Project Deliverable F: Prototype 2

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1.0 Introduction

Prototyping is an important stage of the design process, as it allows us to test our assumptions and verify the functionality of our ideas. Creating a physical or virtual model of a certain concept is also beneficial for visualizing the characteristics of the product's design. In Project Deliverable D, our group developed our first analytical prototype, which was then shown to our peers during the progress presentation in Project Deliverable E. In this deliverable, we will be presenting the creation of our second prototype, which will be a physical representation of the clamping mechanism of our attachment device. We will begin by summarizing the feedback received during the third client meeting and presenting the required updates to our design. After defining the most important product assumptions that we aim to meet, we will demonstrate the functionality of our prototype and explain the purpose behind it. Our second prototype will then be put to the test, and our group will analyze and evaluate the results of the testing process. Finally, we will also present the most up-to-date version of our project plan on Wrike.

2.0 Feedback for Client Meet 3

At the third client meeting, the team presented our first prototype and the results that we obtained after testing it in SolidWorks. We clearly demonstrated how each part of our attachment would function and the potential issues that could occur. During this meeting, we focused on our main frame and clamps as these would be the most critical parts of our product. Based on the discussions with the client, we will now summarize the feedback that was received by our team.

Our client expressed the main concern that they wanted the clamps to be attached to the tie-down hooks on their wheelchair, shown in Figure 2.1, instead of how it is currently designed to be attached to the handlebars. They explained that they use the tie-down hooks to secure their wheelchair on public transportation and believed having the device frame attached there would be safer and more secure.

Taking this feedback into consideration, we decided to change the clamp attachment area from the handlebars to the tie-down hooks. A majority of newer wheelchair models include this option, and the clients expressed to us that this is a universal feature for wheelchairs as they are essential to secure wheelchairs when they are being transported around.

Figure 2.1: Preferred connection area (tie-down hooks)

Based on these changes, our detailed design was also updated accordingly. Our concept now looks like the following:

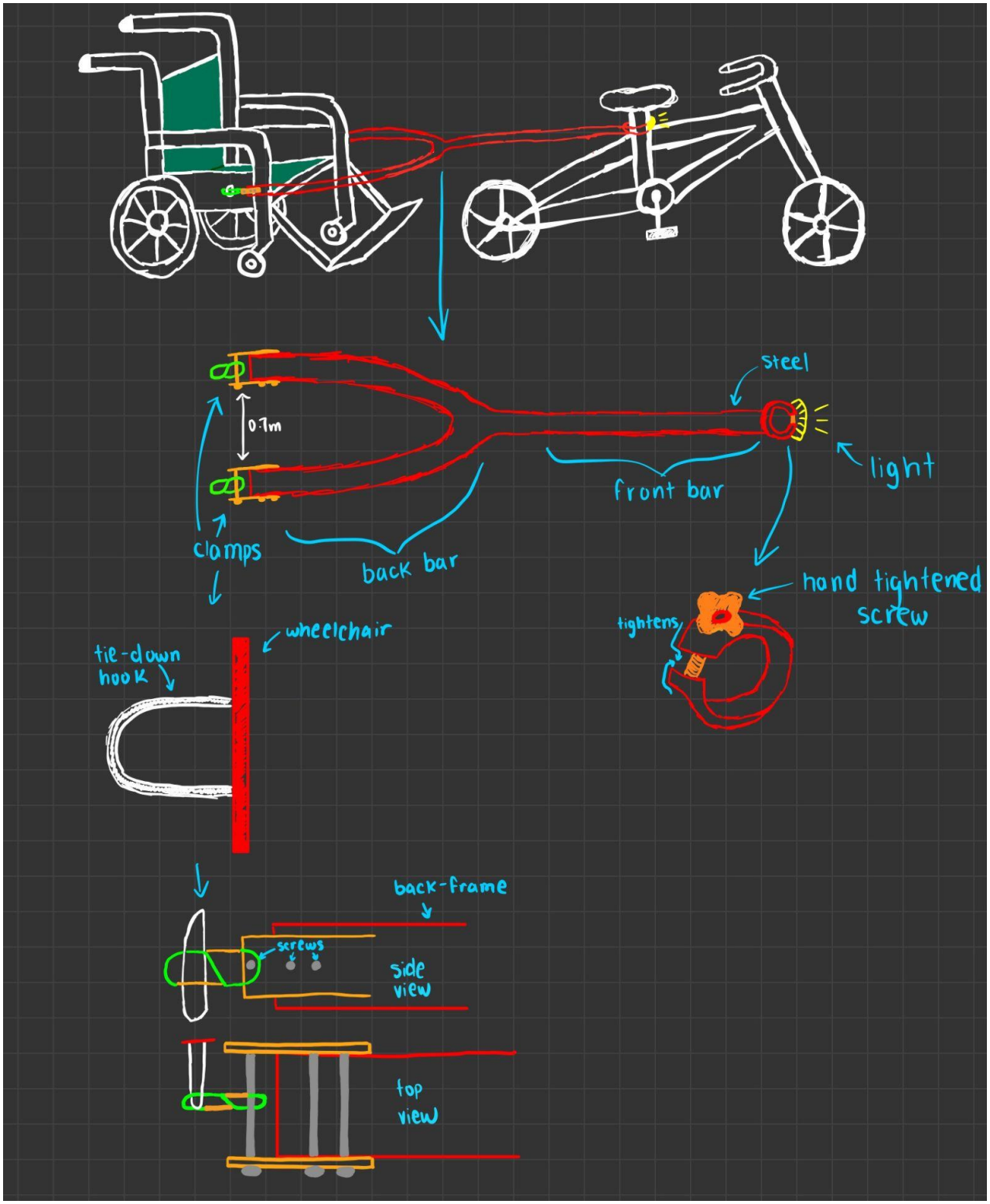

Figure 2.2: Sketch of the detailed design

3.0 Critical Product Assumptions

Next, we will discuss the most important product assumptions that we will aim to meet or exceed during the testing process. These will also serve as a guideline for when we evaluate and analyze the functionality of our second prototype. The most critical product assumptions are as follows:

1. **Acceptable Values**
    a. Maximum User Weight: We are assuming that the wheelchair attachment would not have to pull a weight greater than 90 kilograms.
2. **Material Availability**
    a. Steel Tube
        i. For this medium-fidelity physical prototype, the team has decided to use PVC pipe to test functionality, before utilizing a stronger, more costly material. However, the final steel tubes that we plan to employ, if the tests are successful, are available at local hardware stores.
    b. Heavy Duty Carabiner
        i. Heavy-duty carabiners that are rated to withstand a few hundred pounds are available at stores and are within our budget. For this prototype, we decided to use a cheaper carabiner that costs 5$ in order to put the concept to the test.
    c. Steel Brackets (Flat and 45 degrees)
        i. These are readily available at most hardware stores, as well as online. For this prototype, we used two straight brackets, which one of our group members had in their garage.
3. **Critical Functionality**
    a. The device should be able to pull the bike and wheelchair without undergoing any plastic deformation, and little to no elastic deformation.
    b. The device should be capable of securely and safely pulling the wheelchair and its user.

4.0 Second Prototype

For our second prototype, the team has decided to create a simple physical model of the wheelchair-bike attachment device. This will help us on our way to generating our final prototype, which will be presented at Design Day, as well as to compare the target specifications to the tested results.

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.

Our prototype will now be presented using a variety of images and pictures, with each one showing various angles of the overall design. Then, we will also explain the purpose and functionality of this medium-fidelity prototype.

Figure 4.1: Top view of the connection mechanism

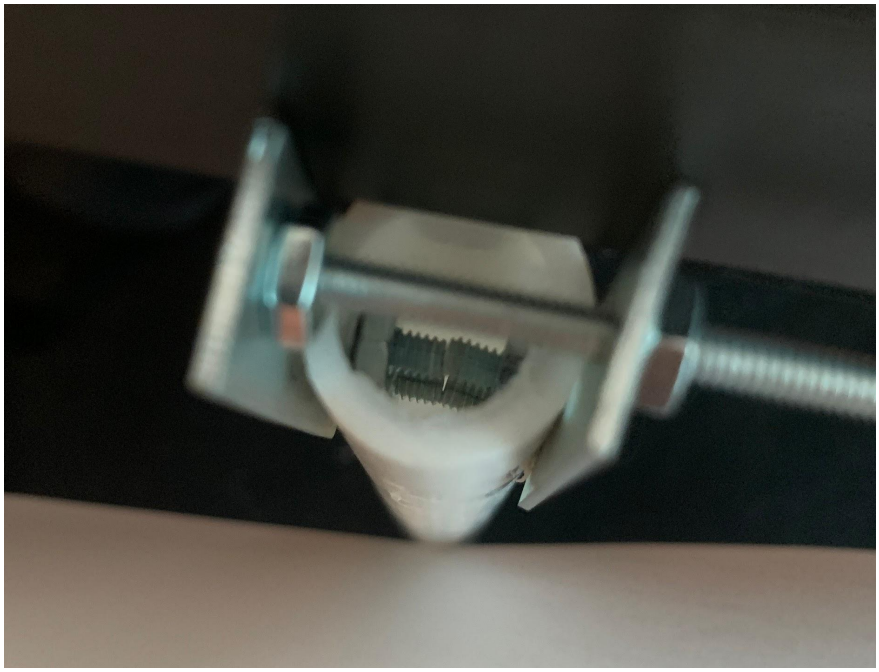

Figure 4.2: Side view of the connection mechanism

Figure 4.3: Side view of the connection mechanism attached to a wheelchair

Figure 4.4: Isometric view of the connection mechanism attached to a wheelchair

Figure 4.5: Prototype attached to the wheelchair while wheelchair is occupied

Figure 4.6: Prototype being put to the test

The purpose of this second prototype is to test the general concept of our new connection mechanism that will attach to the wheelchair hooks instead of the wheelchair handles. Our main goal was to get this physical prototype done with a fairly small budget of five dollars, which is what we have achieved. Furthermore, after the team carries out the necessary tests, another key purpose of building this mechanism is to compare the actual results to the anticipated ones, based on our defined target specifications.

In terms of how this device will function, the PVC pipe would be used to simulate the steel pipe, while the carabiner is to be used for connecting the pipe to the wheelchair tie-down hooks. On the attachment end, the carabiner would be securely fastened to the long bolt that goes through both steel brackets, ensuring the load is spread evenly throughout the PVC pipe. The steel brackets are each attached to either side of the PVC pipe, through the use of small screws and nuts. Our aim was to develop a simple device that would function adequately and allow the team to test the prototype specifications.

5.0 Prototype Testing

Now that we have created our second prototype, it is time to put its performance to the test against our defined target specifications. After documenting the results of the testing process, we will then be able to assess the expected versus actual results, and comment on any discrepancies that may have occurred during the testing of the device.

To test our prototype, our team used the wheelchair available at our laboratory and attached our mechanism to one of the hooks on the wheelchair. One teammate pulled another one of our group members forward for about a distance of 20 meters, at a decently fast speed. This simulates a bike pulling the wheelchair and its user forward.

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.

In Table 5.1 below, we have documented the test results and directly compared them to the target specifications that we aim to meet. In the “Important Notes” section of the table, we have included comparisons to the ideal target specification values and commented on any potential discrepancies. Since we are creating a focused prototype, we expect some results to vary once we create our final prototype and put that to the test.

Table 5.1: Prototype Testing Metrics

Metric #	Metric	Units	Marginal Value	Ideal Value	Tested Value	Important Notes
1	Cost	$ (CAD)	150	5	5	The ideal value is only for the cost of the partial prototype, not the fully completed attachment.
2	Attachment Weight	kg	6	4	1	The partial prototype weighed less than one kilogram but this may not be the case for the fully completed attachment.
3	Maximum User Weight	kg	120	90	90	The mechanism was able to pull 90 kg while only attached to one hook, so we believe the end result could pull more weight.
4	Assembly Time	mins	15	5	1	It takes less than 1 minute to attach the 2 carabiners to the wheelchair hooks, but this may not be the case for the fully completed attachment.
5	Aesthetics	Subjective	6 out of 10	9 out of 10	6 out of 10	This is based on our personal opinions.
6	Material Tensile Strength	MPa	300	400	52	The material strength of PVC is much lower than steel but it was able to withstand the load.
7	Visibility (distance)	m	15	20	20	We were able to see the prototype from 20 meters away in daylight.

6.0 Conclusion

To conclude, we can say that the third client meeting was very valuable, as it generated a lot of useful feedback. Based on the client's comments, we were able to successfully build the second prototype, which is focused on the connection mechanism between the main frame of the device and the wheelchair's tie-down hooks. After that, we tested the strength of the connection mechanism, and the results show that this medium-fidelity prototype is capable of pulling one of our team members in a wheelchair. The outcome is beyond the team's expectations since PVC, a type of plastic material, was used for this device. Furthermore, a carabiner rated for only 11kg successfully pulled our group member, while only being attached to one side. We expect an even more solid and sturdy build with steel when it comes to developing the final product for Design Day.

7.0 Updated Project Plan

Below is the most up-to-date version of our project plan on Wrike.

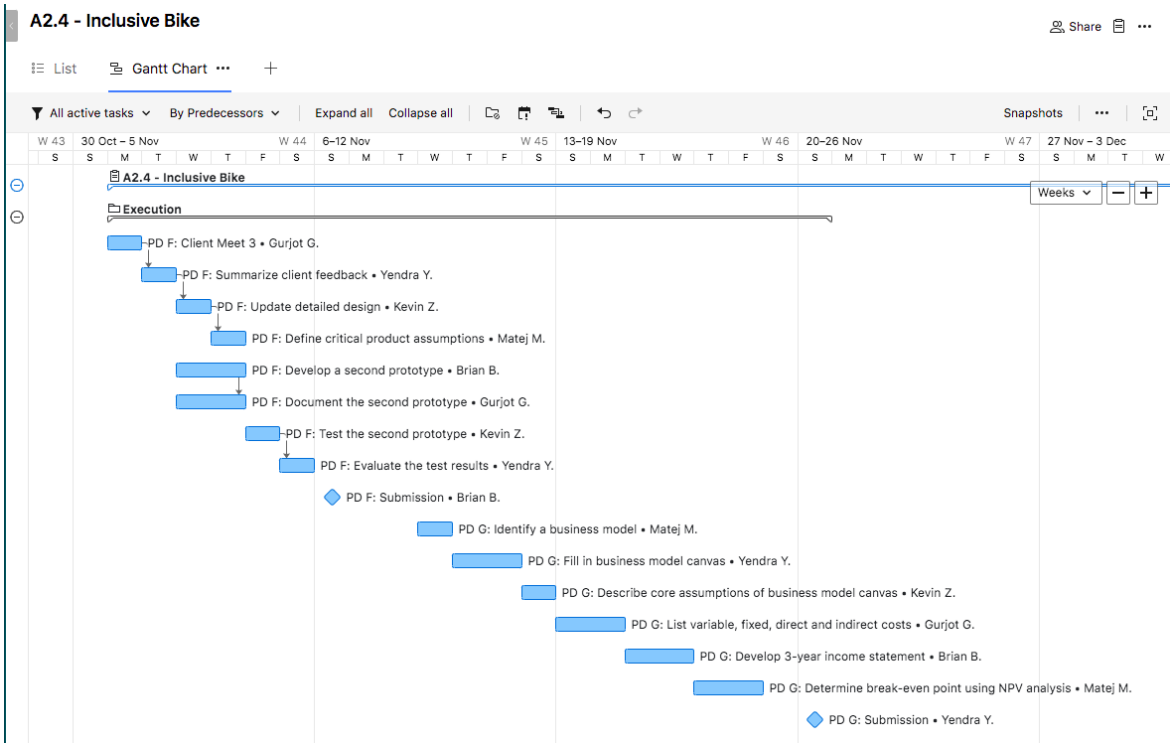

Figure 7.1: Updated Project Plan on Wrike

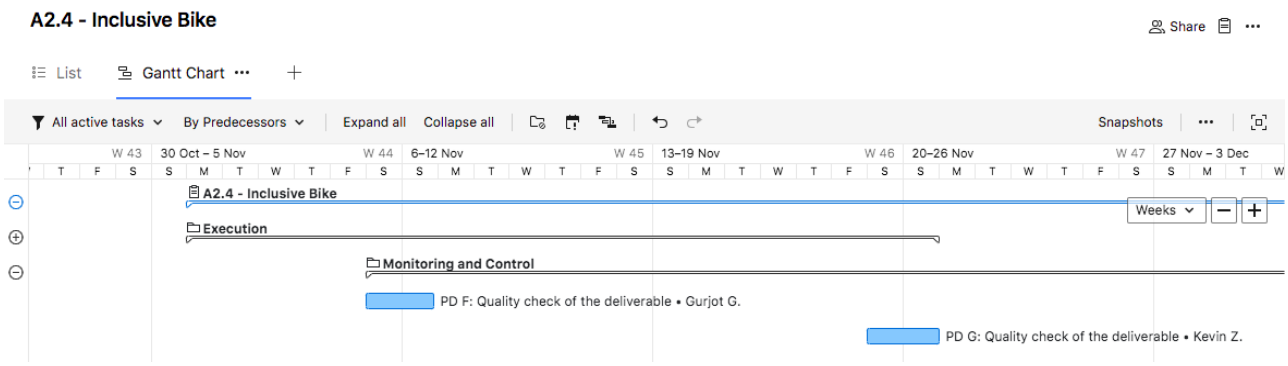

Figure 7.2: Updated Project Plan on Wrike