Project Deliverable I: Video and User Manual

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1.0 Introduction

After a lot of hard work was completed throughout the semester, our group can now present our final prototype in this detailed user manual. This project was done for a second-year product development course, and it taught us the importance and relevance of the engineering design process. Overall, our group has tried to not make any assumptions on the problem statement or the client themself. During the client meetings, we used empathy to understand their needs and to get a full picture of their requirements for this design problem.

Our document is organized in such a way that is easy for the user to read. It is sectioned off into different sub-sections, each of which will dive into the prototype and design process in varying ways. We have also included a separate video that shows our product in action and explains its main characteristics. The purpose of this document is therefore to summarize the work that we have completed this semester. This report will be passed on to our intended audience, which consists of the client and any future students taking this course, so it gives a detailed description of the steps that we took to reach the final solution. We will go through a general overview of the product, before explaining how to get started with it. Then, we will discuss how to fully use the device, and describe how to troubleshoot any possible issues. Finally, we will document our prototypes that we created throughout the term and then we will conclude with our recommendations for future work. Overall, there are no security or privacy considerations that are attributed to the use of this product manual.

2.0 Overview

At the start of the semester, we came up with the following problem statement for this design process: “There is a growing desire for wheelchair users to be able to enjoy a common leisure activity such as riding a bike. There is a need for an attachment-based device that connects a typical bicycle to a wheelchair, without making any permanent modifications to either”. Our task is therefore to design the adequate device that is able to connect a bike to a wheelchair. This problem is important because it is not easy to incorporate a bicycle into a wheelchair. There are many solutions on the market which are able to do this, but they are either expensive, hard to manufacture, and require permanent modifications. We were therefore compelled to find a solution that would solve this tricky problem for the client.

The user is not required to do much in order to put the product into action. Simply, the wheelchair user will start by sitting down in the chair. Then, the bike rider will attach the device to either side of the wheelchair using the carabiners. At this point, the front end of the attachment can be laid onto the ground until the bike rider is ready to attach it to the bicycle. Once ready, the user can then lift up the device and clamp the remaining end onto the metal bar just under the chair of the bike. The rider can then get onto the bike and start riding, which will in turn pull the wheelchair and its user along. Overall, the fundamental needs of the user revolve around the basic install method of the device, which has a relatively short attachment time.

Our wheelchair-bike prototype has a few key aspects that make it better than solutions on the market. It is very lightweight, and can be easily carried around if necessary. Since it is made of steel and has been welded together, it is very strong and durable. This makes for a safe ride for the wheelchair and bike users. Furthermore, it can easily be folded and transported around if this is necessary. This is also due to its relatively small footprint, meaning it can be stored in a small or tight area. Finally, our product is also more beneficial since it is much cheaper than other designs in the industry. The materials required to manufacture this product were under our allocated budget for this project, which is 150 dollars.

Below, you can find a picture of our final prototype (without the carabiners).

Figure 2.0.1: Picture of our final prototype

There are many important features related to our product. First off, the primary material that we used to make it was steel. Steel is known to have a very good durability and resistance to corrosion, among other beneficial properties. Many of the connections on the final prototype have been welded together, making the device more sturdy and secure. We have also included easily removable attachments in the form of carabiners, meaning they can easily be screwed on and unscrewed off depending on whether the product is in use or not. This also means that these components can be quickly replaced if there is some kind of damage done to them. We have included extra triangular supports as well, in order to combat any potential bending in our device when the bike decides to turn or to brake. So, the major functionality of the attachment-device is to connect the bike to the wheelchair and keep both in a secured position.

In non-technical terms, the construction of our system is based on the basic metal frame that can be observed above. It consists of two shorter horizontal bars that will connect to the wheelchair, and one longer horizontal one that will connect to the bike. The longer one is elevated on a higher level through the use of a vertical bar, which is connected to the base of the attachment. We have also included a triangular shaped design in two areas to provide further support to the device. The user access

mode is simply to unfold the frame and clamp it to both the bike and the wheelchair. Finally, the device should be capable of being employed in various outdoor environments, but extra caution should be taken when biking in rain or snow, as conditions become slippery and it is easier to lose one's control of the bike.

Here is also a detailed assembly decomposition that was produced for an earlier deliverable in the semester. It contains the process of attaching and detaching the wheelchair to the bicycle.

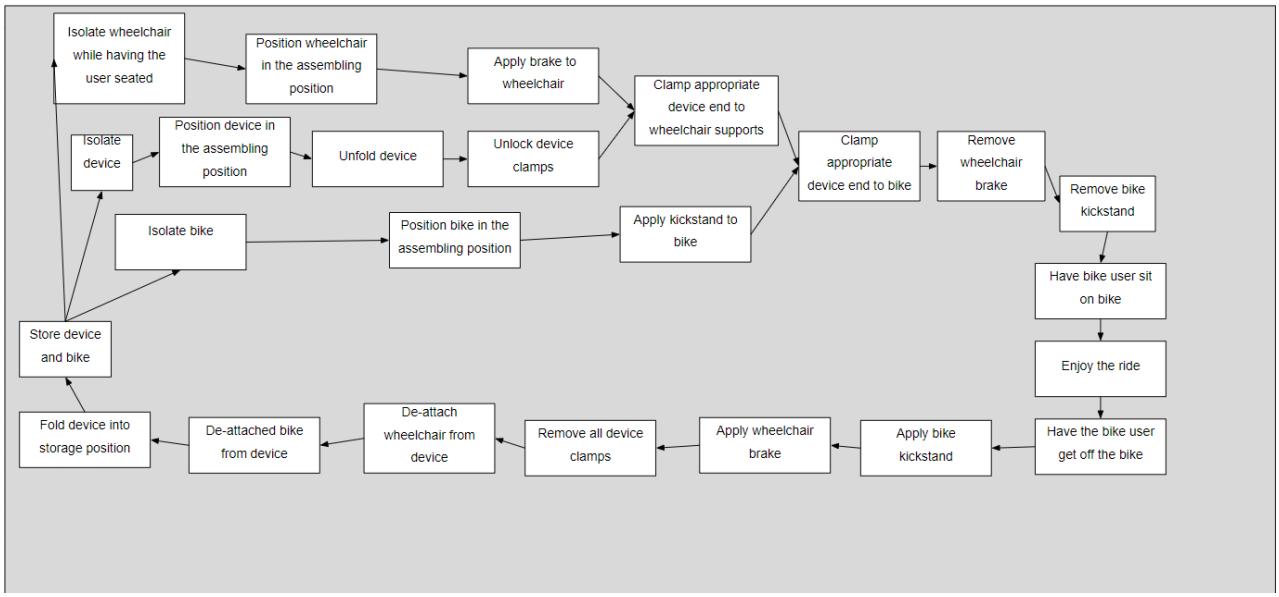

Figure 2.0.2: Detailed assembly decomposition

2.1 Conventions

There are no stylistic and command syntax conventions that are used throughout the document. If this is necessary, then it will be clearly explained at the corresponding section of the user manual.

2.2 Cautions & Warnings

There are no particular cautions or warnings that the user should know about before using our product. Most importantly, the best practice is to always stay safe while riding the bicycle and to avoid doing sharp turns or braking suddenly.

3.0 Getting Started

Initially, the bike will be mounted on its stand and the wheelchair should be placed about one meter behind the bike. As the wheelchair user would already be seated, the device should firstly be clamped on to both sides of the wheelchair through the use of the two carabiners. Then, the front end of the attachment should be lifted up to approximately the same level as the bike seat. Then, using the third carabiner, the attachment should be connected to the vertical bar just under the seat of the bike. The carabiners are hand-tightened, meaning that they can easily be screwed and unscrewed as necessary. In order to de-attach the product, the bike should firstly come to a full stop and then be placed on its stand. The bike user should start by removing the carabiner attached to the bike, and slowly lowering the front of the device to the ground. Then, the carabiners on either side of the wheelchair can be unscrewed and removed. The attachment has a small footprint, and can easily be stored in a limited amount of space. It is important to keep the attachment in a horizontal position when not in use, as this is the natural position that it must be in to avoid any damage. Overall, the sequence and flow of our system is simple to understand and is very logical, meaning that no special steps are needed in order to get the prototype to function.

3.1 Configuration Considerations

Our system is configured to be placed in a horizontal manner and to always remain in that configuration. This will allow for the device to be easily clamped on to both the bike and the wheelchair, and it also permits for the easy storage of the device. The main input and output devices are the carabiners, since these will need to be screwed on and off when the device is in use. No other component in the attachment needs to be modified in any way, as all the pieces are already welded together. Furthermore, no basic tools would generally be required to put the product in action. A screwdriver may be necessary if the client feels to need to tighten some of the nuts and bolts that keep the attachment together.

Below is a labeled image that includes the various components and types of equipment that were used to manufacture our final prototype.

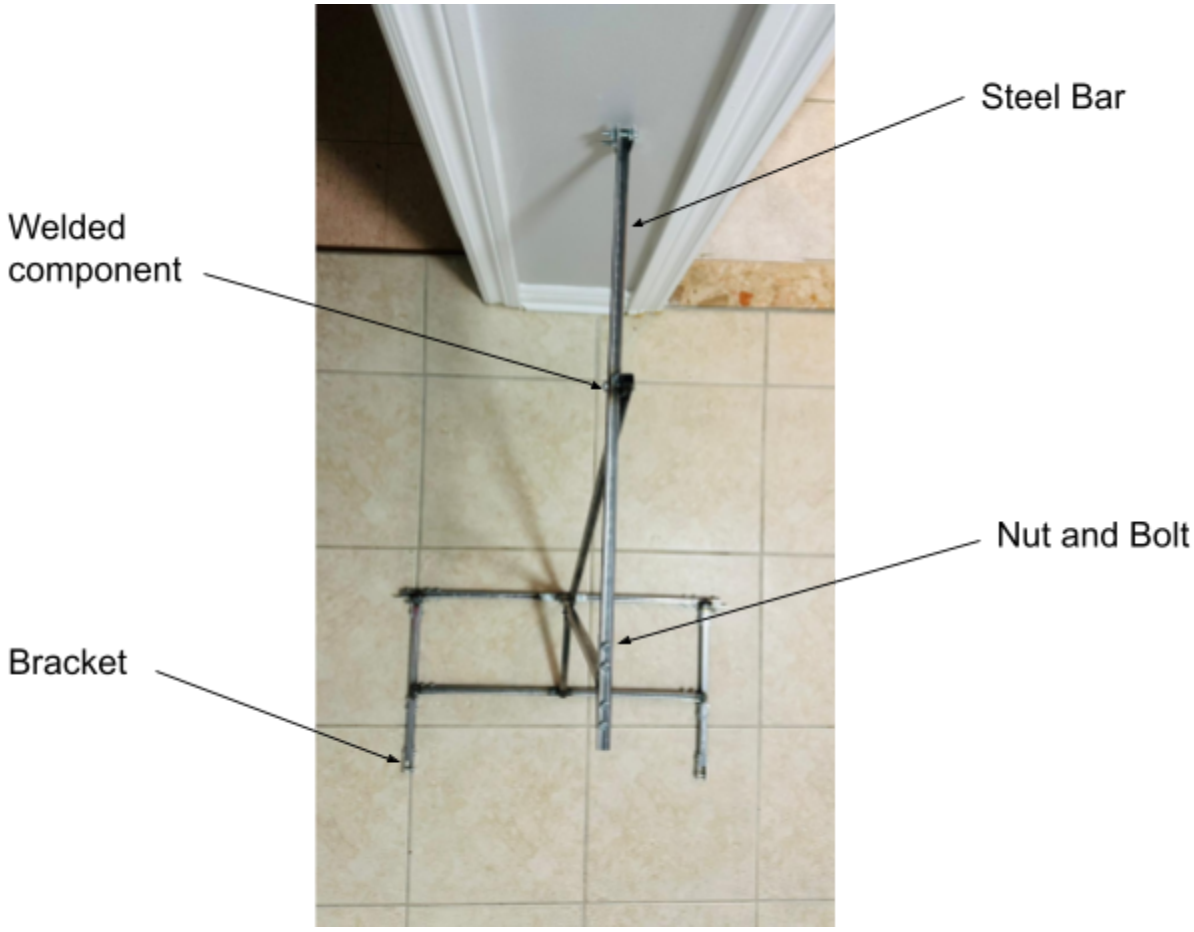

Figure 3.1.1: Visual depiction of the various components of the final product

3.2 User Access Considerations

Our product will be employed mainly by wheelchair users. Our whole goal of the project was to create a device that would allow them to enjoy the activity of riding a bike. Furthermore, it will also be aimed at someone who can also ride a bike, and is capable of connecting the attachment to both the bike and the wheelchair. The main constraint that we can present is that our device may not be used on all types of terrain. Although it can handle some hilly landscape, it should not be used for more aggressive activities, such as mountain or dirt biking. Furthermore, if any of the nuts or bolts do come slightly loose, it is important to immediately tighten them with the screwdriver prior to using the attachment again. Overall, our device is very accessible to wheelchair users and should be able to function for many bike rides.

3.3 Accessing/setting-up the System

Since our product does not contain any technological or software aspects, there is no specific need for anything to be activated. This means that no buttons need to be pressed and no switches need to be turned on or off. Also, this signifies that no user ID or password are necessary to put our product into use. As described previously, the way to set-up the system is to attach the carabiners to either side of the wheelchair and to the seat of the bicycle.

3.4 System Organization & Navigation

Our group made a conscious effort to organize the components of our product in a simple yet effective manner. The main parts of our prototype will be portrayed in zoomed-in screenshots below.

Firstly, here is an image of a carabiner when it is attached to the wheelchair.

Figure 3.4.1: Picture of the carabiner when attached to the wheelchair

As can be seen in the above picture, the carabiner is tightly secured to the hooks on the wheelchair. We can also see how the carabiner is connected to a bolt that goes through two brackets, which are secured to both sides of the metal bar.

Next, we can observe the L-brackets which serve to connect the metal bars to each other. These brackets are held together by nuts and bolts, which are two other crucial components that serve to link everything in our product.

Figure 3.4.2: Picture of the nuts, bolts and L-brackets

Finally, here is a side view of how our product can also be stored when not in use. The attachment, while still connected to the hooks of the wheelchair, can simply be folded over the seat as is shown below. Its unique mechanical structure therefore allows for the presence of some important flexibility for when the device is not being employed.

Figure 3.4.3: Side view of the attachment connected to the wheelchair

3.5 Exiting the System

To exit the system, the carabiners need to be unscrewed and the device needs to be removed from the bike and the wheelchair. The device should be stored horizontally, and it can be stored in a relatively small space due to its footprint.

4.0 Using the System

Our device was designed to do a certain feature which is pulling a wheelchair with a bike. This was done by attaching the wheelchair to our device and attaching our device to a bike. We have three functions with our device. The wheelchair attachment point, bike attachment point and the last function is pulling a wheelchair with a bike.

4.1 Wheelchair Attachment Point

On our device, there are two places where you can attach the wheelchair to this part of the device. These points allow the user to attach a carabiner to this device. The other side of the carabiner can be attached to the tie down hook on the wheelchair.

Figure 4.1.1: Side view of the wheelchair attachment points

4.2 Bike Attachment Point

On our device, there is one place where you can attach the bike to the device. This point allows the user to attach a carabiner to this part of the device. The other side of the carabiner can be attached to the seat post of the bike.

Figure 4.2.1: Side view of the bike attachment point

4.3 Pulling Wheelchair with Bike

The function of pulling a wheelchair with a bike combines features 4.1 and 4.2 together. This action requires both wheelchair attachment points to be attached to the device and to the wheelchair. Also, it requires the bike attachment point to be attached to the bike.

Figure 4.3.1: Front view demonstration of the pulling the wheelchair function

5.0 Troubleshooting & Support

In this section, the user can find our team's protocol for any troubleshooting and issues that someone may face while using our product. There are clear steps the user can follow that our team has devised. These errors have been considered carefully after thorough testing with our product. Therefore, the user can find any solutions for their issues in this section. If you cannot, our team has set up a support system that will allow for direct support with the user and team. It is important to carefully read this section even if you have not run into any issues. The more precaution you take with the product the more use the user can get with it.

5.1 Error Messages or Behaviors

Our product is split into two main components, the main frame and clamps. The clamps are three heavy-duty carabiners that are able to connect the attachment to the wheelchair and bicycle. In order to attach these heavy-duty carabiners to our attachment we used steel brackets to create a hook-on system. The carabiners themselves are very sturdy — considering they are used for activities such as rock climbing. However, as you make extensive turns with the bicycle the steel brackets can start getting weaker as depicted in the illustration below.

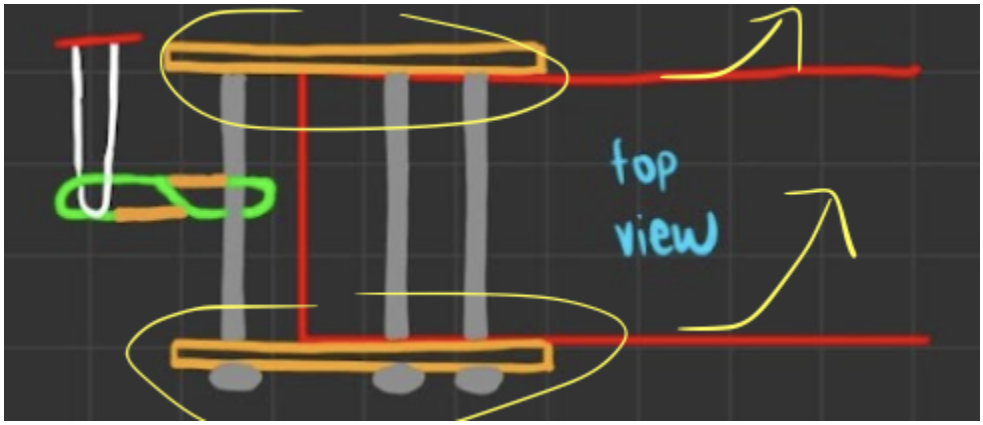

Figure 5.1.1: Top view of the heavy-duty carabiner (in green) attached to the steel brackets (orange)

This bending action will eventually wear out the steel brackets. Luckily, these steel brackets are not welded onto our main frame and instead connected using screws. This means you can easily replace them as you feel fit. Simply unscrew the 10-32 screws and bolts. Then, you can replace the steel brackets by using our extra provided ones or purchasing *2 Inch Steel Mending Plates* to your liking. Furthermore, our main frame is also a very sturdy part of our attachment. With two triangular shapes and a frame built using square steel tubes melded together, our main frame has great support. The more extensively our attachment is used, the more our main frame will slowly deteriorate. There will be cases in which it will wear out after extensive and long use. Our razor blade business model provides replacement of these main frames. This can be done by contacting our support as addressed in 5.4.

5.2 Special Considerations

Our attachments come fully built with all components and extra materials, which include screws, bolts and steel brackets. If any of these extra materials are missing while replacing the clamp component, one can simply contact support for a replacement. Furthermore, if someone wants to quickly replace the clamp component with their own materials, such as zinc brackets, they can view our materials list that comes with the product to see which bracket sizes will work. This materials list will display the screw size, bolt size, materials used, frame sizes, weight, and much more. Finally, this list will also come with recommendations that the user can feel free to consider.

5.3 Maintenance

To ensure that the attachment does not wear down there are a few maintenance suggestions that the user should consider. The attachment comes with a 90 degree design that allows the attachment to rotate as seen in the figure below:

Figure 5.3.1: The 90 degree rotation of the attachment

Storing the attachment as such will be convenient and avoid any extra movement that could cause potential wear and tear. Furthermore, if the user would like to detach the attachment they can simply untighten the heavy-duty carabiners. To store the product it is best to avoid placing it on either side as this can cause unwanted stress. Finally, before using the attachment it is very important to have regular checks to see if the main frame or steel brackets are deteriorating. If they are indeed wearing down the user can contact support.

5.4 Support

In order to get in contact with our team for support, the user can contact our help desk support. This can be done by contacting Gurjot Grewal. When contacting Gurjot it is important to have a clear email so the team can assign your ticket to the appropriate person. Make sure to include a name, phone number, receipt of purchase (not mandatory), product number (available inside the user manual). When picking a subject for the email make sure to be as thorough but short as possible. If your product came without any extra materials simply title the subject, “Replacement for missing steel

brackets”. In the email it is helpful to include images and/or videos that can further help identify the issue. Gurjot will contact you in 48 hours, addressing that your ticket has been processed and assign you another team member that can help you with the process. Yendra Yogarajan and Brian Bulitka are responsible for replacement of the main frame. Kevin Zhang is responsible for any issues dealing with steel brackets and carabiners. Finally, Matej Mincev is responsible for purchase issues. The contact details for all of the team is below:

Table 5.4.1: Contact Details for Team Members

Name	Email
Gurjot Grewal	gurjot_grewal@outlook.com
Matej Mincev	matej.mincev9@gmail.com
Brian Bulitka	bbuli.bulitka@gmail.com
Kevin Zhang	zhjjhzh@gmail.com

6.0 Product Documentation

6.1 Clamping Subsystem 1 of Prototype 1-2

Overall, the team made an effort to produce the simplest prototype that would allow us to meet the objectives of this project deliverable. We also looked to be creative with the materials that were available to us, so as to ensure we remain under the required budget for this project. The PVC pipe is a substitute for the square steel tubing that we expect to use for the final product. We were able to get it for free from the Brunsfield Center. The steel brackets and screws were found in the garage of one of our group mates. The only purchased material for this prototype was the carabiner, which only cost approximately 5 dollars. We purposefully bought a cheaper one, since we want to test the general concept without spending too much of the budget.

Figure 6.1.1: Prototype 1 clamping mechanism

Figure 6.1.2: Prototype 1 clamping mechanism in action

The attachment was able to pull our group member of around 90 kilograms, without any sort of mechanical failure. It is important to note that this was achieved while only being attached to one of the wheelchair hooks instead of both. Furthermore, the carabiner we had used was only rated for around 11 kilograms but was able to pull the combined weight of our group member and the wheelchair with no signs of failure. When taking a closer inspection of the PVC pipe and the steel brackets, none of the areas were subject to high stress. This means that the prototype was sturdy enough to withstand the load applied to it and resist permanent plastic deformation. This is great news for the team, as it means the steel tubing, steel brackets and heavy-duty carabiners that we plan to employ for the final prototype should be more than strong enough.

Taking the results of our initial prototype into consideration, our final prototype was created. Since we knew that our clamping mechanism was strong enough with PVC, we designed the final attachment with steel tubing, galvanized zinc brackets, and steel nuts and bolts.

The material choice of steel for the main frame was due to a few reasons. Steel in itself is a strong metal that would be able to withstand any typical damages that it will absorb from common cycling. The other reason why the group decided to choose steel was because we wanted to leave the option of welding the frame together open. We used galvanized zinc brackets because they are readily available in multiple shapes and sizes at home depot, while also fitting our allocated budget. We chose 10-32 nuts and bolts because they fit the standard holes that were pre drilled into the zinc brackets.

To create the final prototype, we marked the length of each piece, and then marked where the holes would go for each 90 degree or flat bracket. After everything was center-punched, we drilled all the holes on the drill press, then proceeded to cut the steel pieces on the bandsaw. After everything was cut to size, we attached all the necessary components and did a quick rough fit. This is where we noticed that the brackets alone are not strong enough, and the entire frame would begin to bend when pulled forward. To reduce the bending, the team had added two triangle supports, cut on 45 degree angled ends, with nuts and bolts put through them. This was still not enough, as the cuts were not perfect, and there was still noticeable slack. As the final fix, we

welded all the places where a steel piece comes into contact with another steel piece. Mig welding considerably increased the strength of the whole attachment and gave the team confidence that it would be able to safely pull a wheelchair and its user. It is important to note that you must use the correct settings when welding, because too hot of a setting will burn holes through the steel. Furthermore, do not weld the zinc brackets as those will be melted through as well.

Figure 6.1.3: Final prototype in action

6.1.1 BOM (Bill of Materials)

Table 6.1.1: Bill of Materials

Component #	Name	Quantity	Cost ($ CAD)	Link
1	Paulin 1/2 x 36 x 0.065-inch Steel Square Tube	5	12.28*5 = 61.4	https://www.homedepot.ca/product/paulin-1-2-x-36-x-0-065-inch-steel-square-tube/1000861166
2	Everbilt 2 Inch Zinc Mending Plate (4-Pack)	2	2.54*2 = 5.08	https://www.homedepot.ca/product/everbilt-2-inch-zinc-mending-plate-4-pack-/1000773678
3	Everbilt 1-1/2" Corner Brace, Zinc-Plated, 4pc	3	3*1.98=5.94	https://www.homedepot.ca/product/everbilt-1-1-2-corner-brace-zinc-plated-4pc/1000773638

4	10-32 Bolts 1”	2	2*3.47=6.94	
5	10-32 Bolts 1.5”	1	1*3.47=3.47	
6	Nite Ize S-Biner	1	1*3.99=3.99	https://www.canadiantire.ca/en/pdp/nite-ize-s-biner-2-dual-stainless-steel-wiregate-s-carabiner-clip-holds-up-to-10-lbs-0766246p.html?gclid=Cj0KCQiAm5ycBhCXARIsAPldzoXSuTfJlZEWlEtzr37aTMa_2C8_izpftjz0JbR2NefpmlqFFxcJZq0aAmEnEALw_wcB&gclsrc=aw.ds#store=174
7	Everbilt 5/16-inch Zinc-Plated Quick Link Connector with 1550 lb. Safe Working Load	2	2*4.81= 9.62	https://www.homedepot.ca/product/paulin--10-32-inch-wing-nuts-18-8-stainless-steel-unf-3pcs/1000181540
8	Paulin #10-32 Hex Machine Screw Nut - Zinc Plated - 13pcs	3	3.47*3 = 10.41	https://www.homedepot.ca/product/paulin--10-32-hex-machine-screw-nut-zinc-plated-13pcs/1000146172
		Subtotal	106.85	
		Total	120.74	

6.1.2 Equipment list

1. Drill Press
2. Bandsaw
3. Mig Welders
4. Flat Head Screwdriver
5. 10-32 wrench

6.1.3 Instructions

1. Cut 2 pieces of steel that are as long as the distance between the tie down straps of the wheelchair.
2. Cut 2 pieces of steel approximately 20” in length, and another around 10”.

3. Cut 1 piece of steel that is as long as the distance from the tie down straps to the height just underneath the bicycle seat.
4. Mark the holes for the 90 degree brackets that follow the overall layout in the picture shown in the figures above.
5. Mark the holes on the end pieces for the flat bracket.
6. Cut two pieces of metal for triangle supports, the length of this will depend on the bicycle as you want to make sure the triangle support does not touch the rear tire of the bike.
7. The ends of the triangle support off with a 45 degree angle.
8. Use the drill press to drill all the holes for the brackets. Ensure you use the correct bit size and lubricant to avoid overheating.
9. Assemble all the components together with the 10-32 nuts and bolts.
10. Weld all the steel to steel connections and the triangle supports.

6.2 Testing & Validation

Our initial prototype which was built with PVC, was tested to see if the attachment mechanism is able to pull a 90kg person. We tested this by physically attaching the mechanism to the wheelchair on one side only, and had a 90kg person sit in the wheelchair. By only pulling from one side, the attachment is pulling double the weight it would need to in real life. Our test had yielded positive results, and we were able to pull a 90kg human while only being attached on one of the tie down straps, instead of both.

When we initially made the final prototype, we did not have the triangle supports or welds. We conducted a few tests by simply pulling both ends of the frame apart with our hands, and the entire frame began to bend. After these negative results, we decided to enforce the frame with triangle supports and welds. Doing this, significantly increased the strength and did not produce any slight bends when pulled apart with our hands. We then began physical testing of the prototype of the attachment by using a real wheelchair. We tested pulling a 90kg human up and down slight changes in elevation, going around smooth and sharp corners, and pulling a human at faster speeds. Through all of these tests, the prototype did not bend at all. The only concerning result was that

some of the bolts where the device was attached to the wheelchair began to become loose. We fixed this by replacing the shorter bolts with long ones, and tightening the nuts significantly more.

7.0 Conclusions and Recommendations for Future Work

During the semester, the biggest lesson we learned is that we should put our hands on physical products as soon as possible, since potential issues would arise only when physical prototypes are completed. We also suggest other students who would like to work on projects like this one to start their MTC training as soon as possible, since more MTC skills are always beneficial. One interesting story in our design process is we did not have the skill of welding, so we needed to find a friend with experience to help us weld the device together. Other than what is mentioned above, the overall project was very successful. The best way to make sure you are on the productive path is to strictly follow the deliverable and lab instructions.

If time is not a constraint, we could definitely make improvements to our project. Specifically, we would design a soft cover on the carabiners to prevent them from making noises when it is colliding with the tie-down hooks on the wheelchair. This soft cover would also prevent the carabiners from scratching the tie-down hooks, as our clients do not want their wheelchairs to be scratched. Additionally, we would paint the device red as our clients had desired and we would design different hooks to fit a wider variety of wheelchairs and bikes. Finally, if we had a higher budget, we could design the device to have the ability to elevate itself in order to work in a wider range of terrains.

8.0 APPENDIX I: Design Files

Document Name	Document Location and/or URL	Issuance Date
MakerRepo	https://makerepo.com/yyoga038/1304.a24-bike-riders	November 16, 2022
User manual video on YouTube	https://www.youtube.com/watch?v=IaGp9NcKolQ	November 30, 2022