Project Deliverable D: Detailed Design, Prototype 1, BOM, Peer Feedback and Team Dynamics

Professor: Rubina Lakhani

Submitted by: Section A02, Group 04
Yendra Yogarajan - 300239233
Gurjot Grewal - 300263760
Brian Bulitka - 300248903
Matej Mincev - 300056451
Kevin Zhang - 300104907

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1.0 Introduction

The team is now at the stage where we have gathered the necessary information and feedback to get started on an initial prototype. Taking into account the feedback received from our second client meeting, the team will make the required changes to the group design. Based on the analysis of our various design criteria, a list of critical product assumptions with accepted values will also be made.

We will then begin to create our initial CAD design using SolidWorks. Since this will be the first prototype, it would make the most sense for the team to design a low fidelity, analytical model. Creating a CAD model is beneficial as it helps the team design a realistic prototype while giving us access to industry standard stress related tests, as well as providing a rough estimate for a Bill of Materials (BOM). It also helps in the economic viewpoint as it would not cost the team anything to create an initial concept.

2.0 Feedback for Client Meet 2

During our second client meeting, we presented different designs (developed in Project Deliverable C) to the users and elaborated on the advantages and disadvantages of each concept. The meeting was very useful and beneficial, as we were able to gather more valuable information on the client's needs. Below, we have summarized the feedback that we have received:

- The client is not sure in which area they will be biking in, and they do not have a preferred biking area for now
- The client is unsure what type of bike they will be using to attach to the device, as they have not purchased one yet
- They would like the design to be as safe and sturdy as possible
- When we presented the "side-by-side" design, the client made a comment that they were not sure if the bike and wheelchair would fit on the sidewalk when they are positioned side by side

- In terms of additional accessories, the client would like a phone holder, in case a phone is needed to take pictures or videos and use a map to get around
- They said that their wheelchairs have seat belts on them
- The client discussed how they are fine with sitting behind the bike, as they would still be able to see the views around them and give directions from the back
- They said that they would like a device that is foldable and can be stored in an outdoor shed, which the client thinks is probably big enough
- The client is unsure about the model of their wheelchair, and we are not sure what the dimensions are. We can potentially take measurements at the next client meeting
- The client also appreciated how we proposed a wide variety of options to them. They also said that they thought that the main design from our Project Deliverable C was the safest, sturdiest and most efficient.

Based on this feedback, we need to make one main improvement to our main concept that was generated in Project Deliverable C. We will need to add a phone holder to the attachment, which the client said they would like to have as an accessory. The client appreciated the other aspects of our main design, and they reiterated how they thought it was the safest and sturdiest, so this is what they would like to move forward with. At our next meeting, we plan to present our first prototype and its features and to obtain additional constructive criticism from our clients.

3.0 Updated Design

Based on our client meeting and the above feedback that we have received, we will produce an updated design with descriptions of each subsystem. Below, we have visually represented the various aspects of our concept, and have also defined how our subsystems are connected between each other.

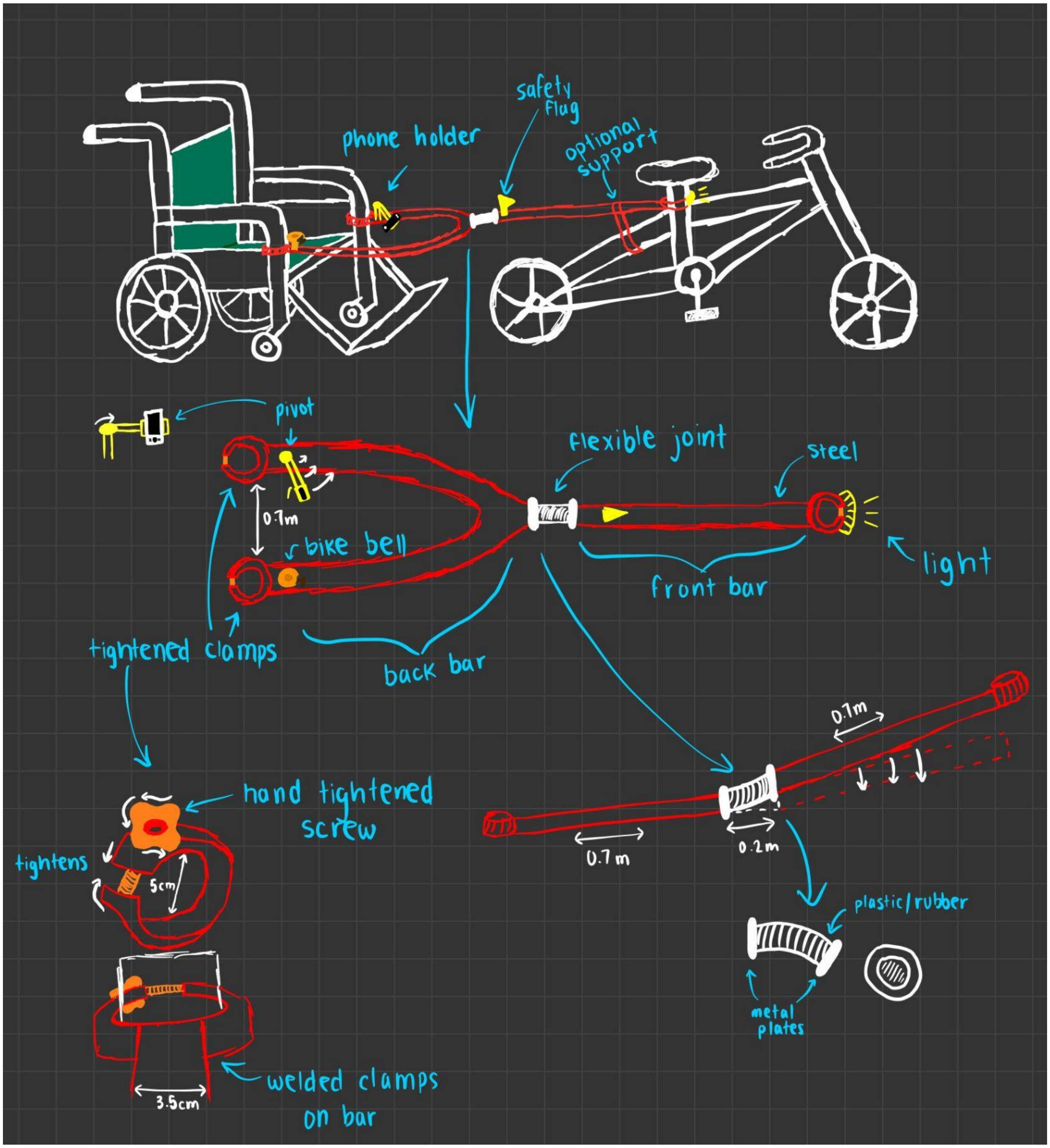

Figure 3.1: Attachment Prototype and its Components

In this design there are four components included: the main frame, flexible joint, clamps and safety accessories. The main frame and flexible joint work very closely with each other. There are two parts to the main frame, the front and back. It is also important to notice that the back part of the main frame splits into two; this is designed in order to clamp onto the arms of the wheelchair. These two parts are connected using the flexible joint's ends. The flexible joint is a rubber/plastic component with metal ends which gives it the ability to move around while still keeping the attachment sturdy. Consequently, this allows the front end of the main frame to move around as well. Therefore, during sharp turns the bike-wheelchair system is not restricted and allows for a smoother process. There are a total of three clamps that are attached to the ends of the main frame. These clamps are designed to reduce the need for any screws and can be done using your hands. As you tighten the hand screw, the clamps themselves tighten and can be secured onto the wheelchair and bike. Finally, the safety accessories are designed such that the bike bell and phone holder are in close contact with the user in the wheelchair. The phone holder is moveable using a pivot such that the user can pull it towards themselves or set it aside. Additionally, a light is attached to the front end of the main frame to increase visibility during night-time riding.

4.0 Bill of Materials

Next, we will generate a detailed bill of materials based on the budget that we have been provided for this project (which is $150, indicated in the project description). These materials will be utilized for the creation of our final prototype, which will be presented at Design Day at the end of the semester. The below table summarizes our BOM, and we have also explained the uses and reasonings behind each one of the products that are listed below. Overall, we have made an effort to maximize the funds that are available to us for this project.

Product	Cost (CAD)	Use	Reasoning
Steel Bar	$51.81	To act as the main frame of the device	Steel is a strong material that could handle the task
Screws and Bolts	$5	To secure the main frame and the clamps	Screws and bolts could secure the frame and clamps well

Clamps	$10.69	To secure the device onto the wheelchair and the bike	Existing clamps are good for the task and it saves a lot of time during assembly
Reflectors and Bell	$14	To increase safety	Client wants some accessories for safety purposes
Flag	$9.99	To increase safety	Client wants some accessories for safety purposes
Spray Paint	$10.99	To paint the device a certain color	Client wants the device to be red
Light	$8.99	To light the road ahead at night	Client wants to bike at night
Phone Holder	$14.99	To hold the user's phone	Client wants to have their phones while in the wheelchair
Tax	$16.44		
Total Cost	$142.90		

Table 4.1: Bill of Materials

Below are the web links for each item that is shown in our Bill of Materials:

Steel Bar:
https://www.amazon.com/Stainless-Corrosion-Resistant-Durable-Diameter/dp/B09C1J5YG2/ref=sr_1_16?crid=2IECJRKBNLWGO&keywords=round%2Bsteel%2Brod%2B10mm&qid=1664981224&sprefix=round%2Bsteel%2Brod%2B10mm%2Caps%2C86&sr=8-16&th=1

Screws and Bolts:
https://www.homedepot.ca/product/paulin--8-x-1-2-in-pan-head-square-drive-self-tapping-sheet-metal-screws-zinc-plated-100pcs/1000139726

Clamps:
https://www.amazon.com/GOVALVE-Sanitary-Stainless-Steel-Tri-Clamp/dp/B09D37RPSG/ref=sr_1_34_sspa?crid=3PP25XTS0L35Q&keywords=clamps%2Bheavy%2Bduty&

qid=1664979124&qu=eyJxc2MiOiI2LjY0IiwicXNhIjoiNS44MCIsInFzcCI6IjUuNDQifQ%3D%3D&sprefix=clamps%2Caps%2C118&sr=8-34-spons&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUEzMTBQSjcyWTJETDBWJmVuY3J5cHRlZElkPUEwOTAyMzE4MjNIOTlSUzhIWk84VSZlbmNyeXB0ZWRBZElkPUEwNTM0ODM1M1VOMkZOSUdZR0U0SyZ3aWRnZXROYW1lPXNwX210ZiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU&th=1

Reflectors and Bell:
https://www.amazon.com/SANNIX-Front-Reflector-Bicycle-Accessories/dp/B08B1LTXKZ/ref=sr_1_1_sspa?crid=2RL1FWA1177MK&keywords=bike+reflectors&qid=1664981327&qu=eyJxc2MiOiI2LjY5IiwicXNhIjoiNS41MiIsInFzcCI6IjUuMDkifQ%3D%3D&sprefix=bike+reflectors%2Caps%2C132&sr=8-1-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFVWTRNOTdHTDRXSFcmZW5jcnlwdGVkSWQ9QTA0MzE0NjBTOUU3WlJQWjUzOFkmZW5jcnlwdGVkQWRJZD1BMDcxNDg1MzFOVVk0VkNUSEM1Nzcmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl

Flag:
https://www.amazon.com/Safety-Fiberglass-Polyester-Reflective-Strip（1/dp/B09Z2TPJ6Q/ref=sr_1_6?crid=6OM6TIJ5T5MU&keywords=safety%2Bflag%2Bfor%2Bbike&qid=1664982333&qu=eyJxc2MiOiI0LjQxIiwicXNhIjoiNC4xMCIsInFzcCI6IjMuNzUifQ%3D%3D&sprefix=safety%2Bflag%2Bfor%2Bbike%2Caps%2C206&sr=8-6&th=1

Paint:
https://www.canadiantire.ca/en/pdp/armor-coat-rust-aerosol-spray-paint-340-g-0489107p.0489104.html?loc=plp

Light:
https://www.amazon.com/BV-Bicycle-Headlight-Taillight-Quick-Release/dp/B00A6TBITM/ref=sxin_14_pa_sp_search_thematic_sspa?content-id=amzn1.sym.6b029eb3-7d41-4744-b45d-69fe835e098d%3Aamzn1.sym.6b029eb3-7d41-4744-b45d-69fe835e098d&crid=2H07MNE594LL&cv_ct_cx=led+light+for+bike&keywords=led+light+for+bike&pd_rd_i=B00A6TBITM&pd_rd_r=db60ed80-2981-4a02-83bc-400d2ec011ef&pd_rd_w=sIybF&pd_rd_wg=pcmJr&pf_rd_p=6b029eb3-7d41-4744-b45d-69fe835e098d&pf_rd_r=QRFDYMTNTQZ5VD8XEP6N&qid=1664982477&qu=eyJxc2MiOiI2LjAzIiwicXNhIjoiNS41OCIsInFzcCI6IjQuOTAifQ%3D%3D&sprefix=led+light+for+bike%2Caps%2C97&sr=1-2-a73d1c8c-2fd2-4f19-aa41-2df022bcb241-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTlZXWVhKVTRNT1QyJmVuY3J5cHRlZElkPUEwNTgzNTM1MTkxT1dMUEFGSTFUMSZlbmNyeXB0ZWRBZElkPUEwNTA1ODA2MTZJMExxMWkZHMVJaTyZ3aWRn

ZXROYW1lPXNwX3NlYXJjaF90aGVtYXRpYyZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU=

Phone Holder:
https://www.amazon.com/Viccux-Motorcycle-Upgrade-Rotatable-Compatible/dp/B09SYXPMPN/ref=sr_1_4?crid=3SFN573ITE1X7&keywords=bike+phone+holder+rotatable&qid=1664981940&qu=eyJxc2MiOiIxLjk0IiwicXNhIjoiMC4wMCIsInFzcCI6IjAuMDAifQ%3D%3D&sprefix=bike+phone+holder+rotatable%2Caps%2C180&sr=8-4

5.0 Critical Product Assumptions

The next step will be to define our critical product assumptions. Based on the bill of materials developed previously, we will include a list of acceptable values for a spec, the critical functionalities of our device and the availability of a certain type of material.

Availability of materials: There are multiple items on the BOM list that you can get at a local hardware store or order off Amazon. The only products that we might have a problem with getting would be the steel bar. The price of steel is at a high at the moment. This could lead to us having a hard time finding the steel bar for the price listed if the item becomes unavailable on Amazon.

Acceptable values for specifications: There are a few specifications we can measure in this prototype and the acceptable values are the following:
- Weight of attachment is 6 kg or less
- Footprint size of the attachment is 0.5 m^3 or less
- Ideal cost for materials is under $150

Critical functionality: This is the first prototype and we will want to make sure the shape we have chosen for the attachment will hold up to different forces.

6.0 Initial Prototype

We have now reached the most important stage of this deliverable. In this section, we will present the first prototype that we have assembled for our selected concept. Our prototype will be used to test the critical product assumptions detailed above, as our team would like to confirm the accuracy and validity of these presumptions. Our goal here is therefore to develop the most effective and useful model that will allow us to carry out accurate testing in the next step of the deliverable.

At the moment, our team decided that creating a CAD model of our attachment using SolidWorks was the most efficient way to proceed for our first prototype. Below, there are various pictures and screenshots that show the different angles and viewpoints of our first prototype. We have zoomed in on critical components in order to demonstrate how our subsystems will work together to allow for the global concept to function adequately. This will also allow us to expand upon the purpose and function of this initial prototype.

Figure 6.1: Isometric view of the attachment device, wheelchair and bike

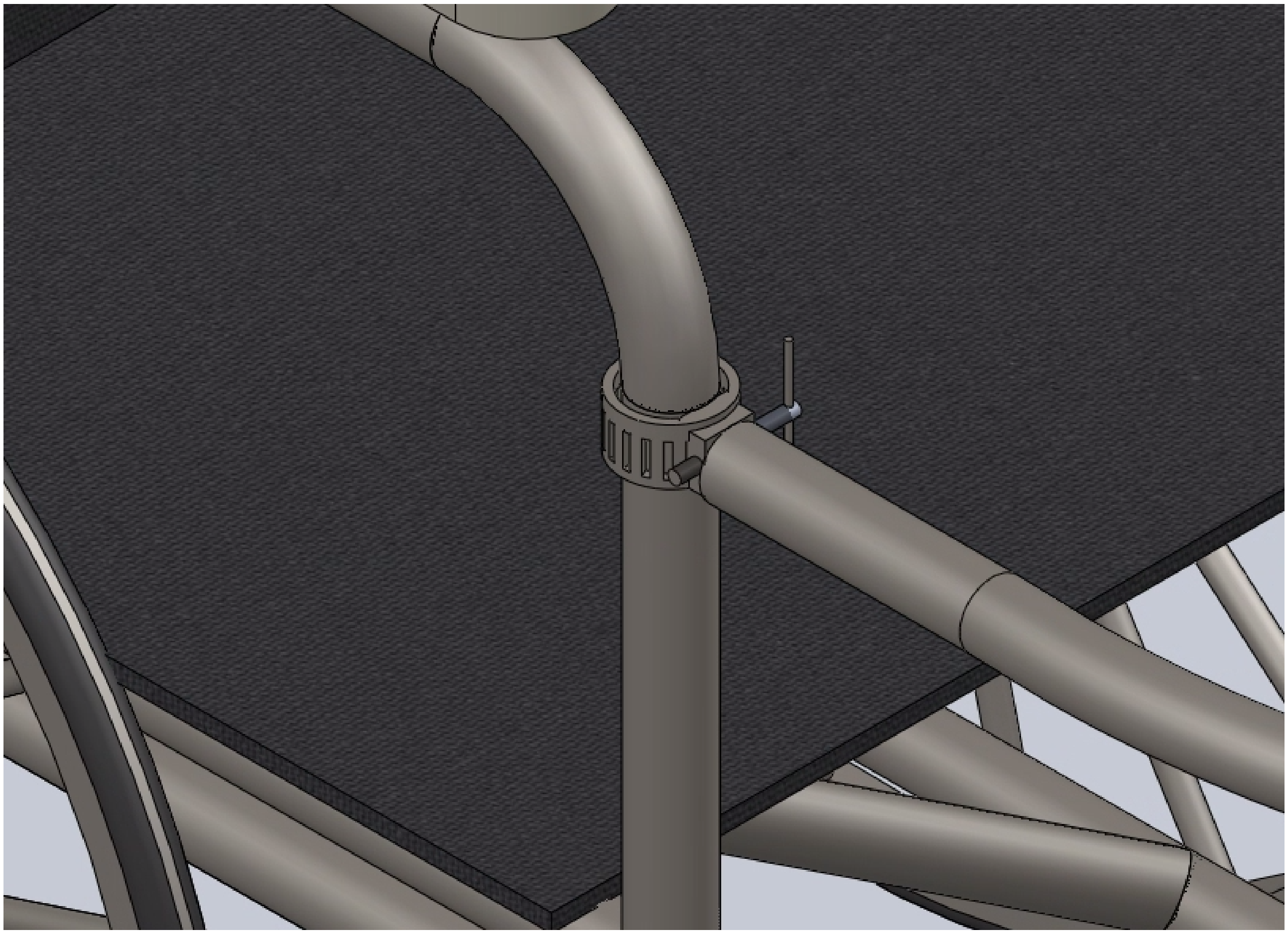

Figure 6.2: Zoomed-in view of the device clamps attached to the wheelchair

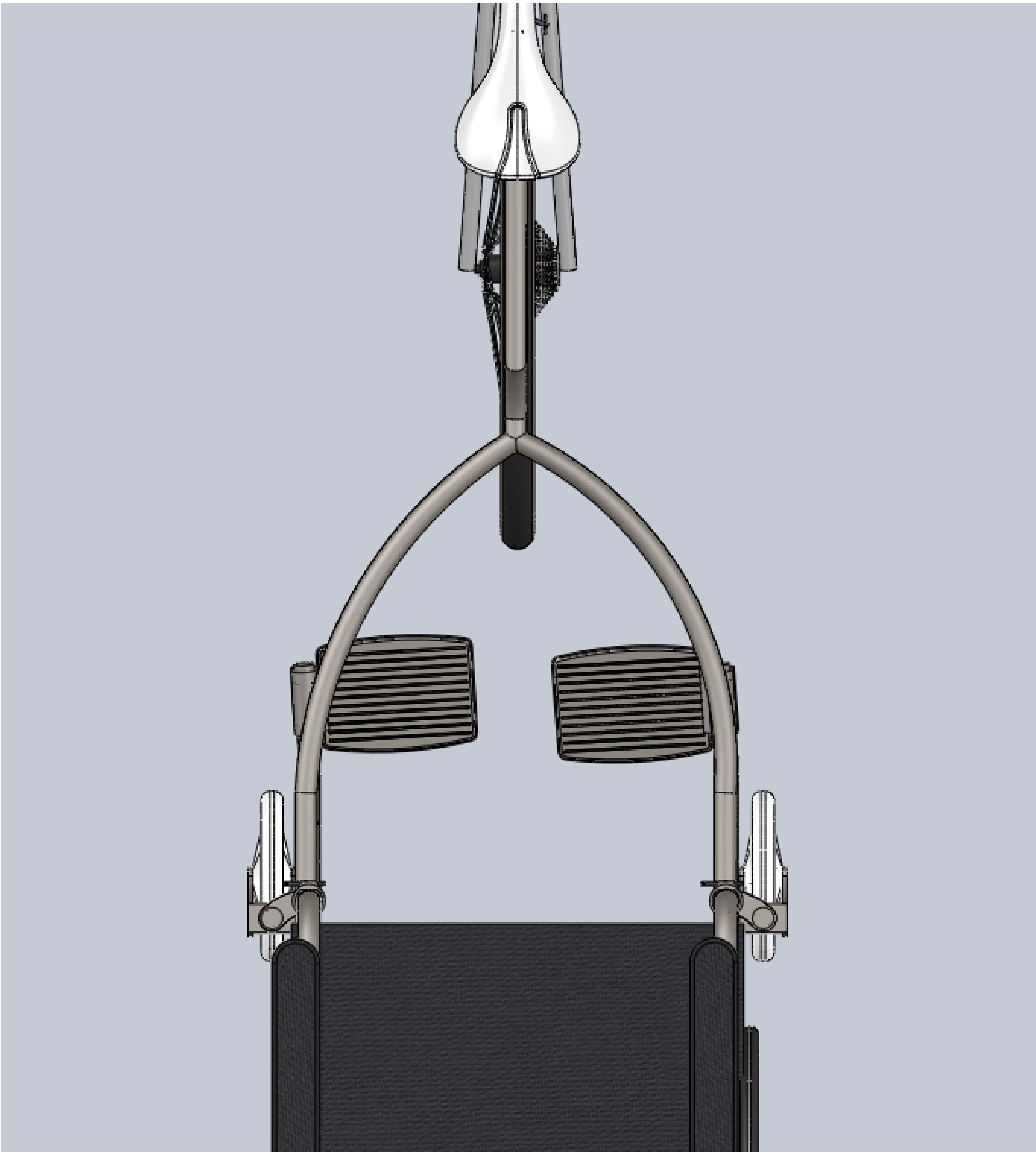

Figure 6.3: Top view of the attachment device

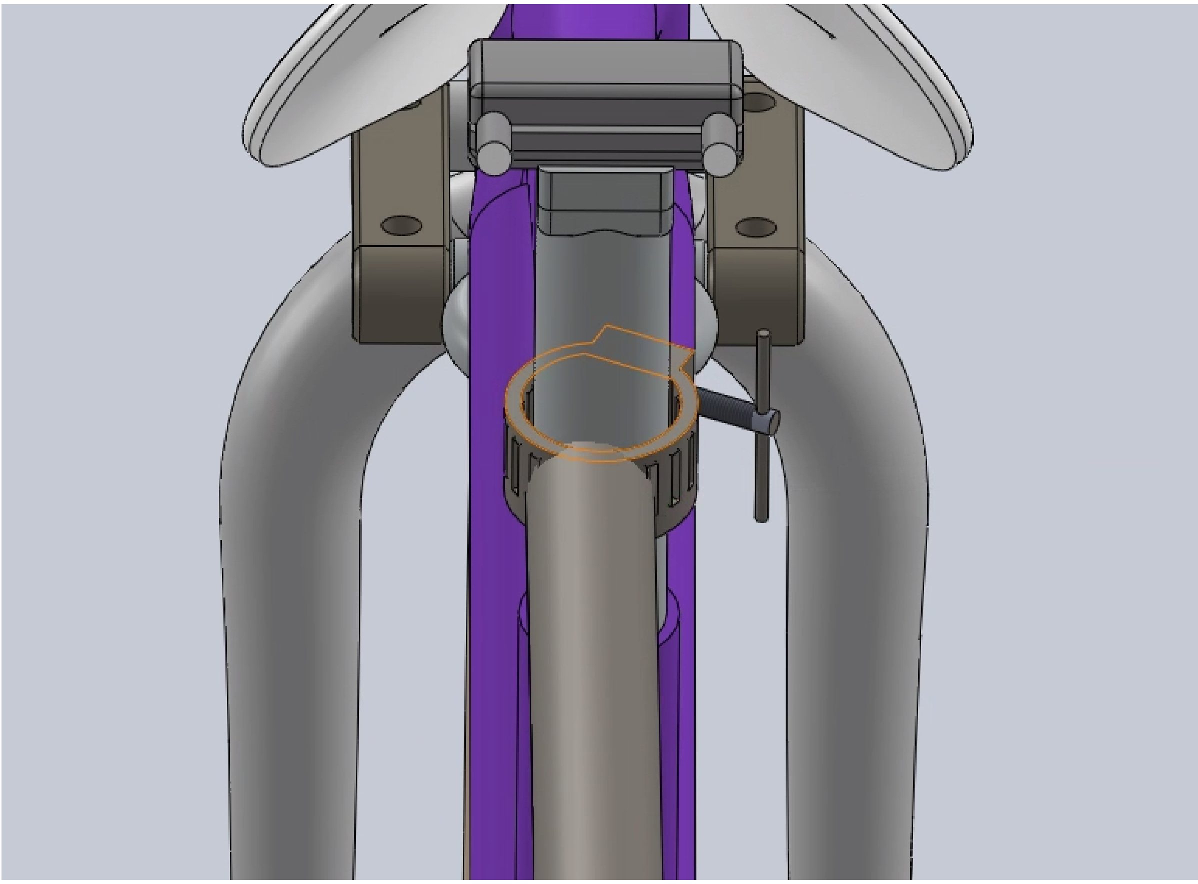

Figure 6.4: Top view of the device clamps attached to the bike

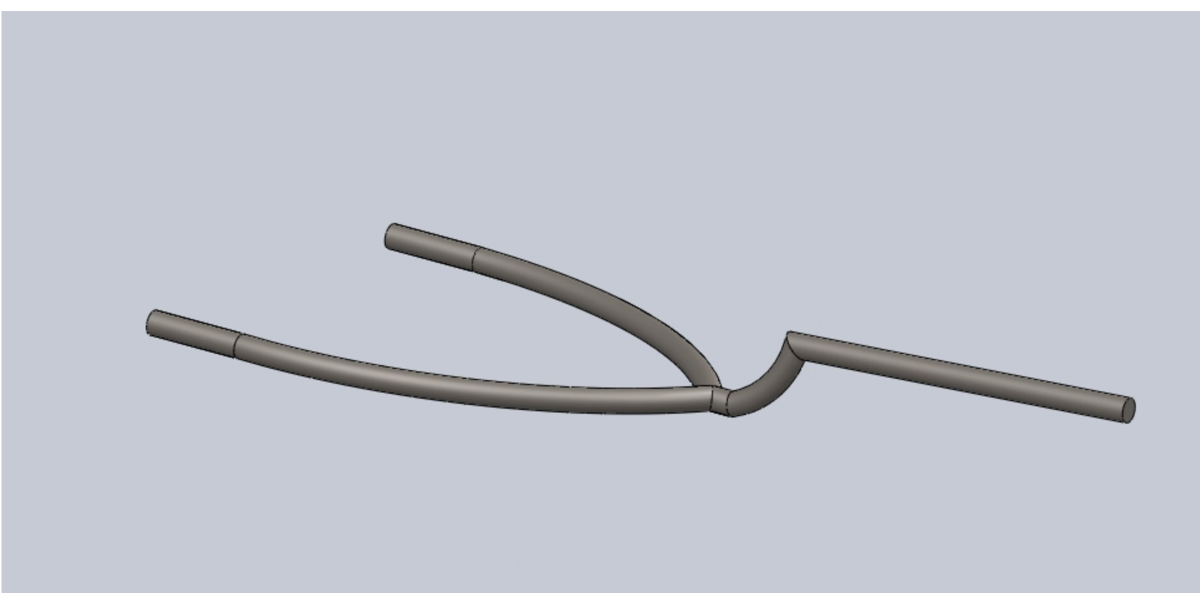

Figure 6.5: Isometric view of the device frame

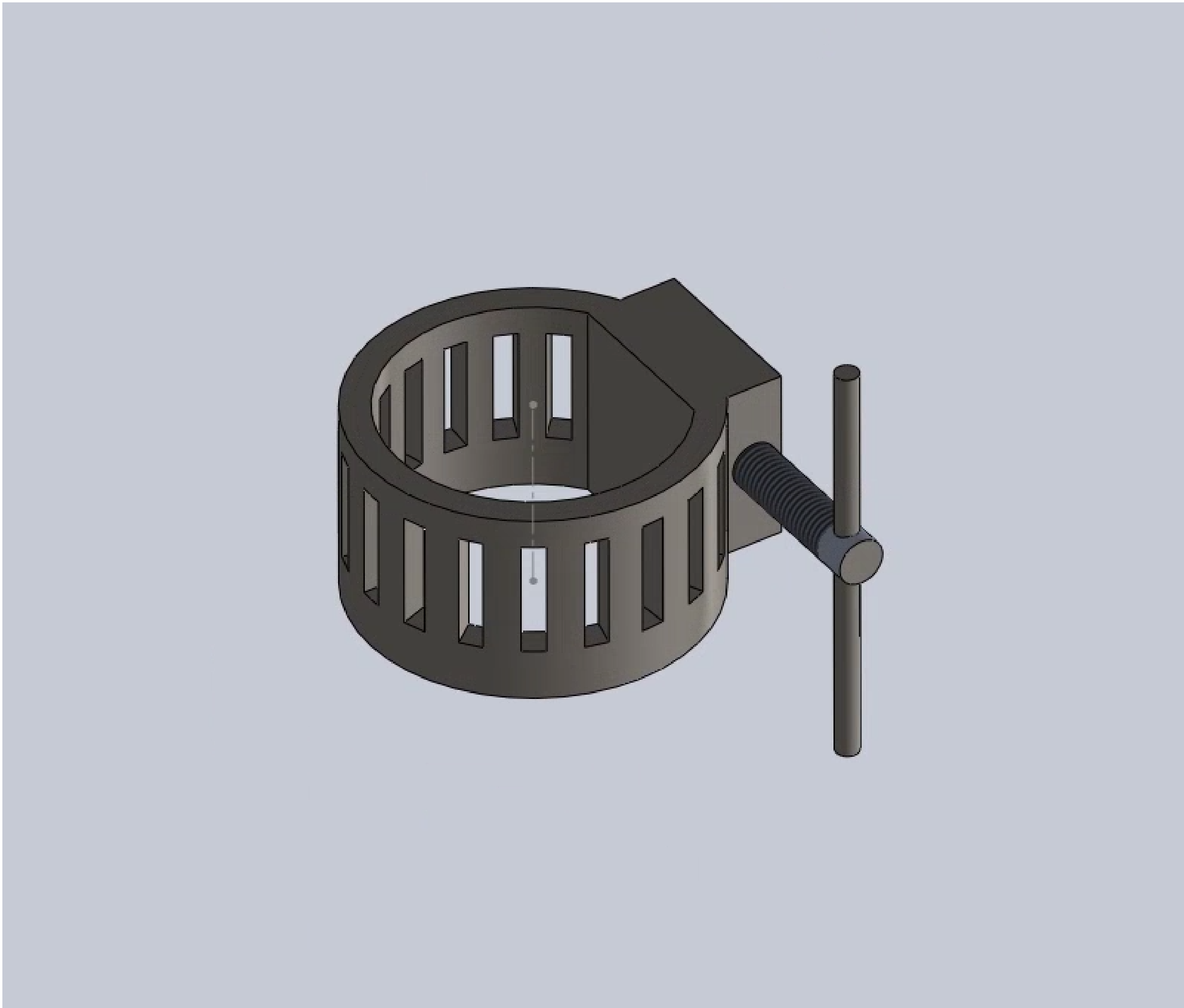

Figure 6.6: Zoomed-in view of the device clamp

This CAD model was developed to serve a few different purposes. First off, it helped the team visualize exactly how our concept would come to life. Sketching an idea on a piece of paper is beneficial, but being able to model the design using sophisticated 3D software is a crucial step of the process. Although this is our first prototype, the team feels like this was the most cost-efficient way to obtain a clear picture of what our future concept could potentially look like. As mentioned before, another key purpose of creating this design was to be able to test it later on. When developing an idea, it is always important to put it to the test before it goes out to the client, so that we can evaluate and process what we did well and where we can improve upon. Finally, we would also like to have a detailed design to show to our client at the next meeting coming up in a few weeks. The team feels that having a 3D model would allow for our client to very easily visualize and take in our attachment device, meaning they can provide more feedback during our discussions with them. As always, the more valuable comments and insights we receive, the better we can conceptualize our final prototype to meet the needs and desires of the customer.

The function of our prototype is to be able to attach a wheelchair to a bike, allowing for the wheelchair user to enjoy this common leisure activity. It is also important to note that we cannot make any permanent modifications to the wheelchair or the bike. Our prototype will firstly be attached to the sides of the wheelchair, using a pair of clamps that are connected to the main frame as shown above. Then, the wheelchair will be positioned behind the stationary bike, so that the long, straight rod can also be hooked onto the bike, again using a clamp. The clamps will be tightened by hand-held screws, meaning that no tools will be required to put the attachment into use. The device will therefore allow for the biker to be able transport the wheelchair and its user around as needed. When the bike ride is over, the attachment can be removed by loosening the clamps on the bike and the wheelchair, before storing the device in a secure place for the next use.

For this prototype, the group wanted to note that the bike and wheelchair models shown in the above images were exported from GrabCAD, as these do not constitute the main focus of this prototyping exercise. The design of the attachment device, which was undertaken by the team members, was the primary goal of this step of the process.

7.0 Prototype Testing

Now that we have produced our first prototype, it is time to put it to the test. Following the testing procedures, we will process, analyze and evaluate the results by comparing them to the target specifications that were developed in Project Deliverable B. So, we are now aiming to verify the product assumptions and to assess their validity in relation to our concept. It is important to note that each prototype has a purpose so that it can be tested in relation to a certain product assumption or target specification.

The main types of analysis that we had completed in SolidWorks were the stress, strain and displacement tests. Our team had decided to test the strength and durability of the frame without the involvement of the clamps. When doing this, we had chosen to use the three extremities of the attachment as our fixtures to make it as realistic as possible. In the figure below, it can be observed that the green points are the fixtures, and the pink arrows show where a 100 N force would be applied.

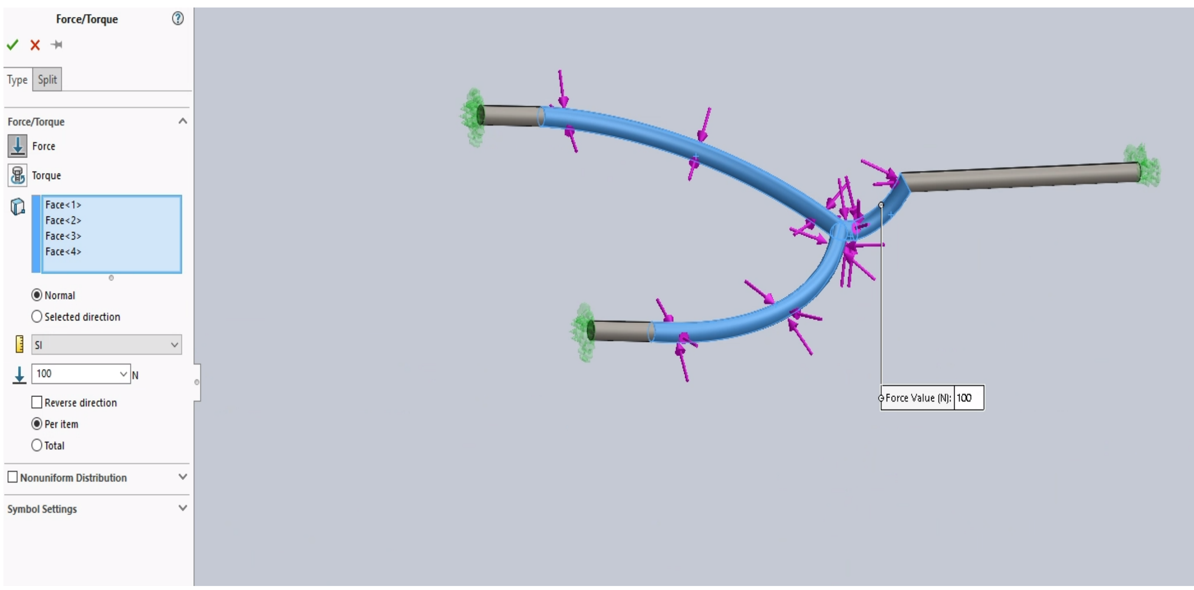

Figure 7.0.1: Fixtures and forces applied

The initial stress test below shows that the stress is focused more towards the center of the attachment, as well as the joint at the top left. The main point of stress is reasonable because it is located where the bike would be attached to the frame.

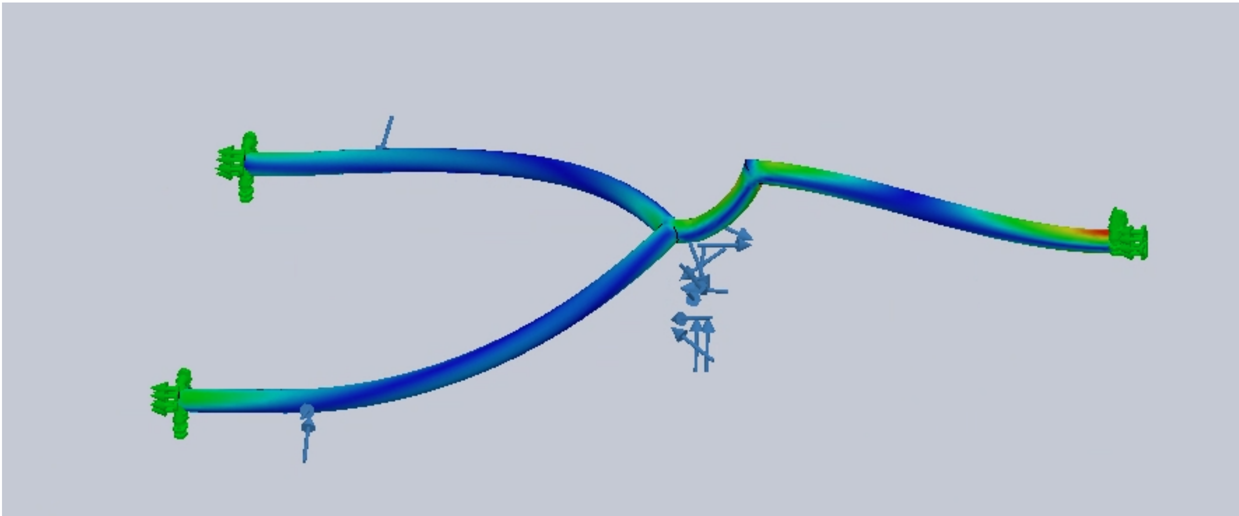

Figure 7.0.2: Initial stress test at 100 N force

Figure 7.0.3 showcases the static displacement representation. Clear plastic deformation has occurred, which shows us that a level change in the center of the device would not be the most structurally sound idea. The strain representation in Figure 7.0.4 gives us the same general idea as the previous two tests.

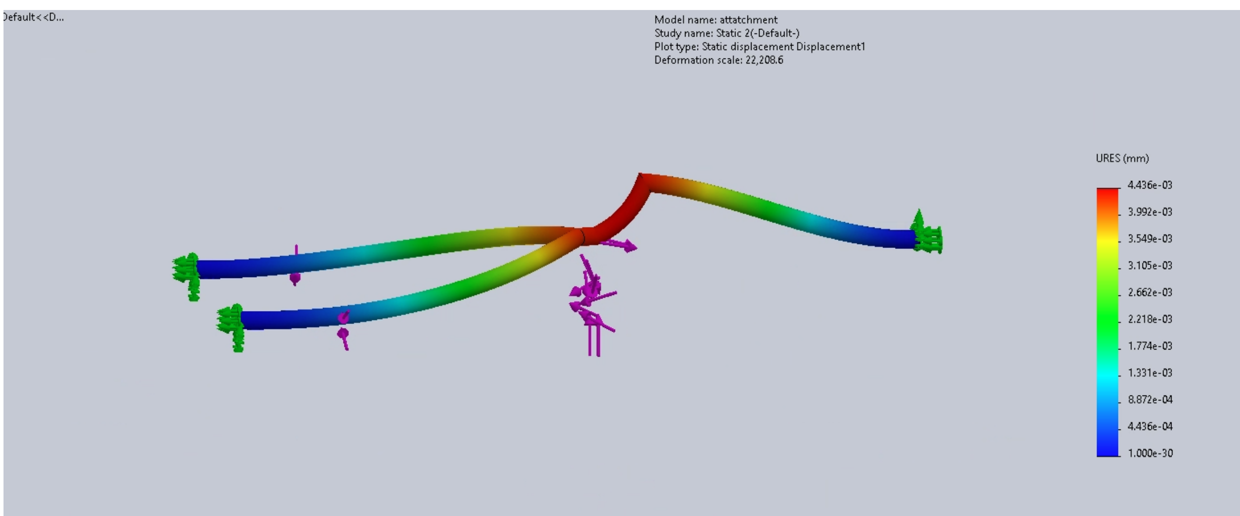

Figure 7.0.3: Initial displacement after 100 N force

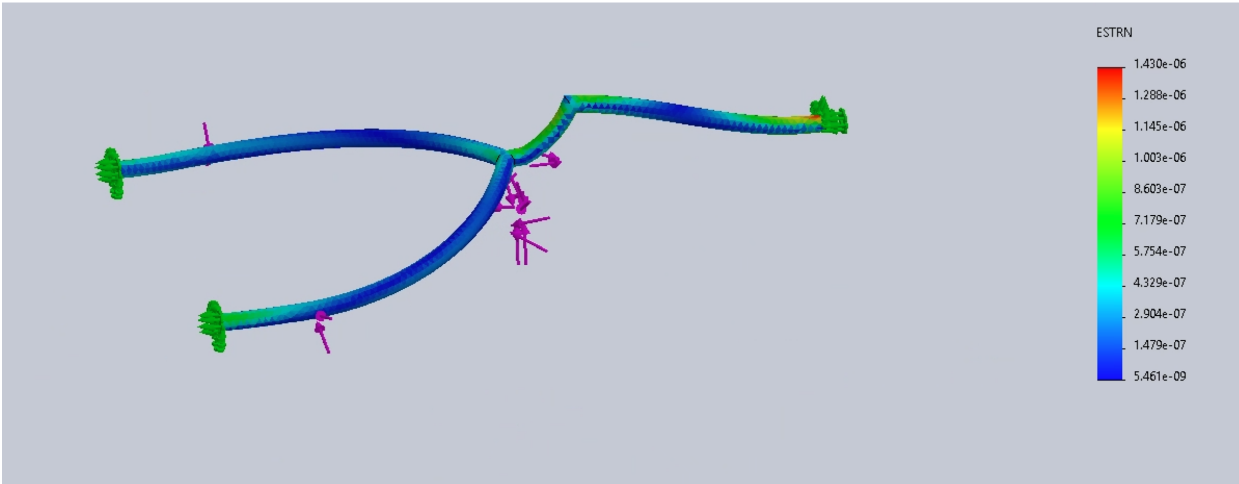

Figure 7.0.4: Initial strain after 100 N force

So, the team had decided to run the displacement test with a fifty newton force instead of 100 N in the hopes of seeing more promising results, but unfortunately the outcome was similar to what it was previously. The central elevated joint receives a high amount of stress and undergoes a lot of plastic deformation.

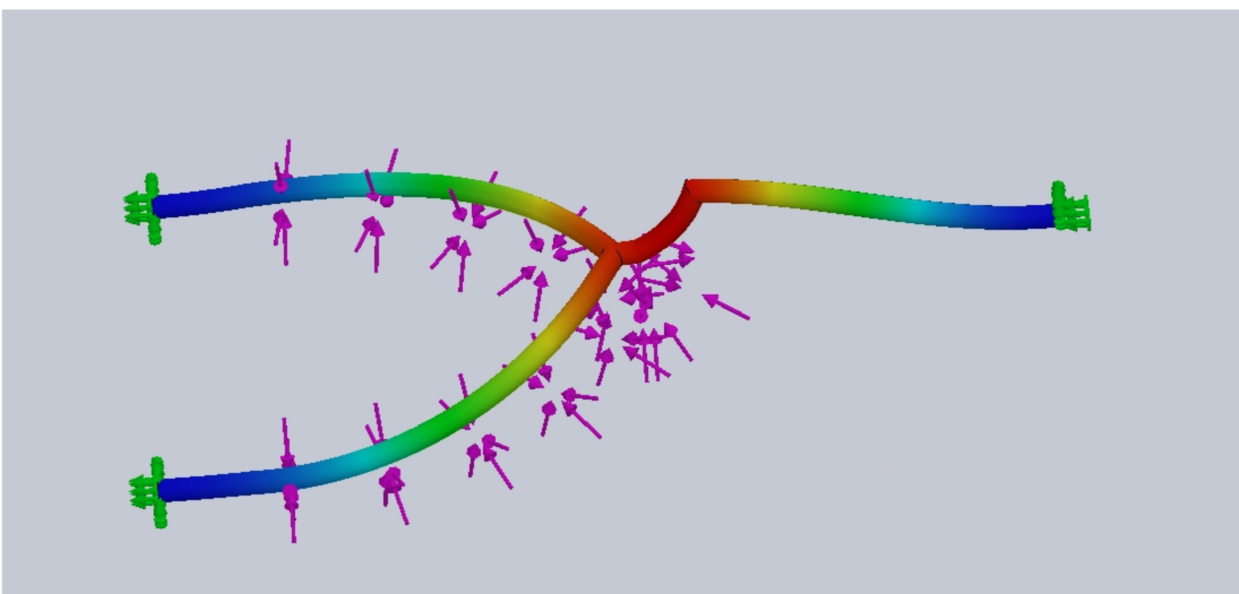

Figure 7.0.5: Displacement after 50 N force

Therefore, our group decided to model an alternate prototype, this time without the elevated joint. The testing conditions were the same as the very first test, where the fixed joints had a one hundred newton force applied throughout. The displacement test results were much more favorable but there were still some minor issues in the long, narrow pieces where the bike would be attached. These deformations could occur in real life during any turning motions performed by the bike rider. However, the team does believe that these results are promising, and this tested prototype can be seen as an adequate representation of the various concepts developed in previous deliverables.

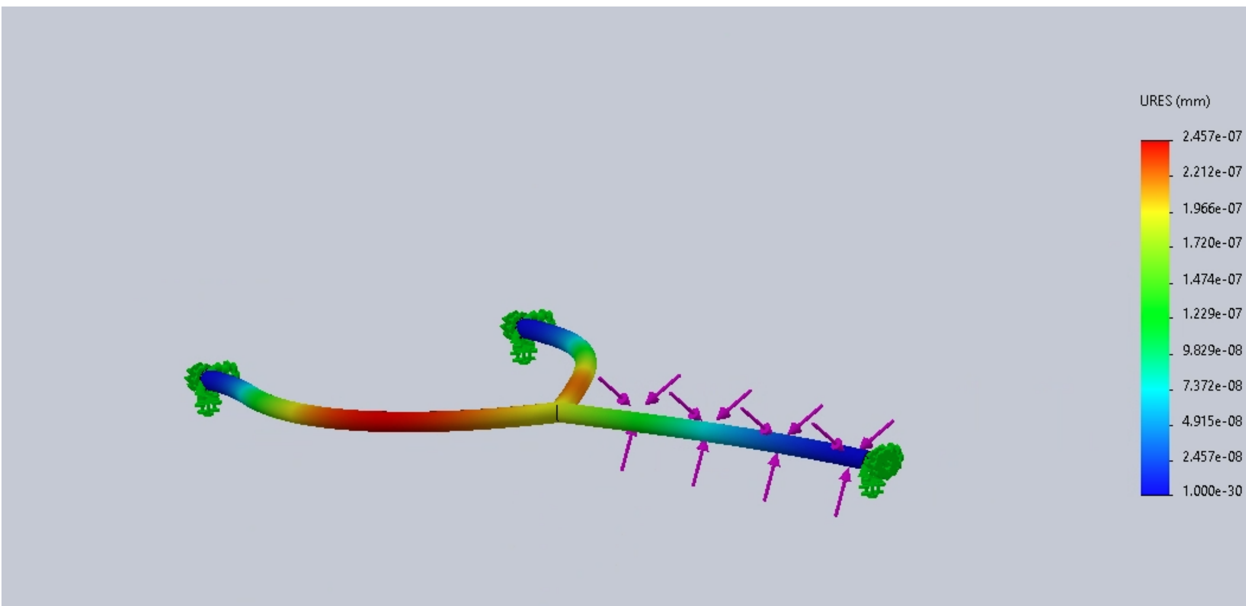

Figure 7.0.6: Displacement after 100 N force in straight bar design

In summary, these tests have given the team lots of necessary insight into the future of our design concept. We believe that these tests could have some potential inaccuracies as the attachment frame is extruded as one piece and not as separate steel tubes, attached together through welding. For future possibilities, the team would look into creating the attachment using the weldments feature available in SolidWorks.

7.1 Target Specification Relations

Using the material of AISI 1035 Steel, the mass of the frame is equal to 14.86 lbs. For the clamps, we have used the material of 1023 Carbon Steel, which makes the mass per clamp equal to 0.16 lbs. When the clamps and frame are assembled, the total mass of the attachment would be equal to 14.86 + (0.16*3) = 15.34 lbs, which is around 6.96 kg. This is slightly over our marginal value of 6 kg for the total attachment weight.

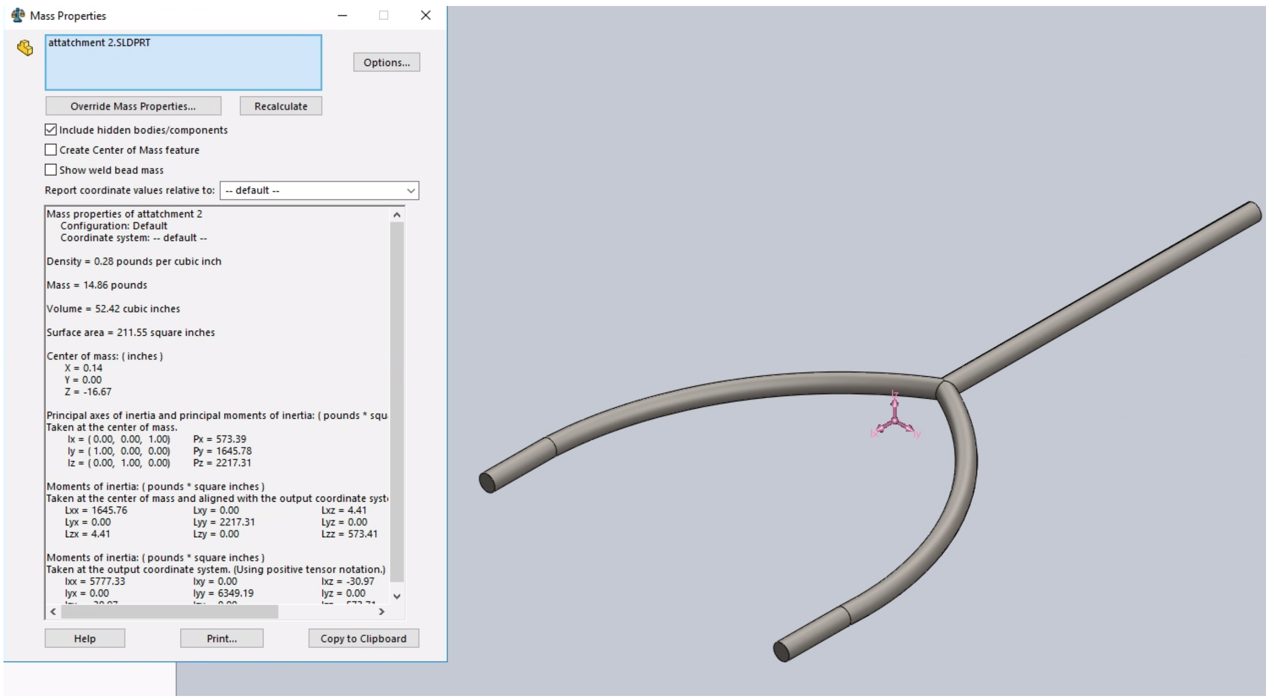

Figure 7.1.1: Frame mass properties

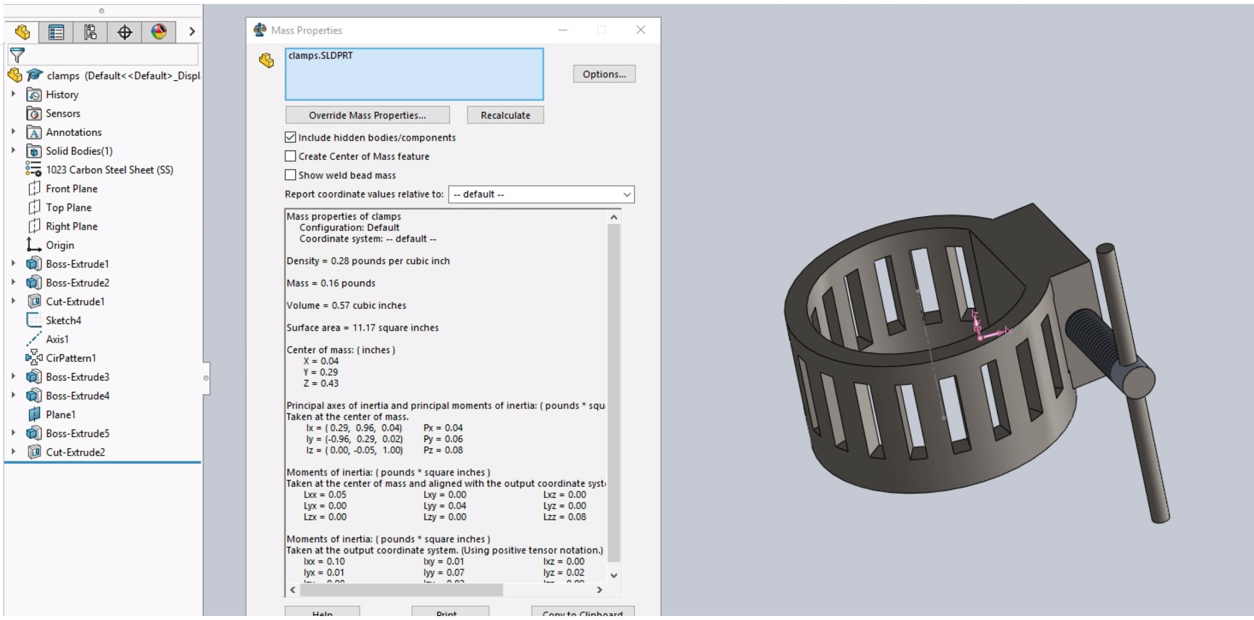

Figure 7.1.2: Clamp mass properties

Referencing Figure 7.1.1, it can be seen that SolidWorks indicates that the volume is 52.42 cubic inches, which converts to 0.00085 cubic meters. Even though this number is well within the ideal value of 0.5 cubic meters, the team believes that this value is not necessarily true. This is because the number that is shown on SolidWorks only takes into account the value for the attachment pipe. So, it does not take into account the actual space it would take to store, including the empty areas between the pipe.

Below, Figure 7.1.3 can be looked at to give us a more accurate value to reference for the volume. We will assume the worst case scenario where the clients will not be able to store anything in the empty spaces of the attachment and will have to use the maximum amount of space that the attachment will take up. With that in mind, the volume it would take up would be equal to the shape of a rectangular prism.

V = L*W*H

V = (40”)(9.5*2”)(1”)

V = 760 cubic inches = 0.012 meters

This value is much greater than the one provided by SolidWorks, but fortunately it is still well within the ideal target specification of 0.5 cubic meters.

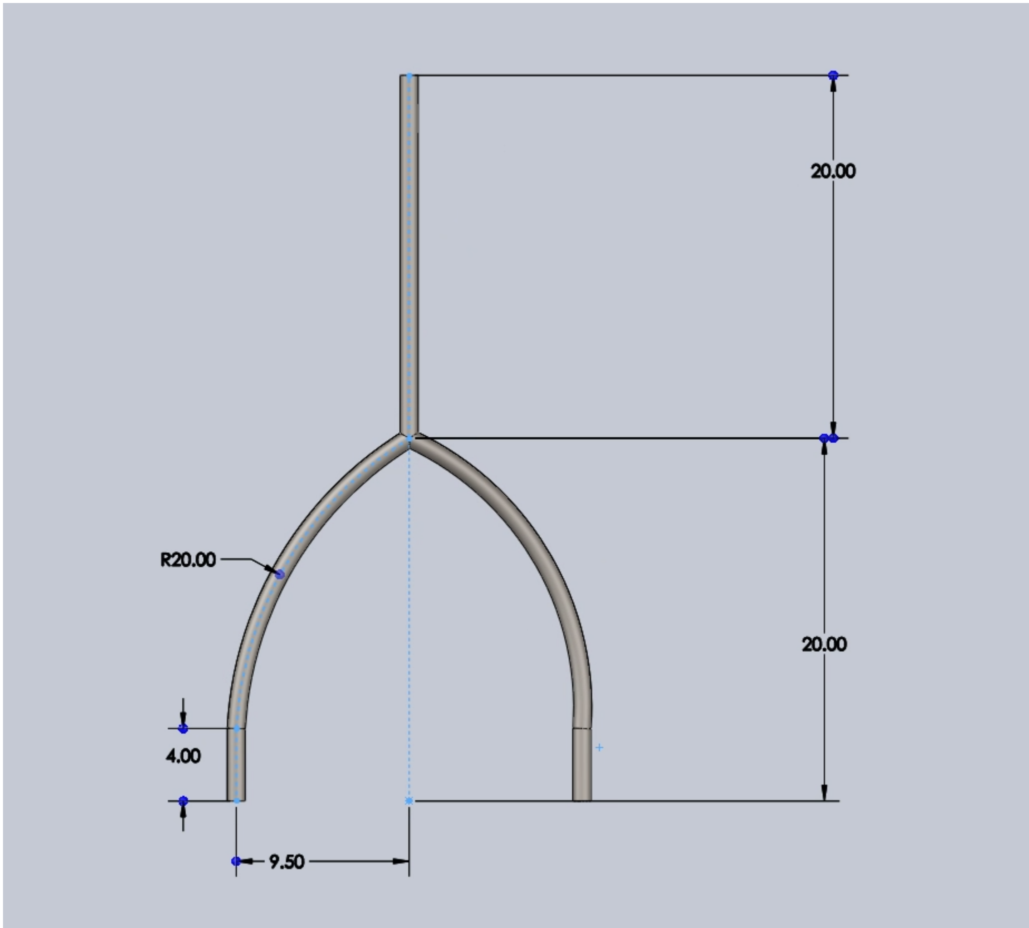

Figure 7.1.3: Frame dimensions

SolidWorks also has the ability to give us a costing estimate for material and machining costs. Machining when using plain carbon steel gives us a costing estimate of $472.57 USD, which is well above the budget. However, this is not an accurate approximation as SolidWorks is assuming that we are going to be machining the teal coloured block referenced in Figure 7.1.4 into the final round pipe form, which is clearly inflating the machining and material costs. As mentioned earlier, using the welding feature would have given the team a much more accurate estimation of the project cost.

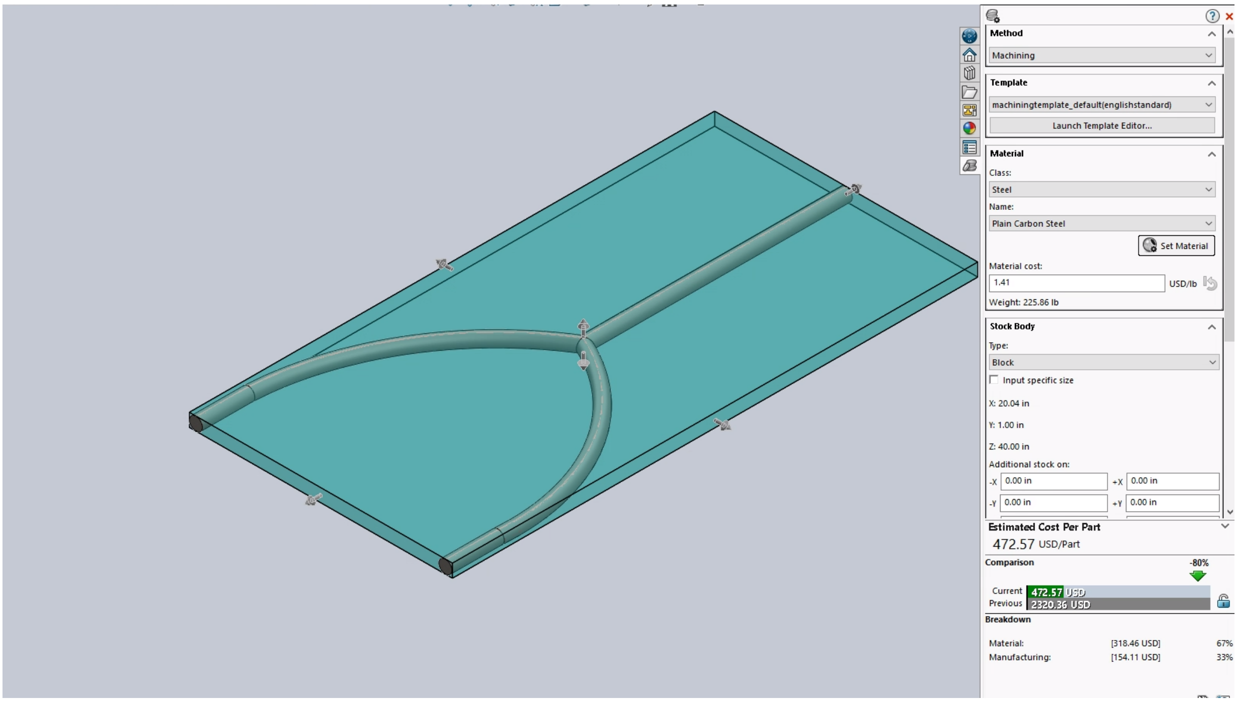

Figure 7.1.4: Costing of machining steel

The team then decided to use the casting option instead of machining since it would be closely related to our real life plan of buying the steel tubes and welding them together. SolidWorks only has the option of aluminum when casting since you cannot cast steel due to its high melting point. The final estimate of casting as 7079 Aluminum Alloy costs $18.37 USD.

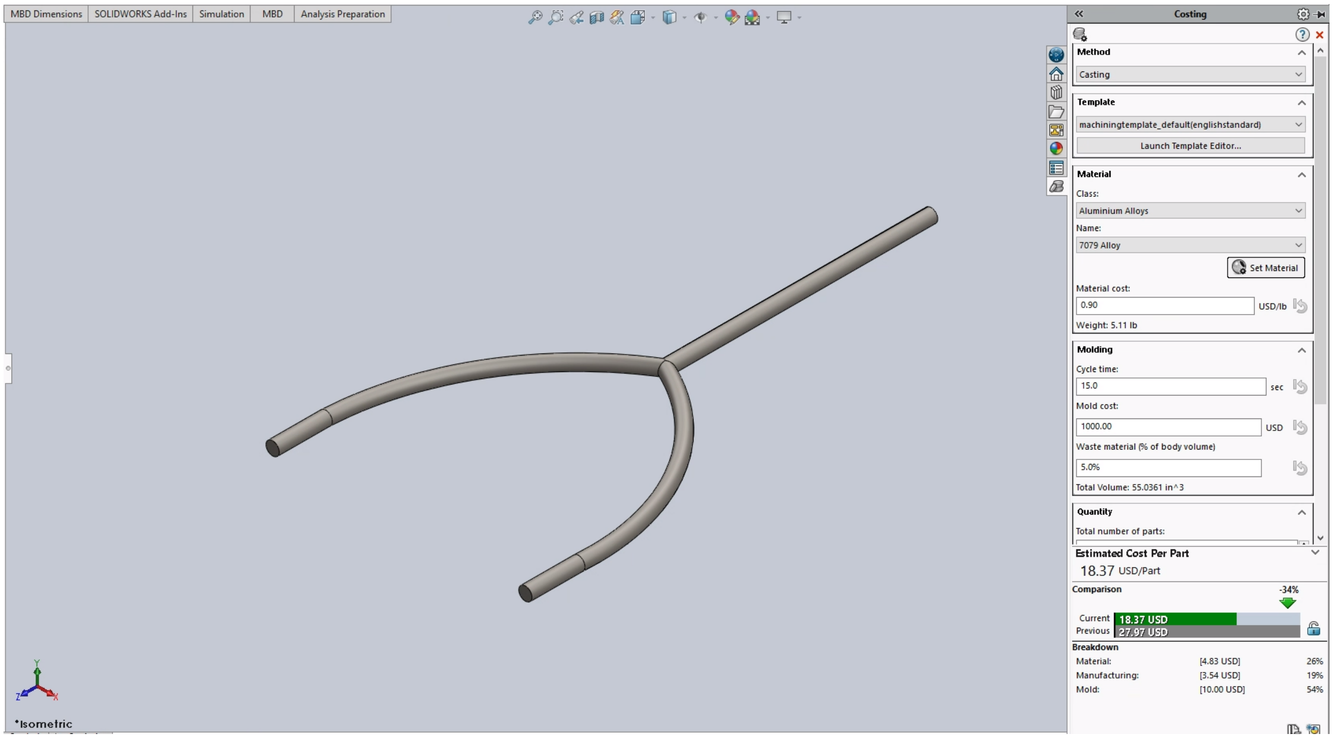

Figure 7.1.5: Costing of casting aluminum

Therefore, the team believes that the costing estimate feature provided from SolidWorks is not accurate enough to use as a basis to compare to our cost target specification. So, we will use the Bill of Materials as our costing estimate, which is in Section 4 of this deliverable. The total cost of $142.90 is within the allocated budget of $150, and takes into account the pricing of all materials and accessories.

8.0 Client Meet 3

Based on the feedback from the second client meet, we have improved our design, generated our first virtual prototype and done some testing. The results of the tests show that our design is feasible, and that we are on the right track in terms of our project progress. We would like to show our clients the CAD model of our concept, so they can have a better understanding of the detailed features and how the device works. Furthermore, in order to better fulfill the requirements of the clients, we plan to pose the following questions during our discussion with them:

1. What specific features do you like and dislike about the designs we showed you?
2. Do you have any specific improvements in mind?
3. Are there any preferred positions that you want the accessories to be?
4. Are you satisfied with the materials we chose? If not, what can be improved?
5. How well do you think this device would work with your wheelchair?
6. Are we allowed to measure the dimensions of your wheelchair? Do you have the model name of the wheelchair?
7. What is your favorite overall design? Why do you like it the most?

9.0 Conclusion

To conclude, the team believes that development of the first prototype has been promising and successful. Creating the initial prototype in SolidWorks has proven to be very beneficial. The stress tests in SolidWorks have given the group the necessary insight on the structural integrity of the attachment. The team is eager and passionate about sharing the results with our clients at the upcoming meeting. The feedback gathered during this meeting will therefore aid the team in designing a higher fidelity second prototype. So, the team is excited about developing a functional prototype in the near future, as well as sharing our continued progress with our peers during the presentation in Project Deliverable E.

10.0 Wrike

Below is an updated version of our project plan. We have included tasks and milestones to plan for the next two weeks of our progress. Every team member's availability was taken into account for the various tasks assigned to them, to make sure that the assigned work can be completed well and in a timely manner.

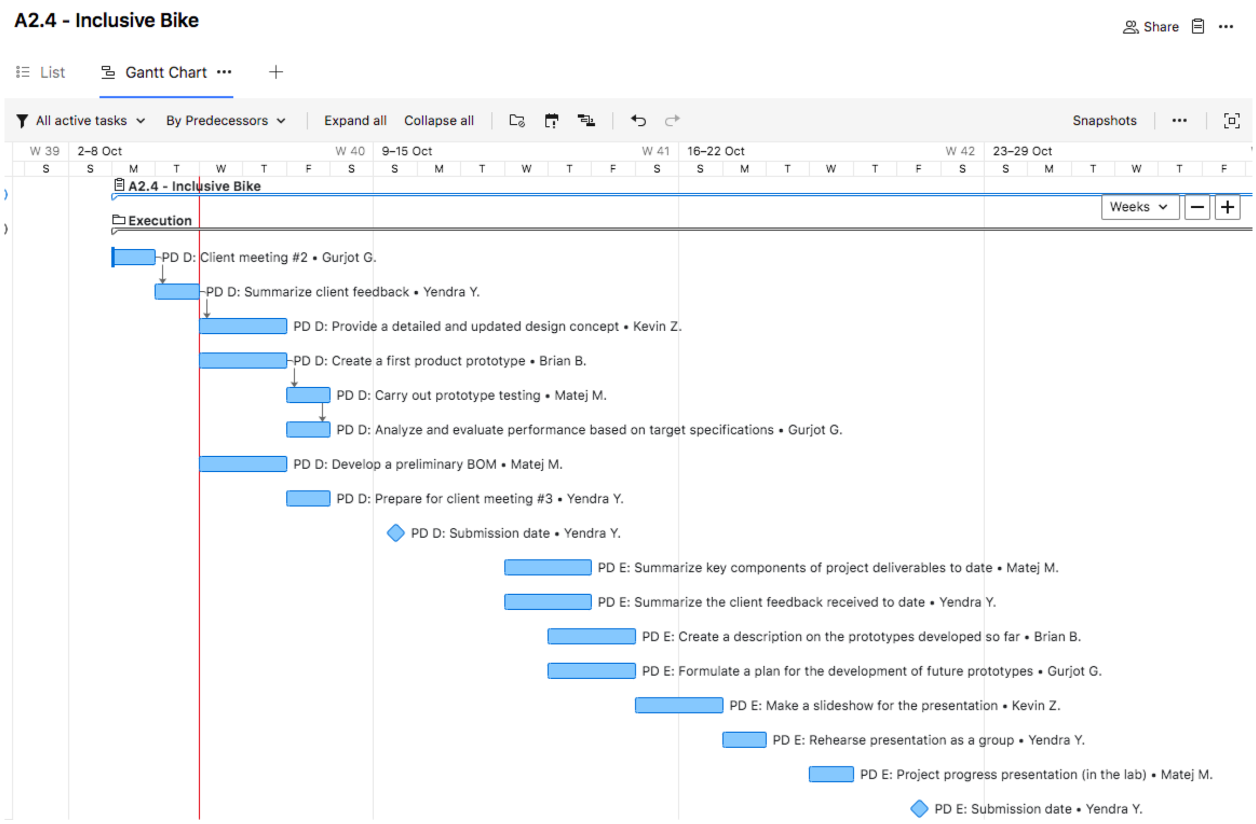

Figure 10.1: Updated Project Plan using Wrike 1

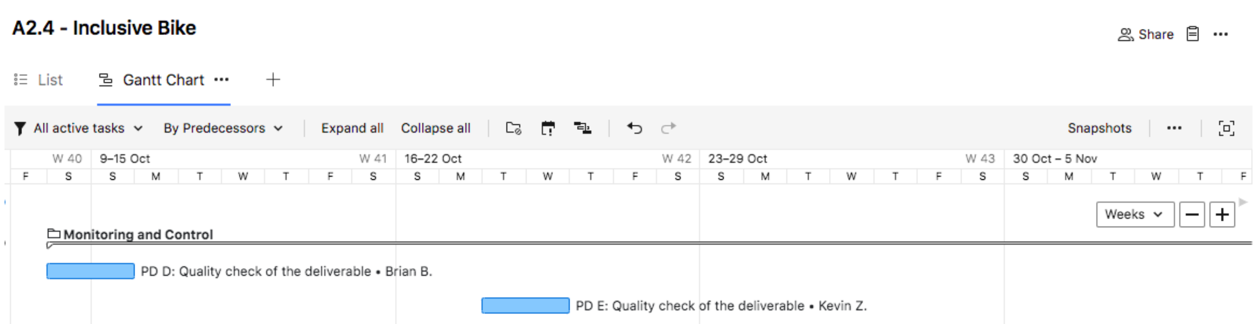

Figure 10.2: Updated Project Plan using Wrike 2

11.0 References

Model of bike: Created by Carlo on GrabCAD
Link to Carlo's GrabCAD Profile: https://grabcad.com/carlo-49
Link to Carlo's Bike Model: https://grabcad.com/library/bike-375

Model of Wheelchair: Created by Shihabdeen A on GrabCAD
Link to Shihabdeen's GrabCAD Profile: https://grabcad.com/shihabdeen.a-1
Link to Shihabdeen's Wheelchair Model:
https://grabcad.com/library/non-reclining-wheelchair-1