Deliverable C - Problem Definition, Concept Development, and Project Plan

Submitted by:
Team A02.2
Etienne Borm 300304140
Alyssa Carter 300234698
Noah Cummings 300287948
Abdullah Ramadan 300218707
Rémi Thomas-Richard 300300437

October 1st, 2023
University of Ottawa

List of Figures 2

List of Tables 3

Introduction 3

C.1 Problem Definition 3

C.1.1 Interpreted Needs 3

C.1.2 Problem Statement 4

C.1.3 Design Criteria and Metrics 5

C.1.4 Benchmarking 5

C.1.5 Target Specifications 7

C.1.5.1 Ideal Target Specifications 7

C.1.5.2 Acceptable Target Specifications 8

C.2 Concept Development 9

C.2.1 Prototype Concepts 9

C.2.1.1 Concept 1 9

C.2.1.2 Concept 2 10

C.2.1.3 Concept 3 11

C.2.1.4 Concept 4 12

C.2.1.5 Concept 5 13

C.2.2 Concept Analysis 14

C.2.2.1 First Concept: 14

C.2.2.2 Second Concept: 14
C.2.2.3 Third Concept: 14
C.2.2.4 Fourth Concept: 14
C.2.2.5 Fifth concept: 14
C.2.4 Global Concept Design 15
C.2.5 Visual Representation 16
C.2.6 Benefits and Drawbacks 16
C.3 Conclusion **17**

List of Figures

Figure 1: Adapt2Row attachment for Concept2 ..……..……4

Figure 2: AROW attachment for Concept2 ……..……..……5

Figure 3: Prototype concept 1 ……..……..……7

Figure 4: Prototype concept 2 ……..……..……..……8

Figure 5: Prototype concept 3 ……..……..……9

Figure 6: Prototype concept 4 ……..……..……..……10

Figure 7: Prototype concept 5 ……..……...……11

Figure 8: Global concept prototype ……..……...12

List of Tables

Table 1: Interpreted Needs Ranking……...……6

Table 2: Interpreted Needs and Metrics…...……..……..……7

Table 3: Product benchmarking.……..……..……..……8

Table 4: Ideal target specifications……..…..…….……..……9

Table 5: Acceptable target specifications ...……...……..10

Introduction

During the meeting with our client, our team identified and noted important needs. We have ranked these needs based on their importance to the final product. Using these needs, we created a problem statement and turned them into metrics which we will use to set target specifications. These metrics will help us benchmark similar products to see what our product needs to function and what it can improve on .

C.1 Problem Definition

C.1.1 Interpreted Needs

With the notes from meeting one, we have interpreted the client's wishes into needs and ranked them from 1 to 5 by their importance (5 being high, 1 being low).

Customer Statements	Interpreted Needs	Rank
Each user has different restriction, such as limited waist and hip movement	The product is adjustable	4
There can't be a worry that the user will fall out	The product is secure	5
It must convert the machine, not the person using it	The product is an addition the the existing machine The product is ergonomic	4 4
It is important to keep the wheelchair's armrest in mind	The product is ergonomic The product is out of the way	4 3
Self-serve device is A+ solution	The product is simple The product is easy to use	3 4
Lock the rower so it can't move	The product is secure	5
Being portable is good, but the simpler the better	The product is light The product is portable	2 2
Wheelchair seats are low and the leg pieces are in the way	The product is small	3

of the rowing machine		
Any movement that the user can do matters	The product is ergonomic The product encourages mobility to the user	4 4
Can modify machine as long as it can still be used normally	The product is an addition to the existing machine The product is removable	4 4
Different wheelchair designs have different setting heights	The product's height is adjustable	4

Table 1: Interpreted Needs Ranking

C.1.2 Problem Statement

Our client is responsible for overseeing the weight and cardio room at the Jack Purcell community center and is looking for a modification to a rowing machine for those bound in a wheelchair. Using these interpreted needs, we have come up with a problem statement that defines what the problem is, who has the problem, and what form our solution comes in:

There is a need at the Jack Purcell community center for a modification to a rowing machine in their weight room that allows wheelchair users to exercise with the machine without getting out of their wheelchair.

C.1.3 Design Criteria and Metrics

In this section, our interpreted needs were evaluated into metrics used to measure our product.

Need #	**Interpreted Need**	**Design Criteria**	**Metric**	**Unit**
	Functional			
1	The product is adjustable	Adjustability of product	Extendable Height	Inches (in)
2	The product is	Removal of the product	Installation time	Minutes (min)
3	The product is an addition to the existing machine	Attachment of the product	Latching system	N/A

	Non-Functional			
5	The product is ergonomic	Shape	Height/Width & Body Supports	Inches (in)
6	The product is easy to use	Product complexity	Set up time	Minutes (min)
4	The product is secure	Safety and robustness of product	Stability (Withstandable Weight)	Kilograms (kg)
	Constraints			
7	The product is light & portable	Weight of the product	Weight	Kilograms (kg)
8	The product is small	Dimension of the product	Size	Feet cube (ft^3)

Table 2: Interpreted Needs and Metrics

C.1.4 Benchmarking

The first product researched is the Adapt2Row attachment for the Concept2 Rowing Machine. This attachment requires removal of the normal seat of the rower, the attachment is then clipped into the same slot as the seat, allowing it to hold up that end of the machine. The attachment itself has 2 wheels, separated by a gap in the middle, thus allowing users to sit themselves in a wheelchair between the wheels, close to the machine. The middle bar is also fitted with padding for the comfort of the user. (Source: https://gerofitness.nl/export/406-adapt2row.html)

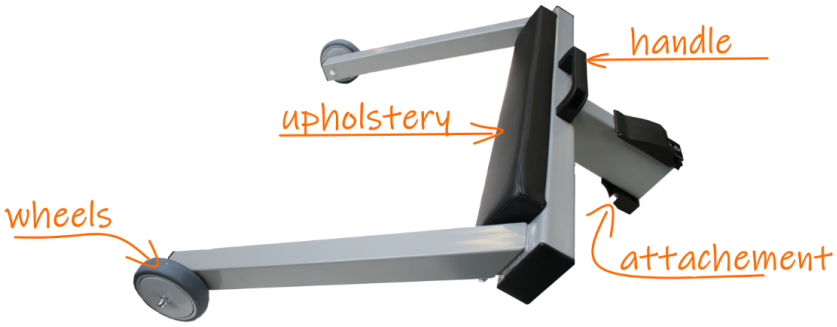

Figure 1: Adapt2Row attachment for Concept2

The second product benchmarked is the AROW rowing machine attachment, also built for the Concept2. This product is attached to the beam of the machine that attaches to the seat, higher up on the arm than the Adapt2Row. The AROW has a long beam which presses up to the user's lap

once they wheel up to it. It also has a holder for the cable to make it easier to grab when it is attached. (Source: https://adaptederg.commons.bcit.ca/rowing-solutions/)

Figure 2: AROW attachment for Concept2

Product/Specifications	**Adapt2Row**	**AROW**
Company	GeroFitness	BCIT REDLab
Price ($)	1021.53	Not for sale
Weight (kg)	~20	N/A
Dimensions (m)	0.81x0.50 (width x length)	Not available
Use From Wheelchair?	Yes	Yes
Ergonomics/Adjustability	Not Adjustable (Fixed Height, fixed distance)	Offers different permutations of padding/arms (Adjustable for many different heights)
Portability/Removability	Easy to clip on/remove Uses latching system	Complicated installation Does not use latching system

Table 3: Product benchmarking

C.1.5 Target Specifications

These specifications are based on our client needs and the benchmarking done with similar products.

C.1.5.1 Ideal Target Specifications

Design Criteria	**Relation**	**Range of Values**	**Verification Method**
Adjustability (Height of Cable holder)	=	25 inches	-Benchmarking Dimensions -Testing
Adjustability of the knee stopper	=	Up to 12 inches of distance	-Testing
Supported Weight	>	26kg (Weight of Concept2 Rowing Machine)	-Materials Research -Testing
Attachment Set Up/Removal Time	=<	2 minutes	-Testing
Product Weight	<	25kg	-Materials Research -Testing
Cost	<	$100	-Cost Estimate -BOMB -Final Price
Attachment of the product	=	Latching mechanism already in use by Concept2 rower	-Test -Research
Dimensions of product	<	$27ft^3$ (3x3x3)	-Measurement

Table 4: Ideal target specifications

For our ideal specifications, we want the height of the cable holder to be a little higher than the height of the holder (17in) , so we feel that an extra 8 inches helps those in wheelchairs who can't bend down to reach the normal height. Having the knee stopper being able to move forward by 12 inches gives plenty of space between the machine and the wheelchair for the wheelchair legs and footrests. The weight of the rowing machine including the default seat and rail is 26kg, so the product being able to withhold that much is more than enough for security and stability. A 2 minute installation and removal time is a feasible time for installation that doesn't interfere with the routine of the user or the person installing the product. Our ideal weight is anything under 25 kg as we want the product to be portable and able to be stored on a shelf or hooked on a wall. The ideal cost is less than 100$ since it's our budget for the product. The ideal latching mechanism is the one used by the rower as it is the easiest to interchange with different Concept2 rowing machines. Our ideal size is less than 27 ft 3 to make it easier to transport, store and weigh less.

C.1.5.2 Acceptable Target Specifications

Design Criteria	**Relation**	**Range of Values**	**Verification Method**
Adjustability (Height of Cable holder)	=	Between 20-30 inches	-Benchmarking Dimensions -Testing
Supported Weight	>=	20kg	-Materials Research -Testing
Attachment Set Up/Removal Time	=<	5 minutes	-Testing
Product Weight	<	30kg (Must be reasonably moveable)	-Materials Research -Testing
Cost	=	$100	-Cost Estimate -BOMB -Final Price
Latching system	=	Any secure attachment method	-Test -Research
Dimensions of product	=	$27ft^3$ (3x3x3)	-Measurement

Table 5: Acceptable target specifications

The acceptable height of the cable holder is between 20 and 30 inches because the average height of armrests in adult wheelchairs is 30 inches. The supported weight should be at least 20 kg as

this is the minimum it should be able to support without breaking if the weight of the steel rail with the default seat is not accounted for. A set up time of 5 minutes is the maximum we feel is acceptable in terms of the time it takes to set up the product. A long set up time deters users from wanting to use the product.

C.2 Concept Development

Our final product will have 2 subsystems: the latching mechanism and the supports. The latching mechanism must be able to attach and detach from the rower while the supports must be able to support the weight of the machine. It is also responsible for keeping the user from moving.

C.2.1 Prototype Concepts

Each group member was tasked with coming up with one concept for the full product that can later be combined with other members' concepts in order to optimize the final design.

C.2.1.1 Concept 1

This concept uses the same latching system as the Concept 2 rowing machine which makes it easy to install and remove. The main frame is made of 3 aluminum tubes which are welded together. Rubber feet stabilize the rower and prevent it from sliding. The estimated mass of the product is 7kg with an average weight of 68N. This weight can be reduced by making the walls of the tubes thinner. It is 24 in wide and the frame is 17 in tall. The latching subsystem of this concept is connected to the legs with bolts. The rubber feet will be glued to the bottom of the legs.

The disadvantages of this concept is that the height is not adjustable and it is heavier than the target weight. It also does not prevent the wheelchair or the user from moving.

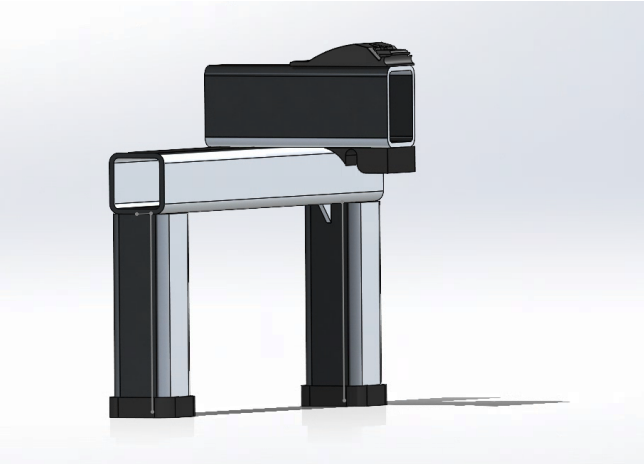

Figure 3: Prototype concept 1 with simple legs and latching system

C.2.1.2 Concept 2

This concept uses a simple mechanism of two hollow aluminum beams, with holes in them to allow height adjustment. The top of the inner beam clamps onto the rowing machine where the seat would normally hook up, allowing the entire machine to be lifted up and down. It also comes fitted with a mat at the base which can allow extra grip for wheels as someone is using the machine. This mat can be lifted up when desired, making it significantly easier to store.

This concept, while simple, allows height adjustability, great ease of use, can be fabricated easily, and is not heavy. However, it does not offer anything in terms of extra support for the person using the rowing machine.

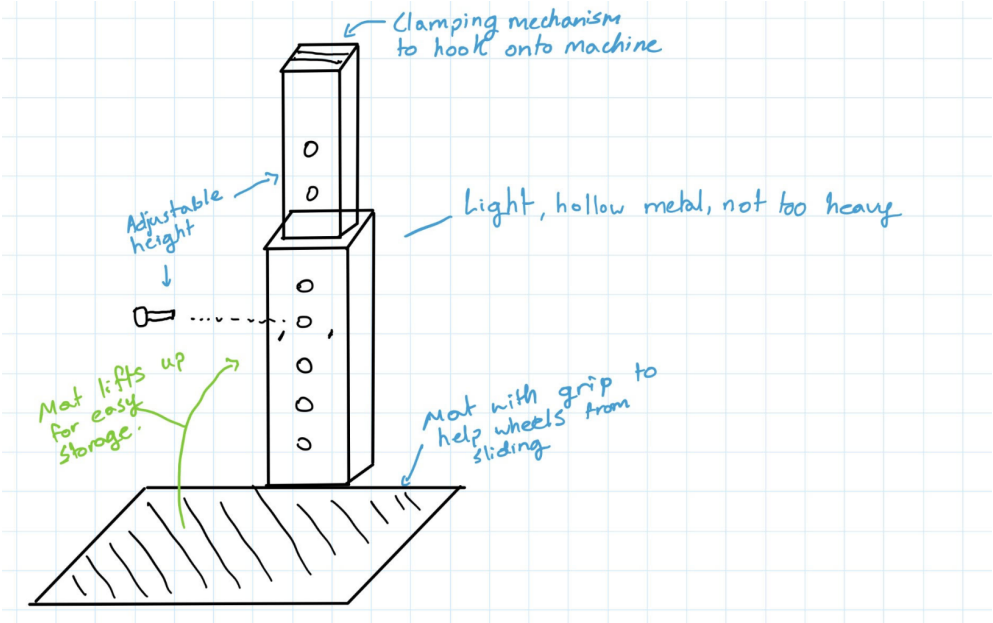

Figure 4: Prototype concept 2 with adjustable height

C.2.1.3 Concept 3

This concept uses a simple tubing system that allows the user to set which distance they want to be from the machine thanks to an extendable arm. This design also takes into consideration the different height of wheelchairs by having a raised hook for the handlebar which is also extended forward to take into account how far the user will be from the default hook placement. This concept also uses the default latch system for the rower which makes it easier to install.

The main disadvantage of this design is the size. Because of the extendable arm and raised handlebar hook, this design is cumbersome and difficult to transport. Also, because of the size, the weight of the product is most likely heavier than our target specification. There is also a production disadvantage where because of the many pieces, it could be expensive in material cost and difficult to make with the different angled pieces.

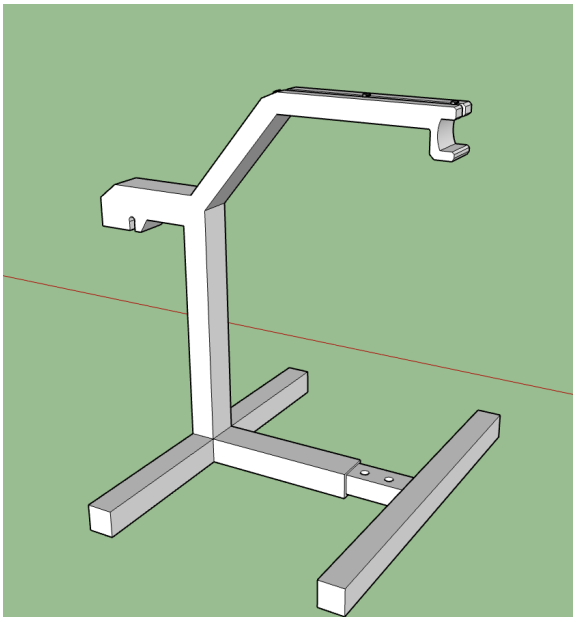

Figure 5: Prototype concept 3 with adjustable distance arm and raise handlebar holder

C.2.1.4 Concept 4

This concept combines the simple latching method the Concept 2 rowing machine currently uses, with a robust and simple tubing system. The device latches to the rowing machine at the top by the same method already in use. Tubing then heads at an angle to the floor in order to support the machine, while simultaneously allowing for a spot to attach the wheel stops. At the bottom of the angled tubing a perpendicular piece of tubing ensures that users will not roll forward while using the machine. This design allows for use by a wide variety of wheelchairs, because the bottom wheel stop will be wide enough to accommodate all.

There are three main disadvantages with this design: tipping, rolling backwards, and adjustability. Tipping may occur when the user pulls the cord away from the machine. Depending on the resistance that the machine is set to, and the weight of the person, coupled with the fact that the wheels would act like a fixed pin system, a situation could occur where a moment around the pin could be strong enough to tip themselves. The issue of rolling backwards would occur at any point other than while the user is pulling

themselves forward. This issue is caused by not having any method to secure the chair to the device. The final issue is the adjustability of the device. The height is not changeable which could be an issue for users wheelchairs of different sizes.

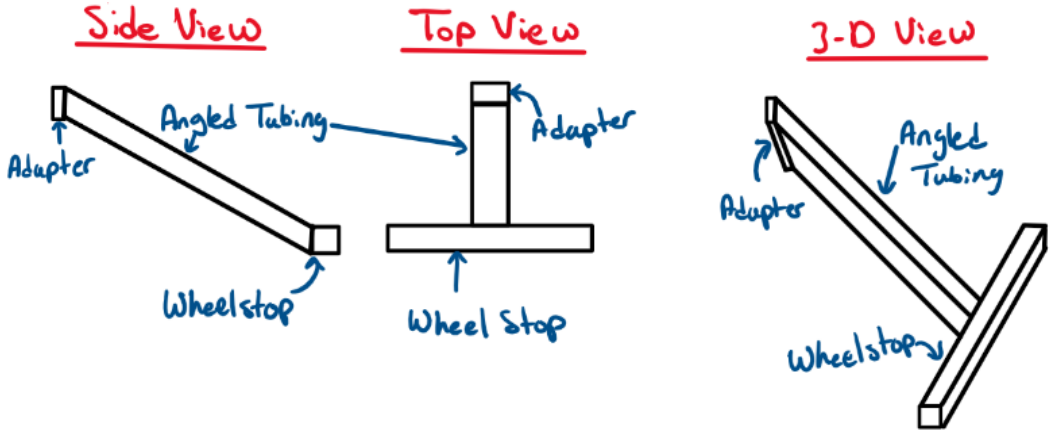

Figure 6: Side, Top, and 3-D Views of Concept 4

C.2.1.5 Concept 5

This concept uses the latch system already used on the current machine to attach this design to the rowing machine. The design features a sturdy base that forms a T-shape for stability. The steep, round bar at the front of the design allows the user to roll into place quickly and easily while discouraging the wheels from dislocating themselves unless intentionally done by the user at the end of their workout. Much like how non-wheelchair users use the machine, the user will slide back and forth with their arm movement to ensure an experience as similar as possible to traditional usage.

The largest disadvantage of this design is that rigorous usage of the machine may cause the wheelchair to dislodge itself from the designs. Theoretically, the fast movements should prevent the wheels from easily crossing the bump and slower movements will not have enough force to cross it either, though in practice this may not be the case. This may also be an issue for wheelchairs with larger wheels that can easily cross the bump.

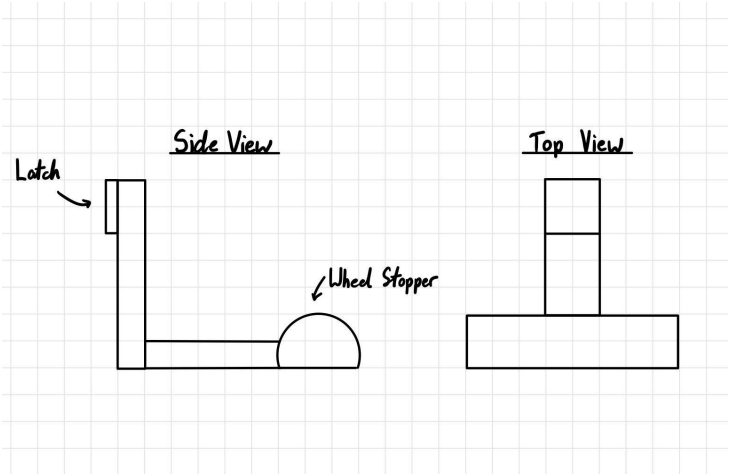

Figure 7: Prototype concept 5 with wheel stopper and latch system

C.2.2 Concept Analysis

C.2.2.1 First Concept:

This concept is effective at being removable, utilizing the same latching mechanism, aswell as being light and moveable. The shortcomings of this concept stem from lacking a few key needs, including not being adjustable and not being secure. All of these needs are interpreted as being more important than the aspect this device excels at.

C.2.2.2 Second Concept:

This concept sufficiently offers adjustability, ease of storage, and simplicity. One key area that this design falls short in is security. Due to there being no way to hold the wheelchair in place, it may roll forward and backwards during the exercise, therefore affecting the quality of the workout and the overall user enjoyability.

C.2.2.3 Third Concept:

This concept covers most of the interpreted needs well, including adjustability, using the same latching mechanism, and is ergonomic. A few issues may arise with this design when thinking about size, which affects movability; secureness, while pulling the user could tip the wheelchair frontwards; and the height is not adjustable.

C.2.2.4 Fourth Concept:

This concept suits the needs well due to using the same latching mechanism, being easy to use, and being portable. Multiple shortcomings can be found when inspecting the design of this concept though, including adjustability, a user may be too far away from the machine to be able to reach the handle; and security, a user may be able to tip over forwards.

C.2.2.5 Fifth concept:

This concept succeeds at being portable, easy to use, and being secure. The wheel stopper not only stops the wheel chair from rolling forward, but also prevents it from popping over the top which could potentially happen with other concepts. Issues occur for this concept when thinking about adjustability and secureness. Similar to other designs, a scenario could arise where a user creates enough of a moment around their locked and secured wheels to tip them over forwards, thus having a negative impact on the user experience.

C.2.3 Promising Solutions

Rather than choose one or two solutions to further develop, we think that all concepts have promising ideas and features that should be integrated into our final concept. A great solution to the latching subsystem is to use the already used latching mechanism as it will be easy to install and detach. It is possible to find the pieces that make up the latching mechanism online via CAD files or purchasable online on the Concept 2 rower website.

The best solution for the legs and frame of the product is to use aluminum tubing as it is light and will be easier to carry around compared to steel or cast iron components. A stopper which prevents the user from moving is also critical to ensure a safe and secure experience with the rower.

C.2.4 Global Concept Design

Following up on C2.3, we have developed a global concept which integrates ideas from each concept based on our provided metrics and target specifications. The design is a combination of the aspects we found the most valuable within each design.

From concept 1, we decided to go with its robustness and simplicity. This wastes less material and weight. The material we chose for our global concept is aluminum, which was inspired fron concept 1. From concept, the adjustable height which helps adapt to different sized wheelchairs was taken to make it more inclusive to different wheelchairs. From concept 3, having a holder for the handlebar closer to the user is advantageous as they do not have to reach down, especially if they cannot. Concept 4 also uses the same latching mechanism as the rower so it makes the

device modular and easy to store. We think the concept 5's more robust wheel stopper would work better to stop any movement coming from the wheelchair

Additionally, we added a knee-stopper. If it deems good enough as is, we can opt to remove the wheel stopper to lower the cost of the product as well as increase its portability. The knee stopper can be extendable to make the user closer or further away from the product.

C.2.5 Visual Representation

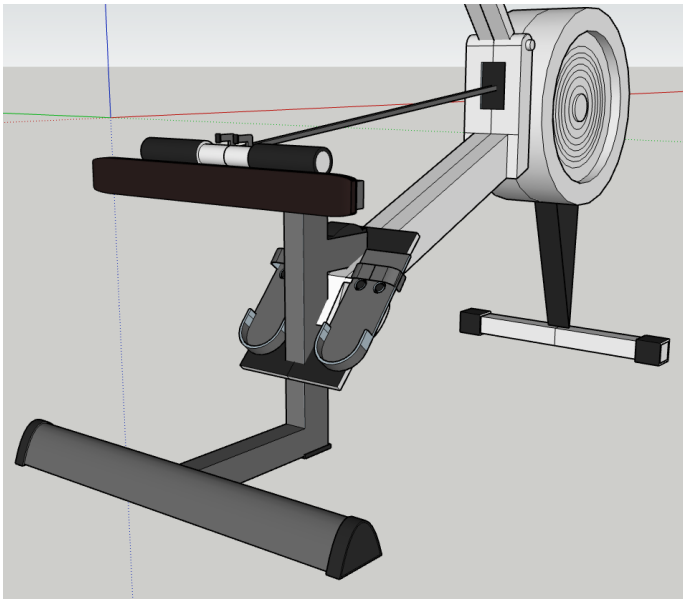

Figure 8: Global concept simulated being attached to Concept 2 rowing machine

C.2.6 Benefits and Drawbacks

The global concept takes the best parts of the previous designs to create the optimal combinations of parts and limit the amount of drawbacks. The design is a simple formation with an adjustable height to accommodate several different kinds of wheelchairs. The concept also features a robust shape to lock the wheels to keep itself and the user steady. In terms of convenience, the design includes a claw to help the user get into a starting position and an adapter to allow the device to be easily attached and unattached from the larger rowing machine structure.

The most notable drawbacks include the fact that the user is not attached to the structure which risks tipping or dislodging from it, and the fact that aluminum is used could result in significant damage from repeated contact with wheelchairs. By not attaching the users directly to the machine, it allows a wider variety of wheelchairs to be able to use it but also risks the

wheelchairs being unstable, which may result in harm to the user. Aluminum is a light-weight metal that makes the design easy to lift, move around, and attach and remove by the user alone, but may also be weak and easily damaged by intense workouts. Another drawback to aluminum is that it is more difficult to weld and shape than harder metals because of its sensitivity and softness.

C.3 Conclusion

In this deliverable, we interpreted user needs into design criteria, created target specifications and analyzed them for ideal/acceptable conditions. We developed a problem statement, different concept designs, and finalized a preliminary design to present for client meeting 2. Through the work completed here we have gained a better understanding of the overall problem and have organized the process of solving it. In the next week we will be meeting with our client again to evaluate our design, where we will then begin working on our first prototype. As a group we are excited to continue designing and prototyping our product, with the hopes of providing a solution that fits our client's goals.