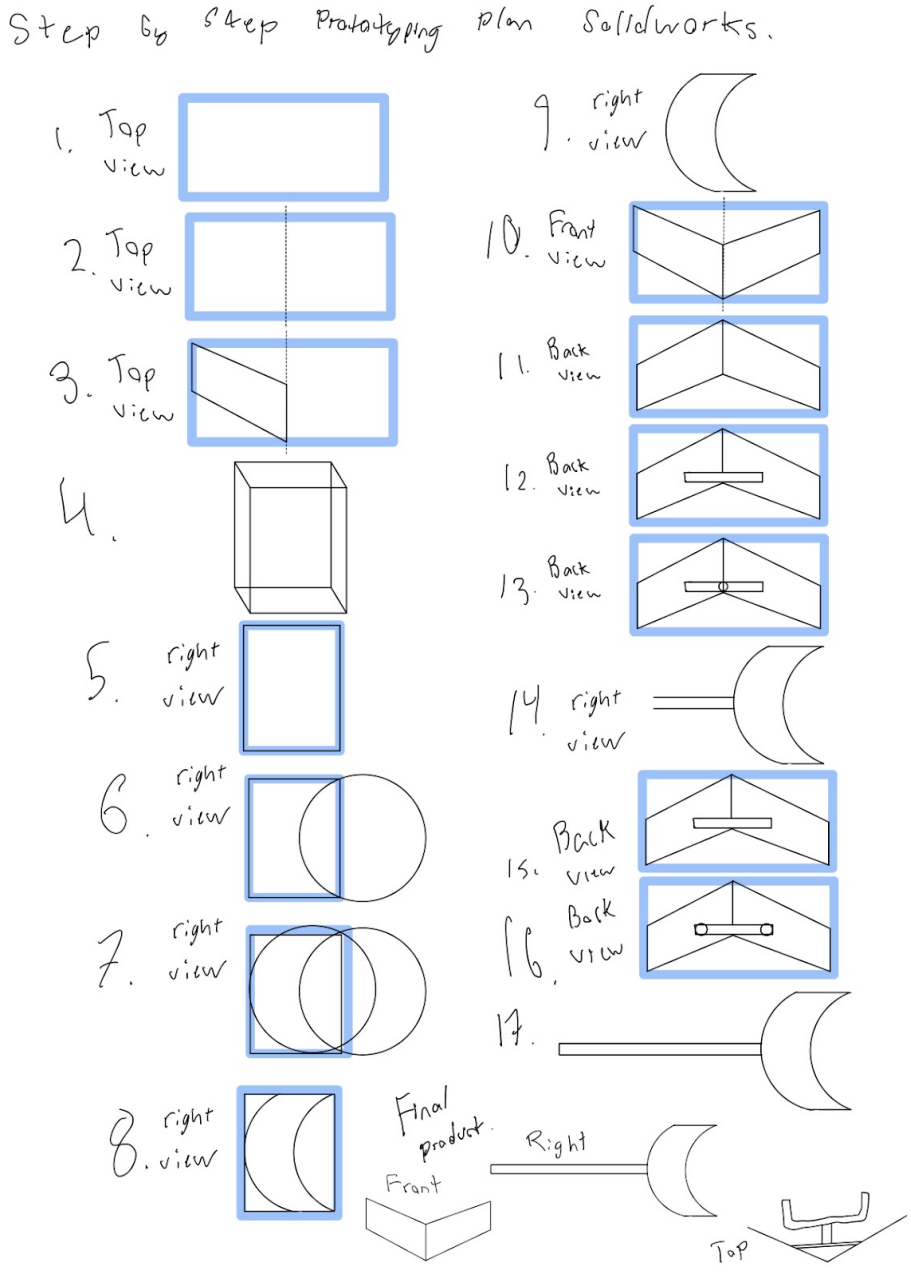
Team I's attachable plow has many unique features, leading to an effective way to prevent snow from obstructing the robots, which improves upon delivery efficiency. The design of the plow shown directly below (Figure 2) is to push snow off the sides of the sidewalk instead of letting the snow pile up in front of the plow. Unfortunately while Team I's plow has unique features, they are anticipating challenges while building their attachable shovel. One challenge they're anticipating is designing the part that attaches to the robot. They believe it will be difficult and challenging due to the concept of the design. Another anticipated challenge Team I believes they will face is choosing appropriate materials to build their plow out of. The materials must be durable, flexible, light, and available. Another anticipated challenge Team I think they will face is budgeting issues. In order to combat anticipated challenges, Team I has thought of possible improvements they might need to make. The material the plow is made of could be changed to something more efficient. The design could be simplified in order to make it easier to use.





The current prototype (shown directly above, Figure 3.2, more views can be found in Appendix A) created by Team I Is simply a mockup made of readily available materials such as cardboard, tape, and pipe cleaners. The current dimensions of the mockup prototype are as follows: plow height = 3.25 in, plow length = 6.5in, attachment piece across the back of the plow = 3 in, The longer pipe cleaner = 3 in, the perpendicular pipe cleaner = 3.5 in, and the two shorter pipe cleaners = 1 in.

Along with creating a mockup prototype of their plow, Team I also made a prototyping plan which is shown below (Figure 4).



Once starting the solid works application Team I will create a new part and start with a top view.Use the mockup to begin creating the part in Solidworks. They will then make an infinite vertical construction line about the origin of the plane. Using the sketch line tool they will make a parallelogram. Once the parallelogram is created it will then be extruded. Once the part is extended Team I will view it from the right view and begin to make the curved section of the plow by creating equal arcs from the front and the back of that plane. They will then make an extruded cut and cut out the area inside of those arcs. Then they will mirror the entire part over the infinite construction line and save the part. Once the part is saved Team I will create a new sketch starting from the back view. They will create a rectangle centered in the middle of the plow. Once the rectangle is created they will sketch a circle, extrude in, and create a longer rectangle on the end of the pip. Once the second rectangular prism is created they will sketch circles of equal radius on each side of the prism in order to have the attachment pieces of the plow. After the attachment piece is extruded the part will be finished.

Prototype Design

a. Description of Prototype

In order to create the attachable plow for the Grubhub rovers that are on many college campuses, Team I will be using a medium level of functionality for their prototyping. Team I will be using a medium level because they are unable to use a high level of prototyping due to the robots being taken off of college campuses for the time being. Team I will either be using Solidworks to create the design for their plow and then create the medium functioning plow out of cardboard.

b. Prototype Design Requirements

The Correlation Matrix, Table 3, shown below compares Team I's design requirements and their user needs, with the first design requirement of clearing the sidewalks efficiently having the highest correlation.

Design Requirements / User Needs Correlation Matrix

	must clear snow from the sidewalks efficently	can be quickly and easily attached to the robot	fits within the given budget	can be used annually	cannot affect the robot's ability to complete deliveries	cannot weigh the robot down	User Need Weight
Easy to attach		9					1
Effective in plowing the sidewalks	9				3		4
Prevents robots from getting stuck	9				3		2
Long term				9			4
Asthetically pleasing							3
Cheap			9	1			1
Delivery efficentcy	3				9	9	5
Importance ->	69	9	9	37	63	45	

Team I will do multiple tests evaluating each requirement in order to aid in the design process and score them based on the ranges shown in the Requirent Ranges, Table 4.

Requirements	**Range**	**Ideal**
The plow must clear snow from sidewalks efficiently.	0-0.5 inches of snow left	0-0.1 inches of snow left
The plow can be quickly and easily attached to the robot.	0-1 minutes	0-30 seconds
Printing the plow is within the budget.	<5% the cost of a robot	<1% of the cost of a robot
The plow can be used annually (durable).	>1 years	>5 years
The plow cannot affect the robots ability to complete deliveries.	0-5 minutes are added	0-1 minutes are added
The plow cannot weigh the robot down.	>10% of the weight of the robot	>5 % of the weight of the robot

c. Testing Methodology/Verification Plan

The mockup has already been tested approximately 10 times by attaching it to Ohio State students' shoes and successfully pushing around a multitude of objects with varying weights. In order to test the first design requirement Team I will use sand from the sand volleyball courts and push it with the medium functioning prototype. In order to test the fourth design requirement Team I will do a multitude of durability tests using the Solidworks application. To test the fifth design requirement Team I will run a series of tests using a control group of Ohio State students walking on a given stretch of sidewalk and then the same group of students walking the same stretch with the plow. The third and sixth design requirements will be tested using the mass properties features on Solidworks. Each test conducted will have 5-10 test runs.

d. Correlation Matrix & Verification Scorecard

The Verification Scorecard , shown below (Table 5), is based off of the Correlation Matrix, Table 3. The scorecard assigns each of Team I's design requirements a certain value based on how much they correlate to the user needs.

Verification Scorecard Points Distribution*

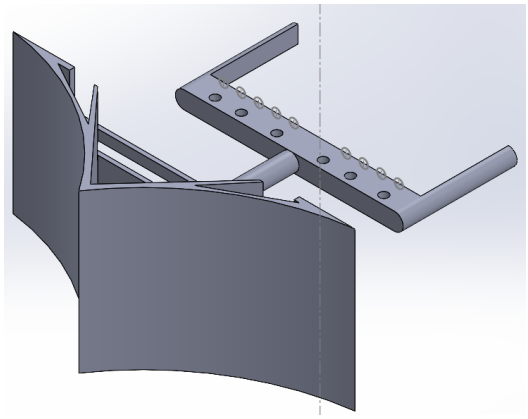
	Raw Percentage	Score Card Points (25 total)
The plow must clear snow from the sidewalks efficently	29.7%	7
The plow can be quickly and easily attached to the robot	3.9%	1
Printing the plow is within budget	3.9%	1
The plow can be used annually	15.9%	4
The plow cannot affect the robot's ability to complete deliveries	27.2%	7
The plow cannot weigh the robot down	19.4%	5
This sum should be 25! --------->		25

Team I will use the rubric, shown above (Table 6), after each trial in order to create the best product possible.

	+2 above expectations	**+1 meets expectations**	**+0 fails to meet expectations**
Requirement 1 weighted at 29.7%	Ideal goal is hit. Less than .1 inches of snow is left after the area is plowed.	The end result is within the range. 0-.5 inches of snow left.	The end result is out of the range. More than .5 inches of snow left after the area is plowed.
Requirement 2 weighted at 3.9%	Ideal goal is hit. The plow takes less than 30 seconds to assemble.	The end result is within the range. The plow can be assembled in a minute.	The end result is out of the range. The plow can not be assembled in a minute.
Requirement 3 weighted at 3.9%	Ideal goal is hit. The plow is less than 1% the cost of a robot.	The end result is within the range. The plow is less than 5% the cost of a robot.	The end result is out of the range. The plow is more than 5% the cost of a robot
Requirement 4 weighted at 15.9%	Ideal goal is hit. The plow can be used for 5 or more years.	The end result is within the range. The plow can be used for more than 1 year.	The end result is out of the range.The plow cannot be used for more than 1 year.
Requirement 5 weighted at 27.2%	Ideal goal is hit. Less than a minute is added to delivery times compared to robots without a plow in good weather conditions.	The end result is within the range. Less than 5 minutes is added to delivery times compared to robots without a plow in good weather conditions.	The end result is out of the range. More than 5 minutes is added to delivery times compared to robots without a plow in good weather conditions.
Requirement 6 weighted at 19.4%	Ideal goal is hit. The plow weighs less than 5% of the weight of the robot.	The end result is within the range. The plow weighs less than 10% of the weight of the robot.	The end result is out of the range. The plow weighs more than 10% of the weight of the robot.

In order to get a 100% on a test an average of a 1 must be scored in every category.

e. Prototype Preliminary Design & Mock-Up



Pictured directly above (Figure 5) is Team I's original solidworks design before meeting with their supervisors. After the meeting Team I has concluded that they must make their product thicker in order to keep the printer from warping the plow.

Pictured directly above (Figure 3.2) is Team I's preliminary mock up. The construction of the mockup has informed Team I of the fact that the back piece must be very secure.

R3-DETAILED-DESIGN REVIEW

Team I's schedule (in order of priority) is listed below and shown in the images (Figure 1 and 2) that are directly under the list.

1. Fix plow in Solidworks—-March 28
2. Talk to instructional team—Before April 1st
3. Send part to printer/ go to shop—April 1st
4. Test durability (Requirement 4) using solidworks simulation—Over the weekend
5. Test other design requirements—once Team I has the part (before April 18th)
    a. Requirement 1 will be tested with sand from volleyball court–Before April 18th
    b. Requirement 2 cant be tested–Before April 18th
    c. Requirement 3 will be tested with mass properties on solid works–Before April 18th
    d. Requirement 4 have people walk around with it–Before April 18th
    e. Requirement 5 will be tested with mass properties on solid works–Before April 18th
6. Finish the documentation for Solidworks– April 23rd
7. Finish the DDR–April 23rd

Gantt Chart Template			
	Project Start Date	Project End Date	Today's Date
	3/22/22	5/2/22	3/31/22
Task Name/Description	Start Date	End Date	% complete
Finish the Solidworks portion of protyping.	3/22/22	3/30/22	100
Talk to someone from instructorial team	3/22/22	4/1/22	100
Send part to printer/request materials from shop.	3/30/22	4/8/22	100
Test the durability of the plow using solid works.	3/30/22	4/8/22	75
Test how efficetive the plow is at moving objects.	4/8/22	4/22/22	50
Test the price and weight using the mass properties on solidworks.	3/26/22	4/15/22	50
Test to see if the plow slows down students who are pushing it.	4/3/22	4/12/22	0
Finish the Solidworks documentation	4/1/22	4/22/22	0
Finish the DDR	4/1/22	4/22/22	0

Figure 1 Gantt Chart

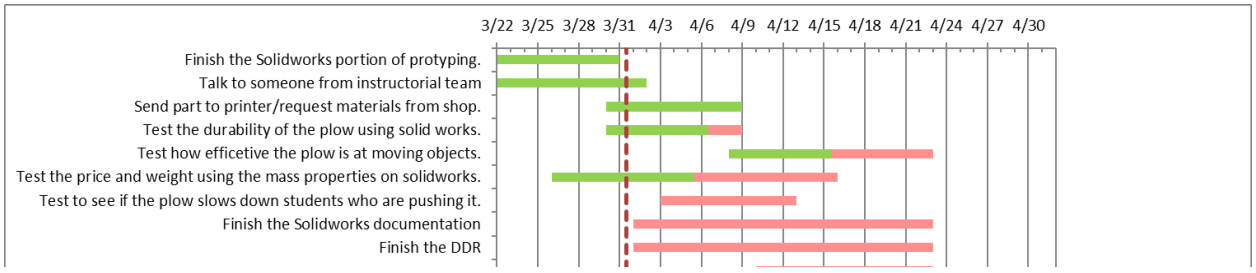


Figure 2 Colored Gantt Chart

Team I is dividing the remaining work by assigning Yingqi Gao to talk to the instructional team, Olivia Scavuzzo giving all presentations and editing all assignments, while the rest of the work will be divided evenly among the team.

Team I will be using a 3-D printer to create a medium level of functionality for their prototype plow. Originally Team I was planning on doing a high level of prototyping, but due to the removal of the Grubhub Rovers for The Ohio State's campus they can no longer get the correct dimensions and have difficulty testing their second design requirement. In order to test their other design requirements they will use Solidworks, sand, and students. Requirement 1 will be tested with sand from volleyball courts. Requirement 3 can be tested with mass properties on solid works. Requirement 4 will be tested by having students walk around with the plow and without the plow and then comparing the time. Requirement 5 can be tested with mass properties on solid works.

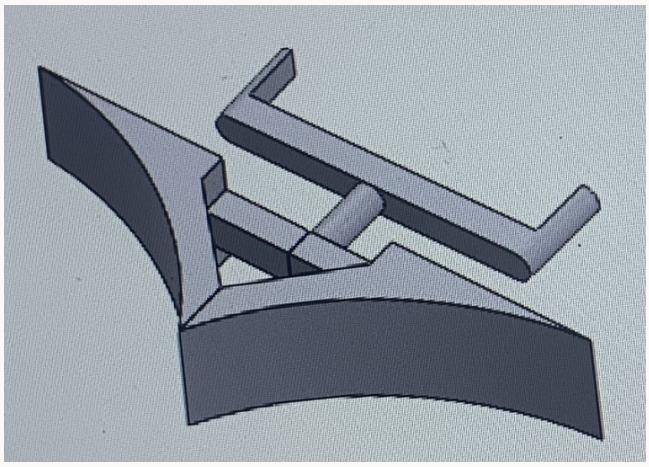
After completing their prototype Team I will be delivering the prototype itself, the solidworks drawing packet, along with all of their research and planning which will be organized in a report. Team I's specific goal for their prototype is to be within their ideal range of all their design requirements.

Detailed Design.

a. Final Prototype Design.

Team I's final plow stayed incredibly similar to their original design and aligns well with the research that they conducted. Throughout the entirety of the design and prototyping stages they knew that their plow was going to have curved edges, pointed in the middle, extend out past the wheels, and have a cut out of the middle of the plow. They knew that the curved edges would be needed in order to ensure that the snow is pushed to the sides of the sidewalk as opposed to letting it pile up in front of the plow. The point in the middle was also included to ensure that the snow is pushed out as opposed to forwards. Making the attachment part of the plow extend out past the wheels was to ensure that the wheels did not get stuck in snow along with being able to protect them. The cut taken out of the middle of the plow was to ensure that the plow would not weigh down the robots and affect their delivery time. Along with making the plow light weight, the cut also made the plow cheaper causing it to be more profitable, and more eco friendly due to the fact that less material is being used.

One major change from the original design is the material that Team I used to create their plow. Team I eventually made their plow out of cardboard due to it being more accessible than a 3D printer. Cardboard had many other benefits as well: it's cheaper and it was all recycled. The cardboard also did not increase the level of difficulty in the creation of non standard parts. Every part Team I used to create their plow was a non-standard part. The curved pieces of the plow and the attachment piece were all non standard parts that Team I had to create. Team I's final Solidworks assembly (right) and final prototype (left) are pictured below.



If Team I were to redesign this plow or make the high functioning prototype they would change some things about their design. Future design considerations include making the edges of the plow a bit strong to increase long term usage. Engineering student at The Ohio State University, Jon, expressed his concerns with Team I's current design, stating "Yeah I really like it, it's a great design. You guys did a great job. If i were to make it I probably wouldn't have made the edges so thin because they could break sooner than anticipated but great job!" Another possible future design consideration includes changing the attachment piece to save money and make the plow more eco friendly by using less materials.

b.Revised Grand Concept Design.

Throughout Team I's prototyping stages their design stayed very similar. Team I knew from the beginning that their plow was going to have to be curved, pointed in the middle, have a cut taken out of the middle, and extend out past the wheels. The plow needs to be curved and pointed in order to ensure that the snow that it is pushing is pushed to the side. The cut in the middle of the plow was to make it less costly, weigh less, and more to make the plow eco friendly. The plow being extended past the wheels was to ensure that the wheels do not get ruined by snow. Even though their plow is similar to our original design, some things still changed. Originally it was going to be 3D printed in a singular piece before they realized that it was too large to print all together. After designing a new model with the plow in three separate parts, Team I decided to scrap the idea of 3D printing all together, and make it out of cardboard. Along with being cheaper cardboard is also more eco friendly because it is all recycled

Final Prototype Verification

Discuss the results of Final Prototype Verification and include the completed scorecard from final verification testing. Explain how these results relate to your initial prototyping plan. How did your team do? In which areas were you successful? In which areas did you come up short? Explain why you were (un)successful.

Requirements	**Range**	**Ideal**
The plow must clear snow from sidewalks efficiently.	0-0.5 inches of snow left	0-0.1 inches of snow left
The plow can be quickly and easily attached to the robot.	Could Not test	0-30 seconds
Printing the plow is within the budget.	<5% the cost of a robot	<1% of the cost of a robot
The plow can be used annually (durable).	>1 years	>5 years
The plow cannot affect the robots ability to complete deliveries.	0-5 minutes are added	0-1 minutes are added
The plow cannot weigh the robot down.	<10% of the weight of the robot	<5% percent of the weight of the robot

- Weighs 1.575 lbs
- Passed multiple durability tests on solidworks
- Moved trash, sand, water bottles, and shoes
    - Left very little sand.
- Used nothing that costs money since it was all cardboard scraps
- If the plow was 3D printed then the budget would be in the required range as opposed to the ideal.

Overall our team did great and we managed to build a medium functional prototype.We successfully built an effective plow which was efficient in its design and functionality.

Due to the robots being removed from campus we did have some problems.We could not get the dimensions of the robot ,which in return did not allow us to test if the plow can fit on the robot or not. We also were unsuccessful in determining the cost of the plow as the cost also depended on dimensions which we dint have. Since we did the tests on sand which although is similar to snow ,it is not similar to sleet. Hence we did not get the opportunity to test it with sleet and ice.

User Validation.

Table 2: Revised Top 3 User Needs Chart

User Needs (Robots)	Score (1-5)
Effective in plowing the sidewalks	4
Prevent the robots from getting stuck	4
Delivery efficiency	5

Team I's top three user needs (shown directly above) are delivery efficiency, being able to effectively plow the sidewalks, and preventing robots from getting stuck in the snow. Delivery efficiency is Team I's most important user need, while being able to effectively plow the sidewalks and being able to prevent robots from getting stuck in the snow are tied for second. Team I's original top three user needs were being an effective plow, being durable enough to use long term, and delivery efficiency, as shown in the pairwise comparison chart below. Upon reevaluation Team I has decided that preventing robots from getting stuck in the snow is more important than the plow being able to be used long term, which is why their top three user needs have been changed.

	Easy to attach	Effective Plow	Keeps robots from getting stuck	Long term	cheap	Aesthetically pleasing	Delivery Efficiency				Total	Normalized	Original
Easy to attach		0	0	0	0	1	0				1	1	2
Effective Plow	1		1	0	1	1	0				4	4	5
Keeps the Robots from getting stuck	1	0		0	1	1	0				3	2	4
Long Term	1	1	1		0	1	0				4	4	5
Cheap	1	1	0	1		1	0				4	3	3
Aesthetically pleasing	0	0	0	0	0		0				0	1	1
Delivery Efficiency	1	1	0	1	1	1					5	5	3

In order for Team I to receive validation from their end users they will work directly with college students and faculty members at The Ohio State University. Team I will conduct another series of surveys, but this time they will include the drawings of their prototype. They will ensure that all participants are aware that the survey's are optional and that they can opt out at any time. They will also let all participants know that the survey will be anonymous and they will receive consent from each participant in order to use their results. Along with conducting the surveys, Team I will also be conducting a handful of interviews from all sorts of end users. Team I will inform those participating in the interviews that their participation is voluntary. They will also inform the student's that the only information that will be used other than their answers will be their first name along with their year in school. No other information will be required of them and they are able to opt out at any time. Team I's goal for this second round of interviews and surveys is to confirm that the end users still believe that the attachable plow is still something college students and faculty members need. Team I wants to know if end users still think their

product is successful after the prototyping stage, especially since a lot has changed since the last time Team I has communicated with their end users. They also want to ensure that the end users think their top needs will be met.

Value & Impact.

Value Categories

Stakeholder	Economic	Social	Environmental
Faculty at colleges with food delivery robot services	Faculty members at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage.	Faculty members at colleges with food delivery robots will not need to walk from their cars through snow and slush.	Faculty members at colleges with food delivery robots will not need to replace their shoes therefore producing less waste.
Students at colleges with food delivery robot services	Students at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage.	Students at colleges with food delivery robots will not need to walk from their dorms through snow and slush.	Students at colleges with food delivery robots will not need to replace their shoes therefore producing less waste.
Dining service employee's at the colleges with robots	N/A	Dining service employees will need to perform less rescue runs to save robots that were stuck in the snow and therefore save time and energy.	N/A
Grubhub and Yandex employees	Food delivery services now have to spend less money to fix robots that are damaged due to harsh winter weather conditions.	Food delivery employee's are now able to spend less time on maintenance required due to harsh winter weather.	Food delivery employee's have to order less parts for maintenance therefore producing less waste.

Team I's attachable plow has four main stakeholders who are all impacted in different ways, as shown directly above in Table 4). Their main stakeholders include faculty at colleges with food delivery robot services, students at colleges with food delivery robot services, dining service employee's at the colleges with robots, and grubhub/yandex employees. Only three stakeholders are impacted economically. The economic impact on faculty is that faculty members at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage. The economic impact on students is that students at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage. There is no economic impact on dining service employees.The economic impact on grubhub/yandex employees is that they now have to spend less money to fix robots that are damaged due to harsh winter weather conditions. While Team's plow is more expensive than typical snow shovels, the plows are still cheaper to make and use than the golf carts with plows. Not only would Team I

make a considerable revenue, college campuses also save money. Each stakeholder is also impacted socially. The social impact on faculty members is that they will not need to walk from their cars through snow and slush. The social impact on students is that they will not need to walk through snow and slush to get across campus. The social impact on dining service employees is that they will need to perform less rescue runs to save robots that were stuck in the snow and therefore save time and energy. The social impact of grubhub/yandex employees is that they are now able to spend less time on maintenance required due to harsh winter weather. Along with those positive effects there are also a few negative effects. The biggest possible negative effect is that there might be a delay in delivery times for anyone ordering from the robots.

Project Recommendations And Next Steps. CHENGXI WANG

Looking holistically at the project provides a formal summary of any recommendations for future work based on information collected thus far. These recommendations may focus on the Grand Concept or Prototype design, additional research that needs to be conducted, steps for additional verification & validation, etc. Discuss the immediate and subsequent steps and any resources required to bring your Current Design to the market.

References

[1] “Grubhub will use Russian-made robots to deliver food on college campuses”. The Verge. 7 July, 2021
Grubhub will use Russian-made robots to deliver food on college campuses - The Verge

[2] First Year, Sara, Self Proclaimed Robot Enthusiast Talks Plows

[3] “Grubhub testing delivery robots on Ohio State’s campus”. The Columbus Dispatch. 28 August, 2021
Grubhub testing delivery robots on Ohio State's campus (msn.com)

[4] “Grubhub Is Using Robots to Make On Campus Food Deliveries”. Thrillist. 9 September, 2021
Grubhub Is Using Robots to Make On-Campus Food Deliveries (msn.com)

[5] Curl Market Employee Talks Rescue Runs

[6] “Starship Technologies is bringing food delivery robots to four more US college campuses this year” Techcrunch. 10 August, 2021
Starship Technologies is bringing food delivery robots to four more US college campuses this year | TechCrunch

[7] First Year Delany, Shares Her Thoughts

[8] “Grubhub Robots/Getting food in the winter” Survey.

[9] Third year, Mechanical Engineering Student Raves About The Idea of Adding a Plow to the Robots.

[10] “Grubhub, Yandex deploy delivery bots to first college campus”. Restaurant Dive. July 7, 2021
Grubhub, Yandex deploy delivery bots to first college campus | Restaurant Dive

Appendix A-Evidence of Brainstorming

Table 1. User Experience Chart

	Grubhub robots getting stuck in the snow	Slush getting in shoes	Sidewalks aren't fully plowed	Snow is pretty	College students need to eat	College students need to get to class	It's cold	Delivery and walking take a long time
++					**x**	**x**		
+				**x**				
0								
-	**x**		**x**				**x**	
–		**x**						**x**

Table 2. Top 7 user needs and descriptions for at-home diagnostic tests.

User Needs (Robots)	**Score (1-5)**
Easy to attach	2
Effective in plowing the sidewalks	5
Prevent the robots from getting stuck	4
Long term (plow can't break)	5
Aesthetically pleasing	1
Cheap	3
Delivery efficiency	3

Table 3. Pairwise Comparison Chart

	Easy to attach	Effective Plow	Keeps robots from getting stuck	Long term	cheap	Aesthetically pleasing	Delivery Efficiency				Total	Normalized	Original
Easy to attach		0	0	0	0	1	0				1	1	2
Effective Plow	1		1	0	1	1	0				4	4	5
Keeps the Robots from getting stuck	1	0		0	1	1	0				3	2	4
Long Term	1	1	1		0	1	0				4	4	5
Cheap	1	1	0	1		1	0				4	3	3
Aesthetically pleasing	0	0	0	0	0		0				0	1	1
Delivery Efficiency	1	1	0	1	1	1					5	5	3

Table 5 Current alternatives

User Need	Golf cart plow	Snow shovel	Robots without a plow	Cooking spray	Snow Blower
Easy to attach/use	X	*	*	*	*
Effective in plowing the sidewalks	X (leaves slush)	X (takes forever)	X	X (takes forever)	X (hard to remove ice)
Prevent the robots from getting stuck	*	*	X	X	*
Long term	*	*	*	X	*
Aesthetically pleasing	X	X	*	X	X
Cheap	X	*	X	*	X
Delivery efficiency	X	X	*	X	X

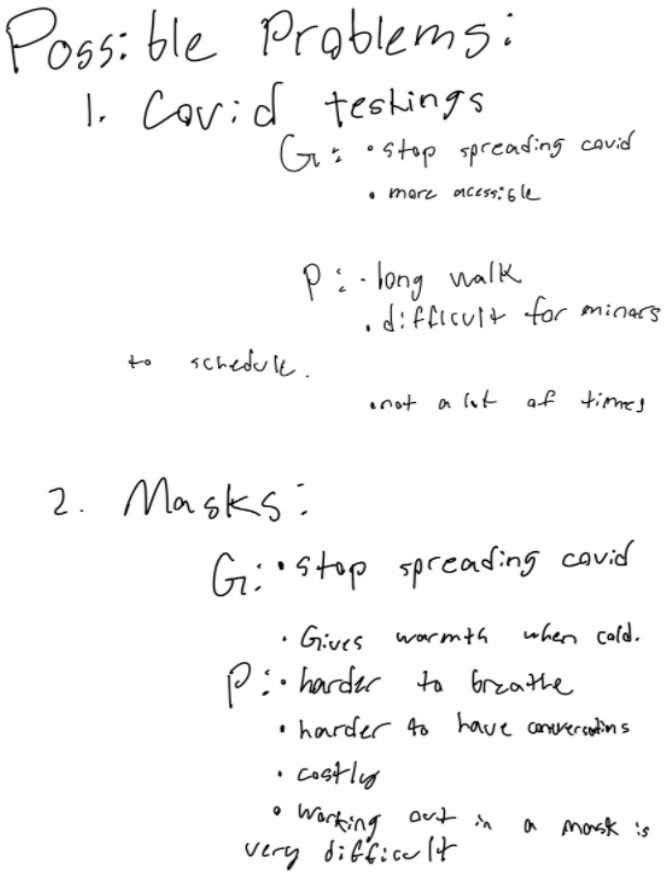
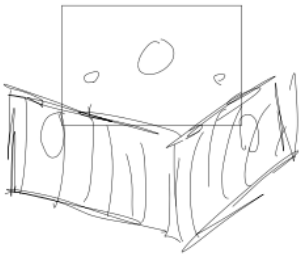


Figure 1.1 Brainstorming in class for PO1



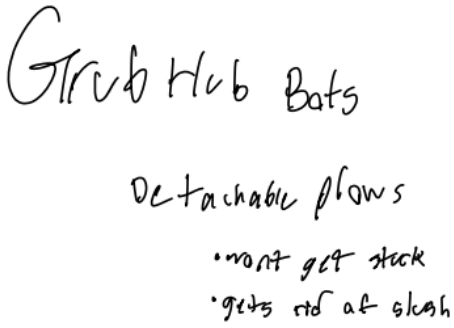


Figure 1.2 Brainstorming in class for PO2

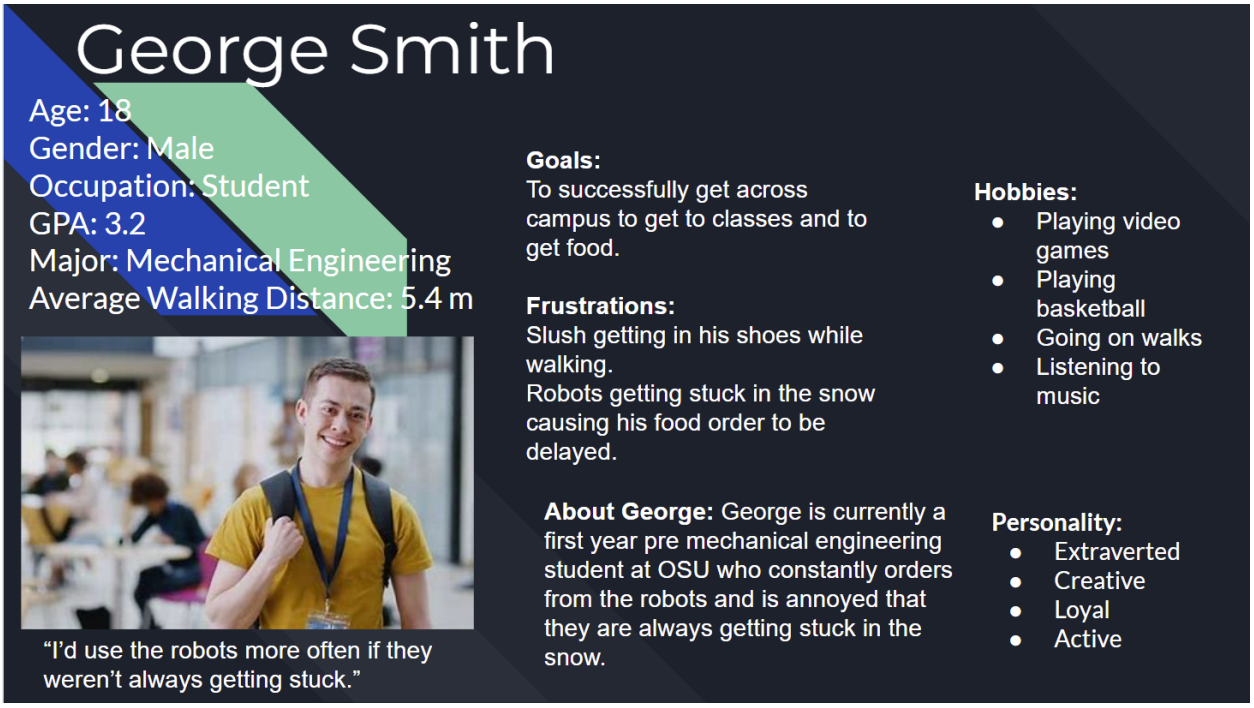


Figure 2 Fictitious persona of an example of an end user

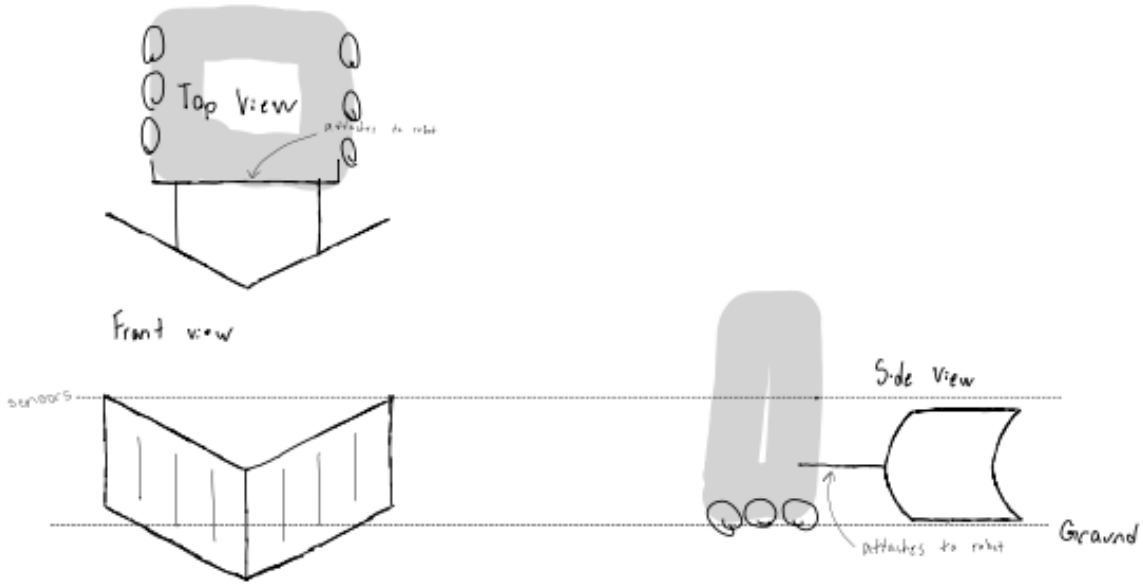


Figure 3.1 Design 1

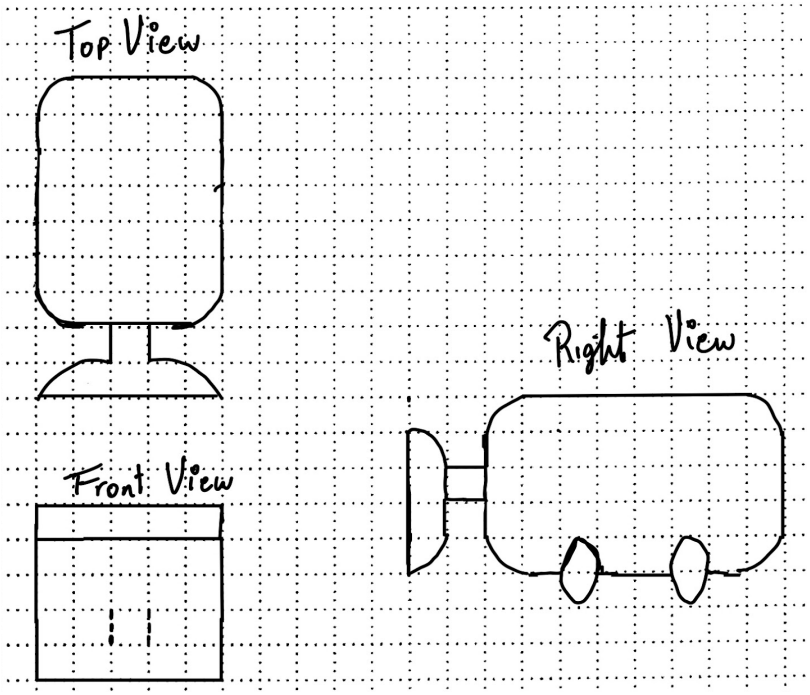


Figure 3.2 Design 2

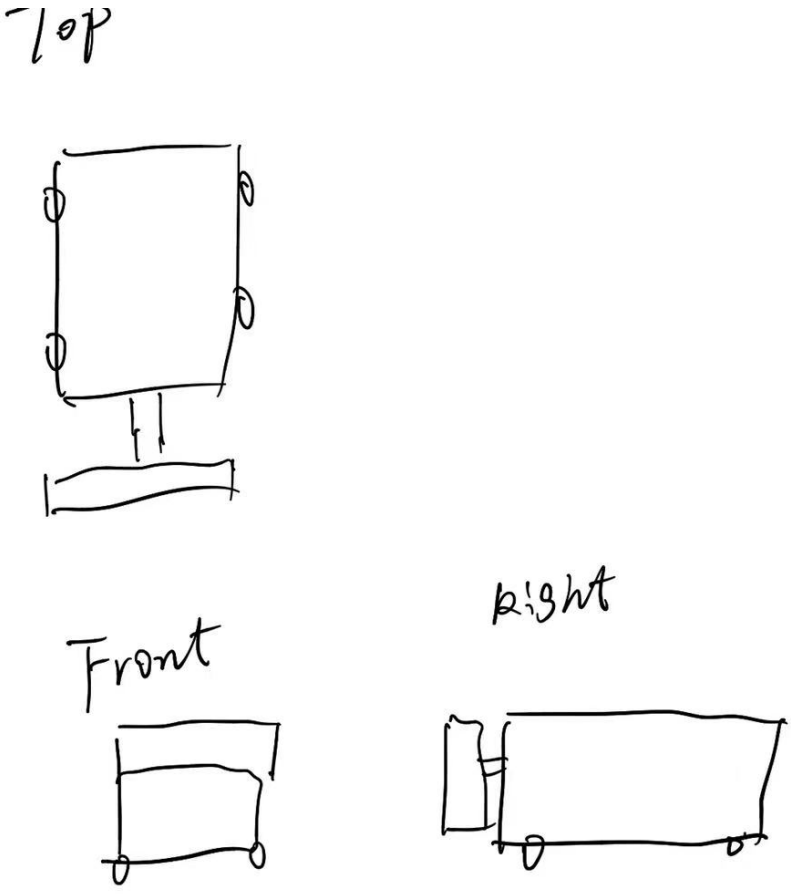


Figure 3.3 Design 3

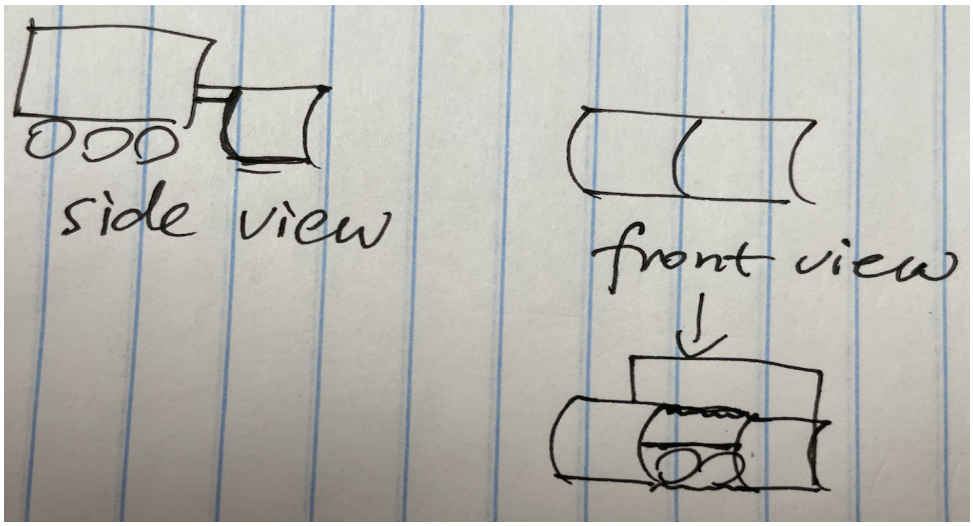


Figure 3.4 Design 4

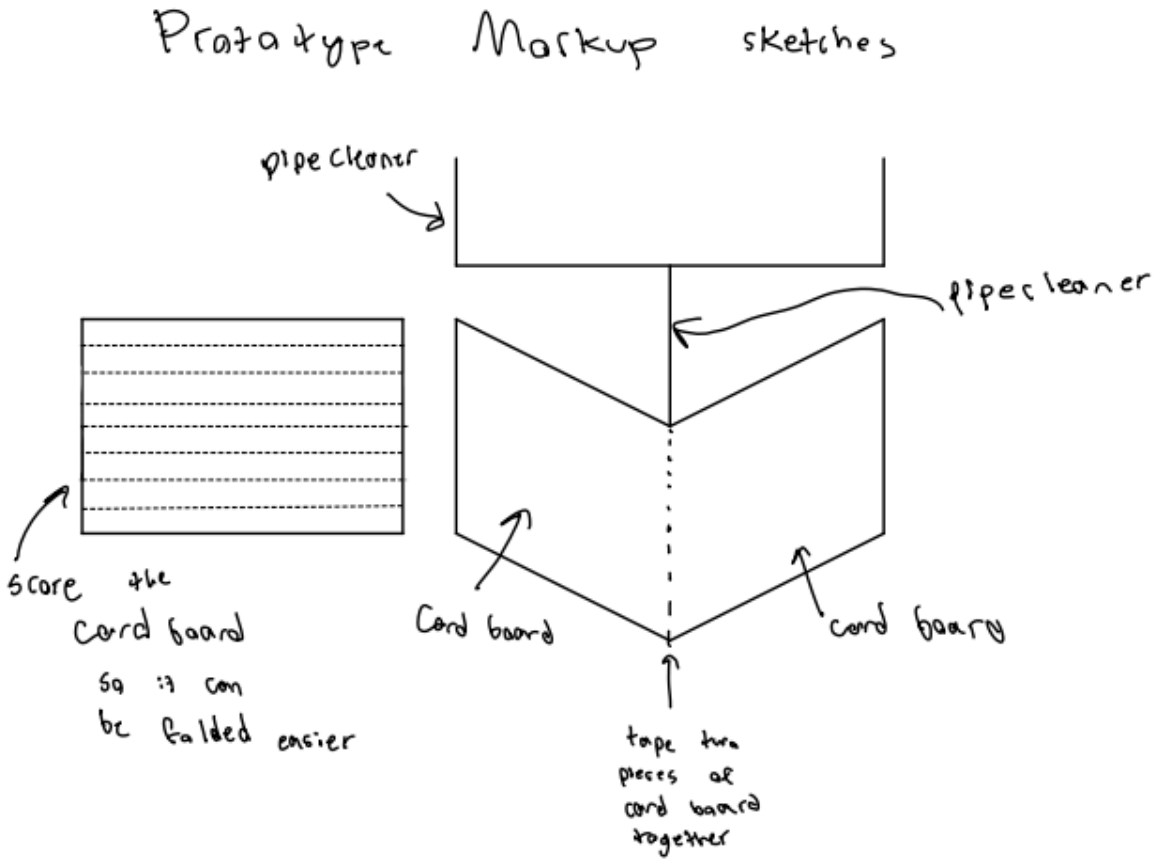


Figure 4 Mockup Sketches

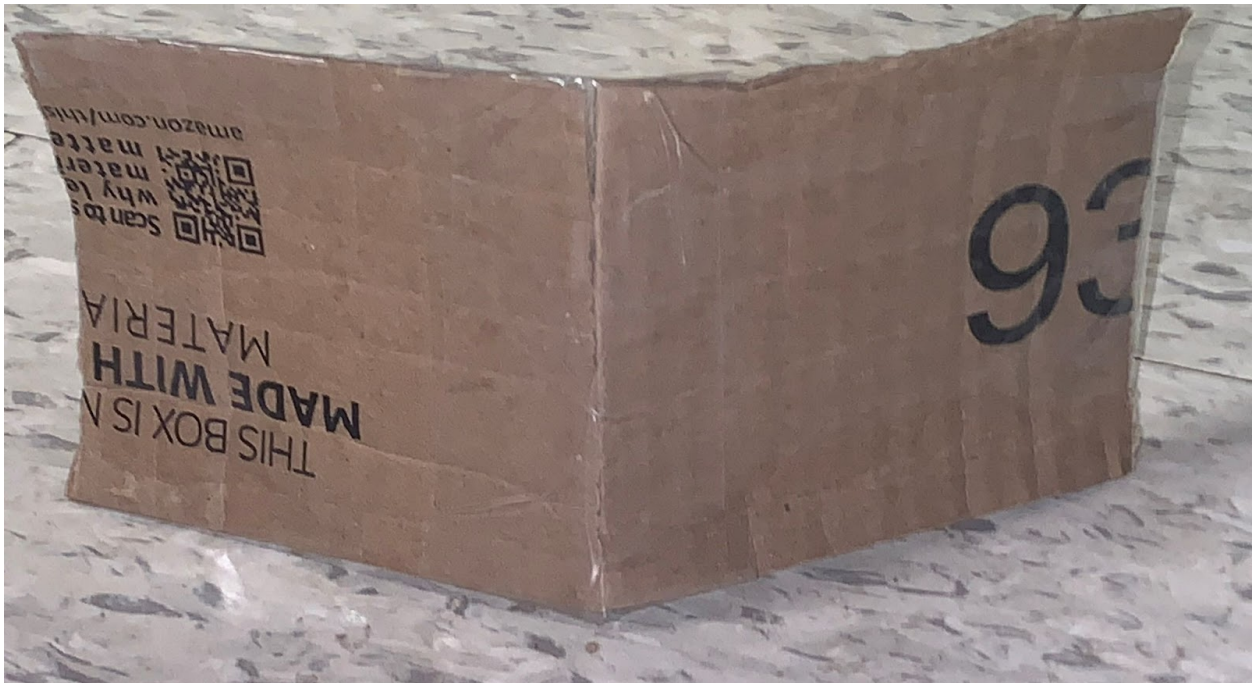


Figure 5.1 Prototype Mockup Front View

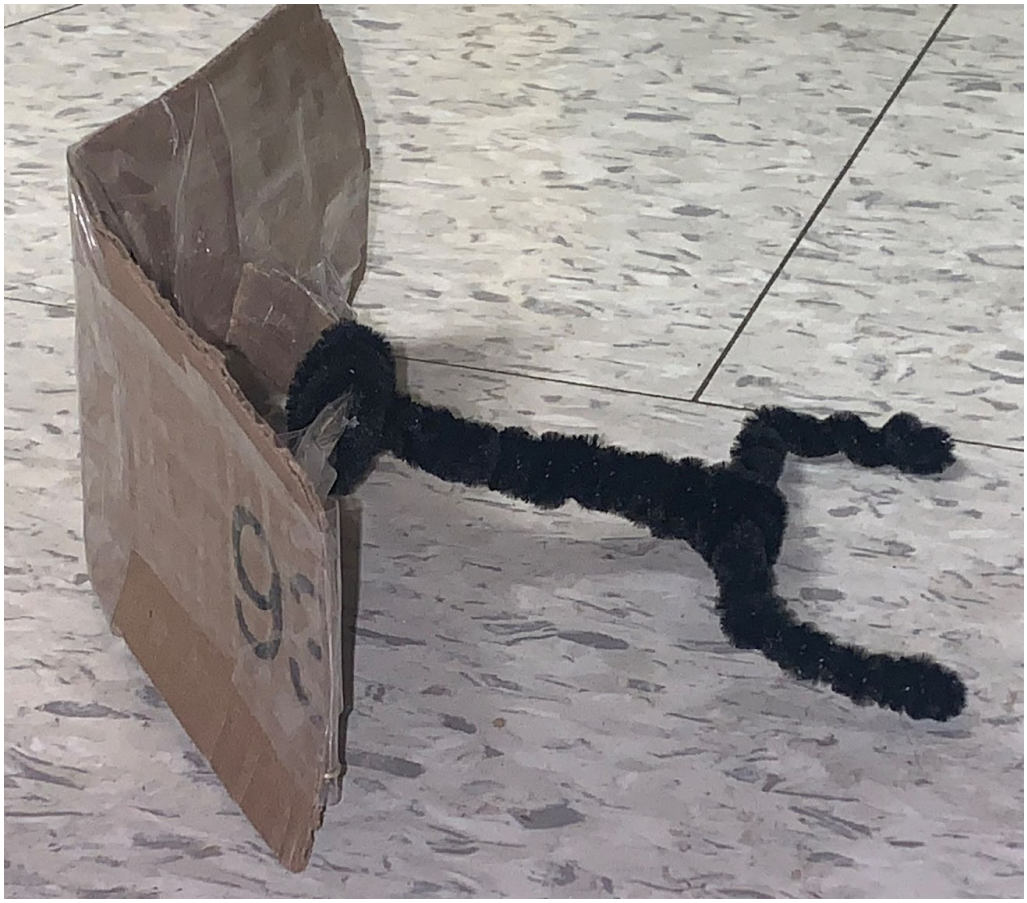


Figure 5.2 Prototype Mockup Side View

Figure 5.3 Prototype Mockup Top View

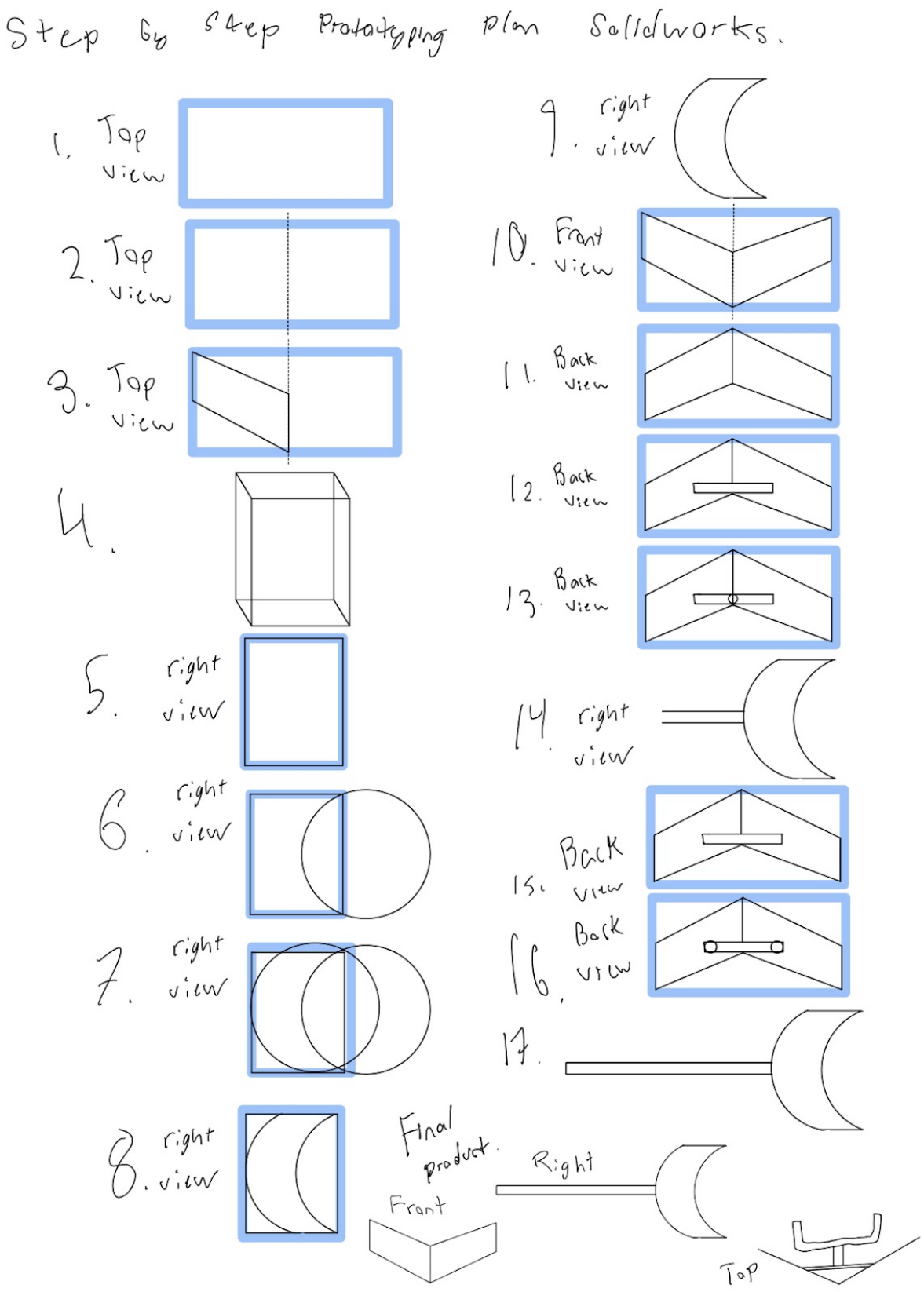


Figure 6 Solidworks Prototyping Plan

Table 6 Pugh Scoring Matrix

		Golf Cart Plows		Drawing 1		Drawing 4	
Need	Weight (1-5)	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Easy to attach	1	4	4	5	5	3	3
Effective in plowing the sidewalks	4	4	16	4	16	5	20
Prevents robots from getting stuck	2	2	4	5	10	5	10
Long term	4	5	20	4	16	3	12
Asthetically pleasing	3	1	3	4	12	4	12
Cheap	1	1	1	5	5	4	4
Delivery efficentcy	5	1	5	5	25	5	25
			0		0		0
			0		0		0
			0		0		0
TOTAL			53		89		86

Table 7 Correlation Matrix

Design Requirements / User Needs Correlation Matrix

	must clear snow from the sidewalks efficently	can be quickly and easily attached to the robot	fits within the given budget	can be used annually	cannot affect the robot's ability to complete deliveries	cannot weigh the robot down	User Need Weight
Easy to attach		9					1
Effective in plowing the sidewalks	9				3		4
Prevents robots from getting stuck	9				3		2
Long term				9			4
Asthetically pleasing							3
Cheap			9	1			1
Delivery efficentcy	3				9	9	5
Importance ->	69	9	9	37	63	45	

Table 8 Requirement Ranges

Requirements	**Range**	**Ideal**
The plow must clear snow from sidewalks efficiently.	0-0.5 inches of snow left	0-0.1 inches of snow left
The plow can be quickly and easily attached to the robot.	0-1 minutes	0-30 seconds
Printing the plow is within the budget.	<5% the cost of a robot	<1% of the cost of a robot
The plow can be used annually (durable).	>1 years	>5 years
The plow cannot affect the robots ability to complete deliveries.	0-5 minutes are added	0-1 minutes are added
The plow cannot weigh the robot down.	<10% of the weight of the robot	<5% percent of the weight of the robot

Table 9 Verification Scorecard

Verification Scorecard Points Distribution*		
	Raw Percentage	Score Card Points (25 total)
The plow must clear snow from the sidewalks efficently	29.7%	7
The plow can be quickly and easily attached to the robot	3.9%	1
Printing the plow is within budget	3.9%	1
The plow can be used annually	15.9%	4
The plow cannot affect the robot's ability to complete deliveries	27.2%	7
The plow cannot weigh the robot down	19.4%	5
This sum should be 25! --------->		25

Table 10 Rubric

	+2 above expectations	**+1 meets expectations**	**+0 fails to meet expectations**
Requirement 1 weighted at 29.7%	Ideal goal is hit. Less than .1 inches of snow is left after the area is plowed.	The end result is within the range. 0-.5 inches of snow left.	The end result is out of the range. More than .5 inches of snow left after the area is plowed.
Requirement 2 weighted at 3.9%	Ideal goal is hit. The plow takes less than 30 seconds to assemble.	The end result is within the range. The plow can be assembled in a minute.	The end result is out of the range. The plow can not be assembled in a minute.
Requirement 3 weighted at 3.9%	Ideal goal is hit. The plow is less than 1% the cost of a robot.	The end result is within the range. The plow is less than 5% the cost of a robot.	The end result is out of the range. The plow is more than 5% the cost of a robot
Requirement 4 weighted at 15.9%	Ideal goal is hit. The plow can be used for 5 or more years.	The end result is within the range. The plow can be used for more than 1 year.	The end result is out of the range.The plow cannot be used for more than 1 year.
Requirement 5 weighted at 27.2%	Ideal goal is hit. Less than a minute is added to delivery times compared to robots without a plow in good weather conditions.	The end result is within the range. Less than 5 minutes is added to delivery times compared to robots without a plow in good weather conditions.	The end result is out of the range. More than 5 minutes is added to delivery times compared to robots without a plow in good weather conditions.
Requirement 6 weighted at 19.4%	Ideal goal is hit. The plow weighs less than 5% of the weight of the robot.	The end result is within the range. The plow weighs less than 10% of the weight of the robot.	The end result is out of the range. The plow weighs more than 10% of the weight of the robot.

In order to get a 100% on a test an average of a 1 must be scored in every category.

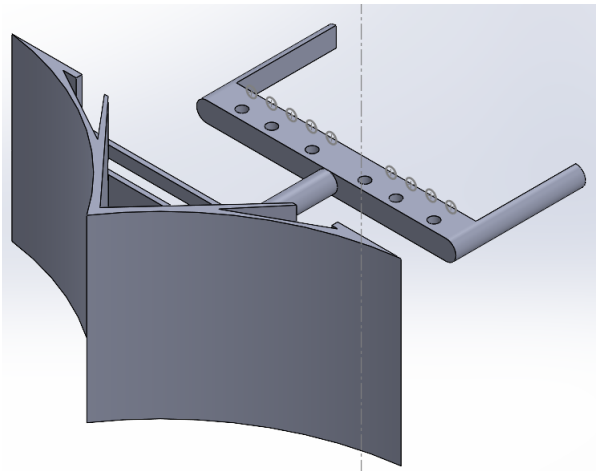


Figure 7 Original SolidWorks design

Gantt Chart Template			
	Project Start Date	Project End Date	Today's Date
	3/22/22	5/2/22	3/31/22
Task Name/Description	Start Date	End Date	% complete
Finish the Solidworks portion of protyping.	3/22/22	3/30/22	100
Talk to someone from instructorial team	3/22/22	4/1/22	100
Send part to printer/request materials from shop.	3/30/22	4/8/22	100
Test the durability of the plow using solid works.	3/30/22	4/8/22	75
Test how efficetive the plow is at moving objects.	4/8/22	4/22/22	50
Test the price and weight using the mass properties on solidworks.	3/26/22	4/15/22	50
Test to see if the plow slows down students who are pushing it.	4/3/22	4/12/22	0
Finish the Solidworks documentation	4/1/22	4/22/22	0
Finish the DDR	4/1/22	4/22/22	0

Figure 8 Gantt Chart

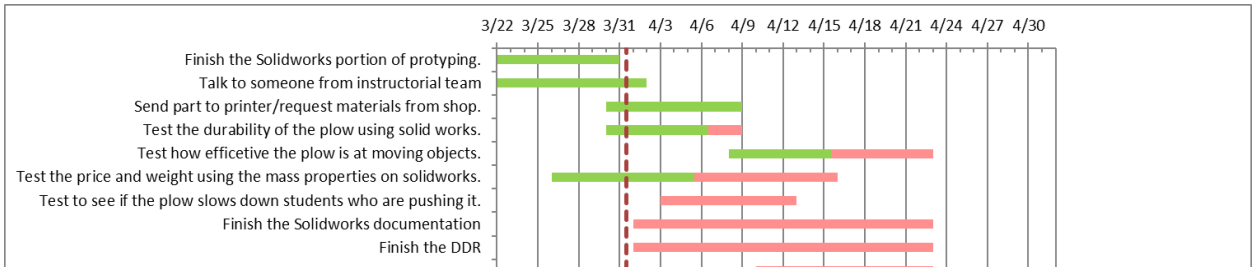


Figure 9 Colored Gantt Chart

Table 11: Revised Top 3 User Needs Chart

User Needs (Robots)	**Score (1-5)**
Effective in plowing the sidewalks	4
Prevent the robots from getting stuck	4
Delivery efficiency	5

Table 12. Pairwise Comparison Chart

	Easy to attach	Effective Plow	Keeps robots from getting stuck	Long term	cheap	Aesthetically pleasing	Delivery Efficiency				Total	Normalized	Original
Easy to attach		0	0	0	0	1	0				1	1	2
Effective Plow	1		1	0	1	1	0				4	4	5
Keeps the Robots from getting stuck	1	0		0	1	1	0				3	2	4
Long Term	1	1	1		0	1	0				4	4	5
Cheap	1	1	0	1		1	0				4	3	3
Aesthetically pleasing	0	0	0	0	0		0				0	1	1
Delivery Efficiency	1	1	0	1	1	1					5	5	3

Table 13. Stakeholders and Value

Value Categories

Stakeholder	Economic	Social	Environmental
Faculty at colleges with food delivery robot services	Faculty members at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage.	Faculty members at colleges with food delivery robots will not need to walk from their cars through snow and slush.	Faculty members at colleges with food delivery robots will not need to replace their shoes therefore producing less waste.
Students at colleges with food delivery robot services	Students at colleges with robotic food delivery services don't need to replace shoes due to winter weather damage.	Students at colleges with food delivery robots will not need to walk from their dorms through snow and slush.	Students at colleges with food delivery robots will not need to replace their shoes therefore producing less waste.
Dining service employee's at the colleges with robots	N/A	Dining service employees will need to perform less rescue runs to save robots that were stuck in the snow and therefore save time and energy.	N/A
Grubhub and Yandex employees	Food delivery services now have to spend less money to fix robots that are damaged due to harsh winter weather conditions.	Food delivery employee's are now able to spend less time on maintenance required due to harsh winter weather.	Food delivery employee's have to order less parts for maintenance therefore producing less waste.

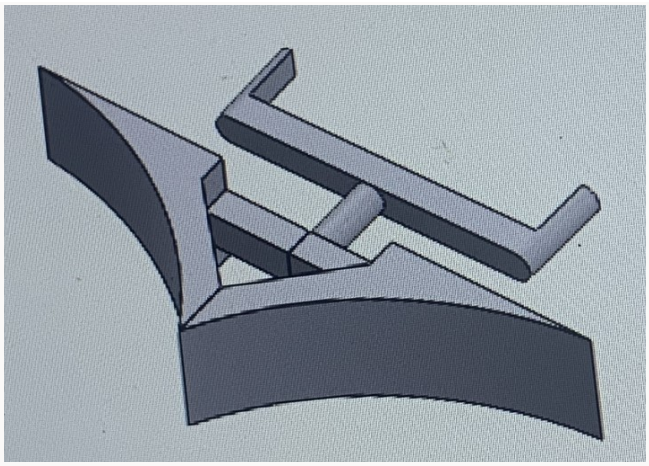


Figure 10 Final Solidworks Assembly

Figure 11 Final prototype

Appendix B-Research Methodologies

Survey 1:

Title:Grubhub Robots/Getting food in the winter

Questions:

Q1: How often do you order from a grubhub robot
1 2 3 4 5 6 7 8 9 10
Never Always

Q2: Have you ever had a robot with your order get stuck in the snow?
Yes
No
Maybe, I'm not sure it took a long time

Q3: While walking across campus to get food(or just get to class) have you noticed slush making your walk miserable?
1 2 3 4 5
Not Really Yes a ton

Q4:Would having grubhub robots plow the slush when they are making deliveries make your winter experience more enjoyable
Yes, it would
Maybe, I'm not sure
No

Results:

Total entries: 302

Q1:
1- 114 (37.9%)
2- 30 (10%)
3- 29 (9.6%)
4- 24 (8%)
5- 14 (4.7%)
6- 16 (5.3%)
7- 27 (9%)
8- 23 (7.6%)

9- 7 (2.3%)
10- 17 (5.6%)

Q2: (out of everyone who has ordered from a grubhub robot or 188 people surveyed)
Yes- 28 (14.9%)
Maybe, I'm not sure- 46 (24.5%)
No- 114 (60.6%)

Q3:
1- 10 (3.3%)
2- 15 (5%)
3- 46 (15.3%)
4- 88 (29.2%)
5- 142 (47.2%)

Q4:
Yes, it would- 234 (77.5%)
Maybe, I'm not sure- 58 (19.2%)
No- 10 (3.3%)

Survey 2:

Title: Robot Plows

Questions:

Q1: Do you like the design of our attachable plow? (Figure 10 was included in the survey)
Yes
No

Q2:Do you think our plow will be beneficial?
Yes
No
Maybe

Q3:Do you think our plow will impact delivery times? (it weighs less than 4 lbs and will not cover any sensors)
Yes
No
Maybe

Results:
Total entries: 50

Q1:
Yes- 83.7%
No- 16.3%

Q2:
Yes- 87.5%
No- 10.4%
Maybe- 2.1%

Q3:
Yes- 34.7%
No- 30.6
Maybe- 34.7%

Interviews:

Interview one was with a first year robot enthusiast named Sara.
Q:"Do you enjoy having the robots as a food delivery service? Have you noticed any effects that the recent winter weather has had on them?"
R:"I really like using the robots, but I think I saw rust in a wheel well of a nearby robot due to the snow so I'm worried if they'll be okay."

Interview two was done with a first year robot enthusiast named Delany.
Q:"Do you use the robots? What are your thoughts on adding a plow to them?"
R: "I love using the robots, but I'm scared the robots aren't well equipped for winter weather. Adding a plow could possibly help protect them from the elements."

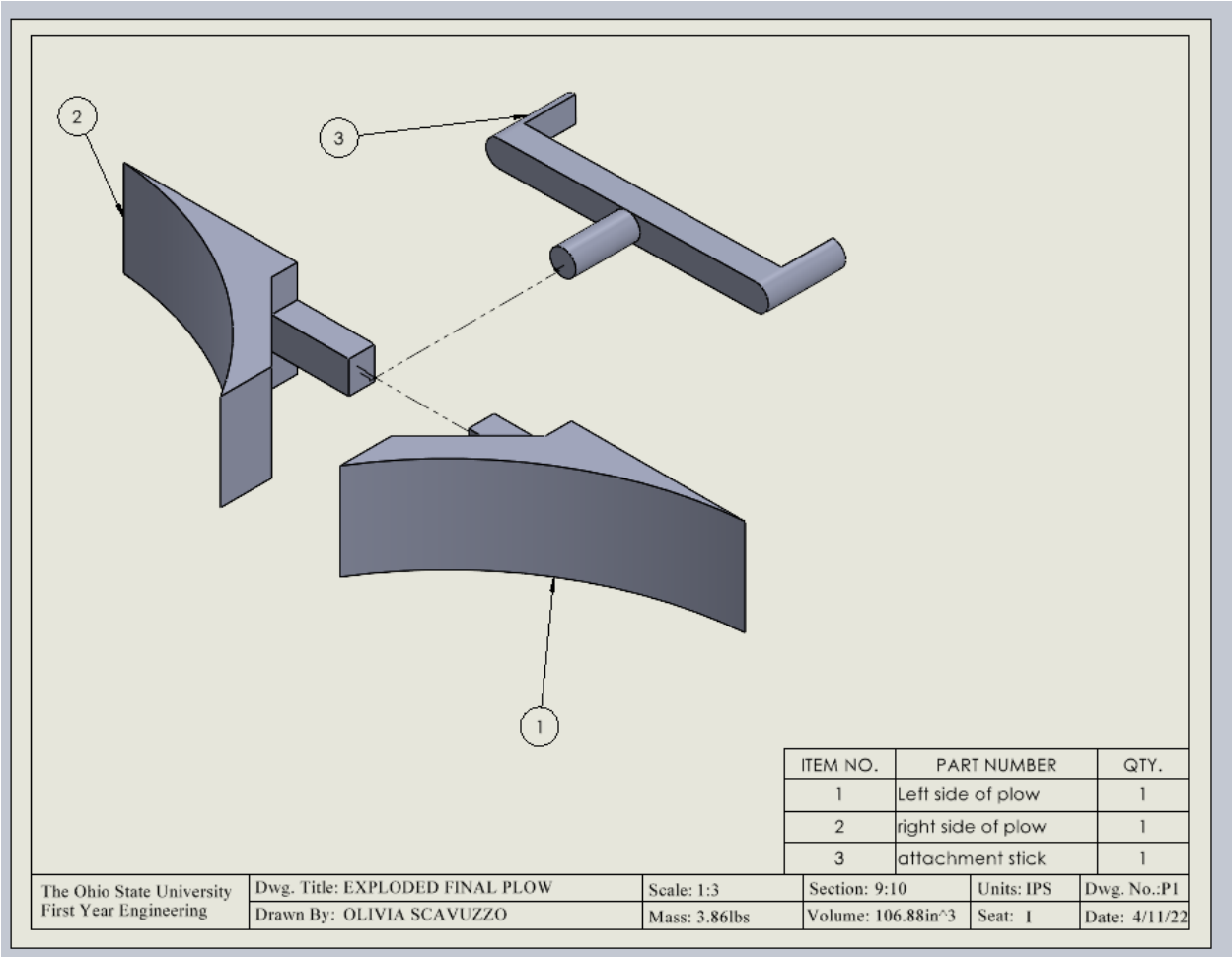
Interview three was done with a Curl Market employee.
Q: "Have you ever had to save a robot that got stuck in the snow during one of your shifts? Would adding a plow limit the number of rescue runs?"
R:"I personally haven't had to save any robots, but a few of my coworkers have and it was very inconvenient and they were very annoyed. I think adding a plow would make the amount of rescue runs virtually none.

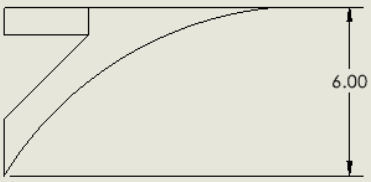
Interview four was done with a third year mechanical engineering student.

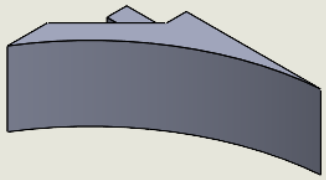
Q: “Do you think that adding a plow to the grubhub robots is a good idea? Do you think it will benefit students?”
R: “That is such a good idea. Honestly I wish my group would have thought of that freshmen year. That’s going to help everyone during their day to day lives all winter long.”

Interview five was done with an engineering student named Jon.
Q: “Do you like the design for our plow? If you were the one designing it what would you have done differently?”
R:“Yeah I really like it, it's a great design. You guys did a great job. If i were to make it I probably wouldn't have made the edges so thin because they could break sooner than anticipated but great job!

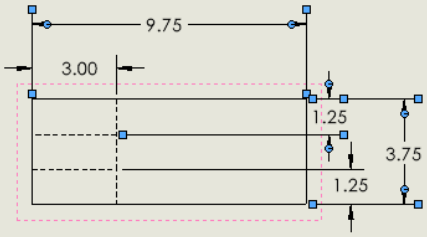
Appendix C-Prototype Working Drawings

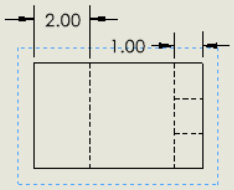




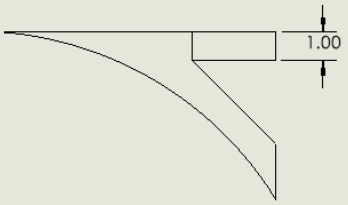


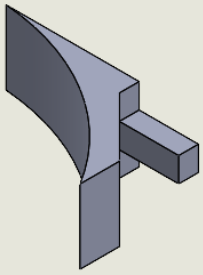
All unmarked curves have a radius of 12.67



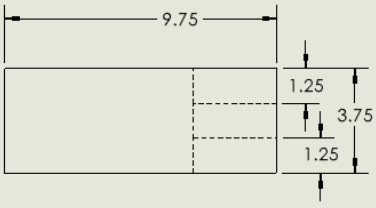


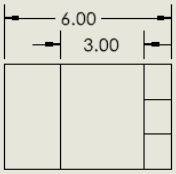
The Ohio State University First Year Engineering	Dwg. Title: LEFT SIDE OF PLOW	Scale: 1:4	Section: 9:35	Units: IPS	Dwg. No.:F2
	Drawn By: OLIVIA SCAVUZZO	Mass: 1.65 lbs	Volume: 45.77in^3	Seat: 1	Date: 4/15/22



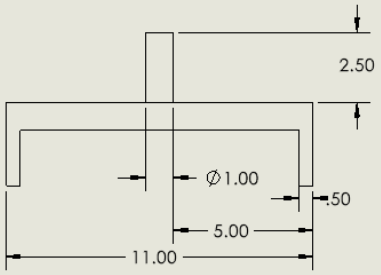


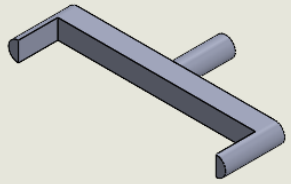
All unmarked curves have a radius of 12.67



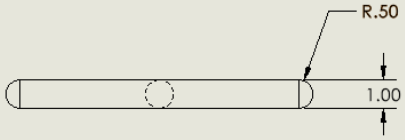


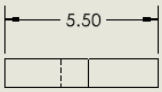
The Ohio State University First Year Engineering	Dwg. Title: RIGHT SIDE OF PLOW	Scale: 1:4	Section: 9:35	Units: IPS	Dwg. No.:F3
	Drawn By: OLIVIA SCAVUZZO	Mass: 1.65lbs	Volume: 45.77in^3	Seat: I	Date: 4/15/22



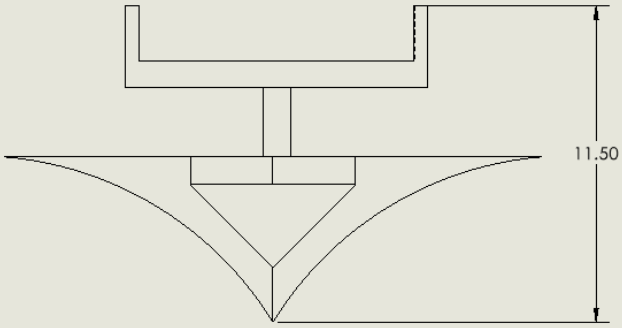


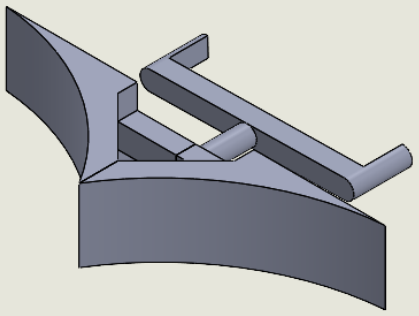
This part is symmetrical from top to bottom and left to right.



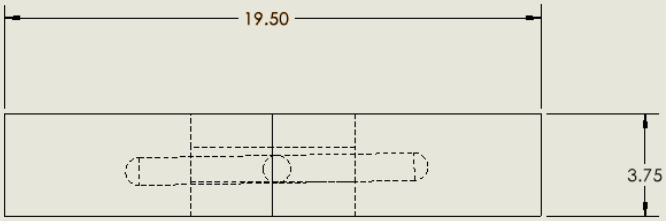


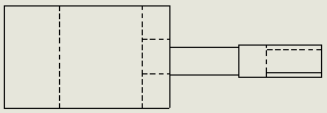
The Ohio State University First Year Engineering	Dwg. Title: ATTACHMENT PIECE	Scale: 1:4	Section: 9:35	Units: IPS	Dwg. No.:F4
	Drawn By: OLIVIA SCAVUZZO	Mass: .52lbs	Volume: 14.32 in^3	Seat: I	Date: 4/15/22





The assembly is parallel from top to bottom and left to right





The Ohio State University First Year Engineering	Dwg. Title: ASSEMBLY OF PLOW	Scale: 1:4	Section: 9:35	Units: IPS	Dwg. No.:F5
	Drawn By: OLIVIA SCAVUZZO	Mass: 3.86 lbs	Volume: 106.88 in^3	Seat: I	Date: 4/24/22

Appendix F-Project Management

Schedule:

1. Fix plow in Solidworks—-March 28
2. Talk to instructional team—Before April 1st
3. Send part to printer/ go to shop—April 1st
4. Test durability (Requirement 4) using solidworks simulation—Over the weekend
5. Test other design requirements—once Team I has the part (before April 18th)
    a. Requirement 1 will be tested with sand from volleyball court–Before April 18th
    b. Requirement 2 cant be tested–Before April 18th
    c. Requirement 3 will be tested with mass properties on solid works–Before April 18th
    d. Requirement 4 have people walk around with it–Before April 18th
    e. Requirement 5 will be tested with mass properties on solid works–Before April 18th
6. Finish the documentation for Solidworks– April 23rd
7. Finish the DDR–April 23rd

Meeting Minutes 1:

Header —04/04/2022, 8pm and class today, in class and Zoom Call, Olivia Scavuzzo, Yingqi Gao, Vishal Sagi

Objective statement — Came across a problem which was to print the plow. Talked to Dr. Ratcliff about assembling the parts as the object was too big to print.

Completed tasks from previous week or last meeting, including:

- Fixing the plow in solidworks- Olivia Scavuzzo. We needed to redesign the plow in order to ensure that it would not warp in the 3-D printer. After we redesigned the plow, we had to redesign it again because the part was too wide therefore it wouldn't fit in the printer
- Talking to TA's- Yingqi Gao. We had questions about our design and needed to email the TA's.
- DD1- Olivia Scavuzzo and Yingqi Gao. We had to develop a schedule for the rest of the project.
- A20- Olivia Scavuzzo and Vishal Sagi. We had to create a more in-depth schedule for the rest of the semester.

Tasks to be completed for the upcoming week or next meeting, including:

- Bulleted list of tasks

- Documentation of the plow
- Testing the parts
- Work on getting the permission to print the plow

People Assigned to upcoming tasks:

- Person(s) assigned to the task - Olivia Scavuzzo
- Documentation - Olivia Scavuzzo, Vishal Sagi,Yingqi Gao, Chengxi Wang
- Testing - Olivia Scavuzzo

Project timeline We have finished our first two tasks from the Gantt Chart and are about to finish the third.

Decisions N/A

Meeting Minutes 2:

Header — 4/11/22, 9:10, class, Olivia Scavuzzo

Objective statement — The goal for today's meeting was to work on Solid works documentation, the mini presentation that will take place on Wednesday, and testing design requirement 4.

Completed tasks from previous week or last meeting, including:

- Approval to print- Olivia Scavuzzo. We needed to talk to a TA or Dr. Ratcliff to get approval to send our 3-D parts to the printer.
- Ordered the parts-Olivia Scavuzzo. We needed to fill out the order form in order to receive our parts.
- Exploded assembly-Olivia Scavuzzo. We needed to assemble our parts in SolidWorks and then explode them for documentation purposes.
- Exploded drawing-Olivia Scavuzzo. We needed to make a drawing of our exploded assembly for documentation purposes.

Tasks to be completed for the upcoming week or next meeting, including:

- Finish testing design Requirement 4-Olivia Scavuzzo
- Create a survey-Olivia Scavuzzo
- Gather survey results-Everyone
- Interview end users-Everyone
- Finish mini presentation- Olivia Scavuzzo
- Work on documentation while we wait for parts-Olivia Scavuzzo

Project timeline We have gotten the parts approved and sent to the printer. We are also beginning to test our design requirements.

Decisions n/a

Meeting Minutes 3

Header — 4/18/22, 9:10, class, Olivia Scavuzzo and Yingqi Gao
Objective statement — 1-2 sentences that establish the goal or purpose of the meeting
Completed tasks from previous week or last meeting, including:

- Finish testing design Requirement 4-Olivia Scavuzzo. Our fourth design requirement (durability) needed to be tested to see how long our plow will last in order to verify and validate our part.
- Create a survey-Olivia Scavuzzo. We needed to create a survey to gather insight from end users.
- Gather survey results-Everyone. We needed to gather results for our survey in order to get feedback.
- Interview end users-Olivia Scavuzzo. We needed to interview end users in order to get feedback.
- Finish Solidworks documentation-Olivia Scavuzzo. We needed to finish the working drawings packet.
- Split up the TDR and FDR-Olivia Scavuzzo. We needed to divide work evenly.
- Talk to Dr. Ratcliff-Yingqi Gao and Olivia Scavuzzo. We needed to talk to Dr. Ratcliff about dividing work evenly.

- Talk to lab supervisor-Yingqi Gao and Olivia Scavuzzo. We needed to talk to the lab supervisor to find out how we're going to construct our part.
- Come up with a new plan to designour plow-Yingqi Gao and Olivia Scavuzzo. We needed to figure out how we will be designing our part due to our parts at the 3-D printer being canceled.

Tasks to be completed for the upcoming week or next meeting, including:

- Finish DDR-everyone
- Finish TDR-everyone
- Finish the presentation (FD3)- everyone
- Finish the plow- everyone

Project timeline We finished testing a design requirement and the solidworks documentation.
Decisions We had to decide how we are going to create the plow now that we can not print it.

Appendix G-Team Working Agreement

PD1-Problem Definition and Task

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Yingqi Gao	Chengxi Wang	Vishal Sagi	Olivia Scavuzzo

Created Figures	Created Tables
Yingqi Gao, Olivia Scavuzzo	Yingqi Gao, Olivia Scavuzzo, Vishal Sagi, Chengxi Wang

Other Contributions
Collecting and Writing down the ideas, Checking out the format and syntax.
Problems Overcome
Picking a topic, Finding a meeting time/place, Quarantine, Thinking about pains.

Table 1.1 Assignment PD1 Table

PD2-Research Plan:

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
NA

Drafted	Reviewed	Revised	Proofread

Assignment	Assignment	Assignment	Assignment
Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
Olivia Scavuzzo	Olivia Scavuzzo

Other Contributions
Creating a survey, conducting interviews
Problems Overcome
Discussing and picking a new task

Table 1.2 Assignment PD2 Table

PD3-End User Needs:

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Chengxi Wang	Yingqi Gao	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
Olivia Scavuzzo and Chengxi Wang	Olivia Scavuzzo

Other Contributions
NA

Problems Overcome
Thinking of enough needs and comparing them all

Table 1.3 Assignment PD3 Table

PD4-Market Character:

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
NA

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Olivia Scavuzzo/Vishal Sagi	Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
Olivia Scavuzzo	Olivia Scavuzzo

Other Contributions
NA
Problems Overcome
Fixing earlier steps, Thinking of competitors

Table 1.4 Assignment PD4 Table

PD5-:Research Results and Value Proposition

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
NA

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Olivia Scavuzzo	Olivia Scavuzzo	Yingqi Gao/Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
NA	Olivia Scavuzzo

Other Contributions
NA
Problems Overcome
Finalizing everything along with putting everything into words

Table 1.5 Assignment PD5 Table

CD3- Concept Selection

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Vishal Sagi

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Chengxi Wang	Yingqi Gao	Vishal Sagi	Olivia Scavuzzo

Created Figures	Created Tables
Yingqi Gao, Olivia Scavuzzo, Vishal Sagi, Chengxi Wang	Yingqi Gao, Olivia Scavuzzo, Vishal Sagi, Chengxi Wang

Other Contributions
NA
Problems Overcome
NA

Table 1.6 Assignment CD3 Table

CD4- Grand Concept Design

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Chengxi Wang, Yingqi Gao, Vishal Sagi, Olivia Scavuzzo	Yingqi Gao	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
Olivia Scavuzzo	Olivia Scavuzzo

Other Contributions
NA
Problems Overcome
Time Management

Table 1.7 Assignment CD4 Table

CD5- Prototype Requirements and Verification Plan

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Yingqi Gao, Vishal Sagi, Olivia Scavuzzo	Yingqi Gao, Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
Olivia Scavuzzo	Olivia Scavuzzo

Other Contributions
Finding the weight and cost of the robots.
Problems Overcome
Finding the weight and cost of the robots.

Table 1.8 Assignment CD5 Table

DD1: Project Management

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment

Yingqi Gao/Olivia Scavuzzo	Yingqi Gao/Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
NA	Olivia Scavuzzo

Other Contributions
Talking to TA's about how to construct the plow
Problems Overcome
Time Management

Table 1.9 Assignment DD1 Table

DD2: User Validation Plan

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment
Yingqi Gao

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Yingqi Gao	Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
N/A	Olivia Scavuzzo

Other Contributions
N/A
Problems Overcome

N/A

Table 1.10 Assignment DD2 Table

DD3: Social and Economic Value

Project Manager for the Assignment
Olivia Scavuzzo
Deputy Manager for the Assignment

Drafted Assignment	Reviewed Assignment	Revised Assignment	Proofread Assignment
Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo	Olivia Scavuzzo

Created Figures	Created Tables
NA	Olivia Scavuzzo

Other Contributions
N/A
Problems Overcome
Thinking of the third category and parts getting canceled

Table 1.11 Assignment DD3 Table