Project Deliverable C: Conceptual Design and Project Plan

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1.0 Introduction

Developing a concrete plan for how our project will be executed is a critical step at this stage of the design process. In this deliverable, we will be presenting a conceptual design for our device, which will allow us to create multiple prototypes before the end of the semester. We will begin by implementing the functional decomposition step, where we will break down the necessary product functions into basic sub-functions. Then, each member will think of and visually represent at least three possible concepts, either for the entire system or a subsystem of the product. Next, we will analyze each of these generated ideas, before selecting a few solutions that portray themselves as the most promising. The following step will then be to choose one concept, either a brand-new solution or an integration of the previously chosen ideas, that we wish to develop further in the design process. We will then tie our selected concept to the target specifications that were established in Project Deliverable B. We will also include an updated project plan using Wrike, and prepare a new set of questions for our next meeting with the client.

2.0 Functional Decomposition

Functional decomposition is a set of tasks that are needed in order to meet the needs of the client. Here, we will present the core functionality of our product by dividing the main functions associated with our device into simplified sub-functions. This will lead to concept generation, where various ideas will be generated for each sub-function that is presented in the below chart.

2.1 General Assembly Decomposition

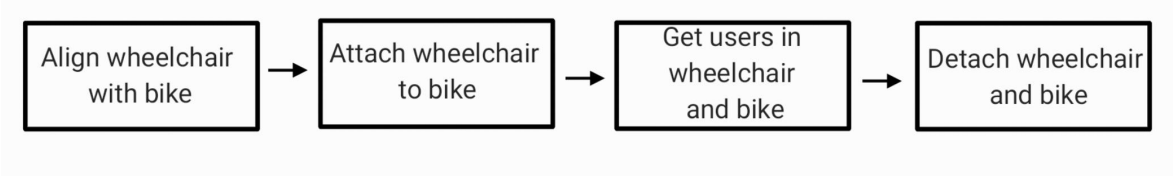

Figure 2.1: High-level decomposition of wheelchair-bike attachment device

2.2 Detailed Assembly Decomposition

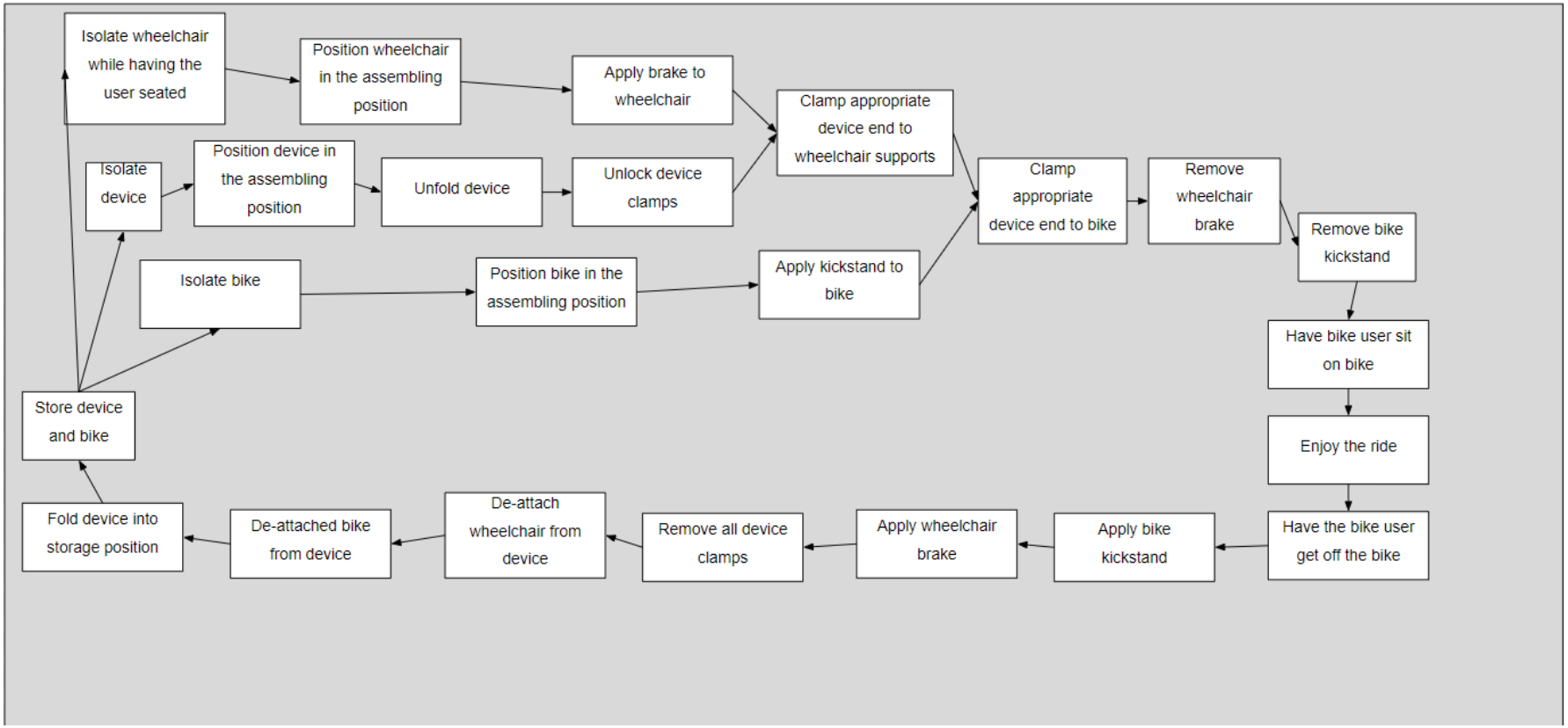

Figure 2.2: Detailed functional decomposition of attaching and detaching the wheelchair to the bike

Written Assembly Decomposition Steps

1. Isolate wheelchair while having the user seated
2. Isolate bike
3. Isolate device
4. Position wheelchair, bike and device in the assembling position
5. Apply brake to wheelchair
6. Apply kickstand to bike
7. Unfold device
8. Unlock device clamps
9. Clamp appropriate device end to wheelchair supports
10. Clamp appropriate device end to bike
11. Remove wheelchair brake
12. Remove bike kickstand
13. Have bike user sit on bike
14. Enjoy the ride
15. Have the bike user get off the bike
16. Apply bike kickstand
17. Apply wheelchair brake
18. Remove all device clamps
19. De-attach wheelchair from device
20. De-attached bike from device
21. Fold device into storage position
22. Store device and bike

2.3 Subsystems

1. Clamps
2. Main Frame
3. Flexible Joint
4. Safety Accessories

3.0 Concept Generation and Analysis

Based on the functional decomposition diagram shown in the previous section, the team will now present the product concepts that each member has come up with. These potential solutions, no matter how crazy they may be, are all included below, meaning that we have made this a divergent process as we want to generate a wide variety of ideas. The concepts are visually portrayed as either simple sketches, drawings or pictures, while a list of pros and cons is also included for each possible solution. This will aid us later on once we evaluate the possible solutions, where we will converge and select the ones that are the most encouraging.

3.1 Brian's Sketches

Concept #1:

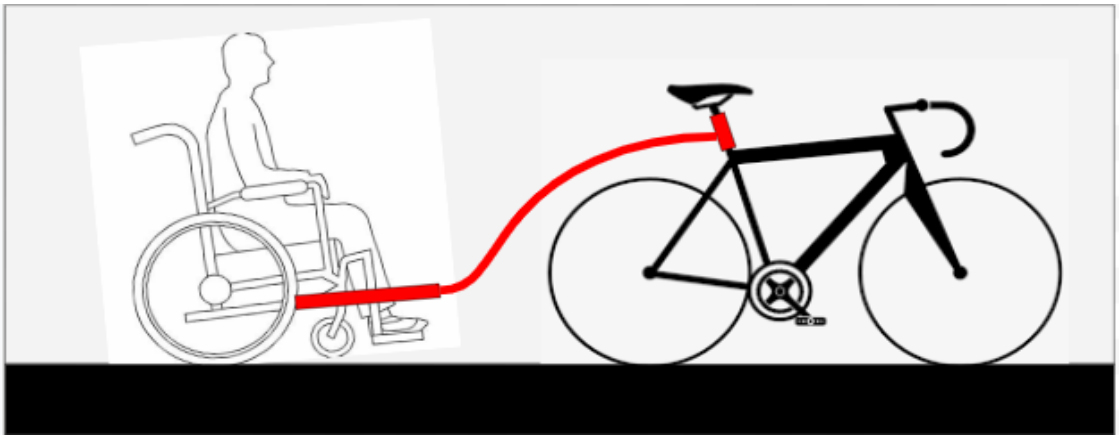

Figure 3.1.1: Brian's Concept 1 Sketch

Pros

- Strong frame attaches bike to wheelchair
- Easy to turn the bike while with the wheelchair attached
- Pulling wheelchair instead of pushing

Cons

- Wheelchair is at the back making it hard to give directions from the wheelchair

Concept #2:

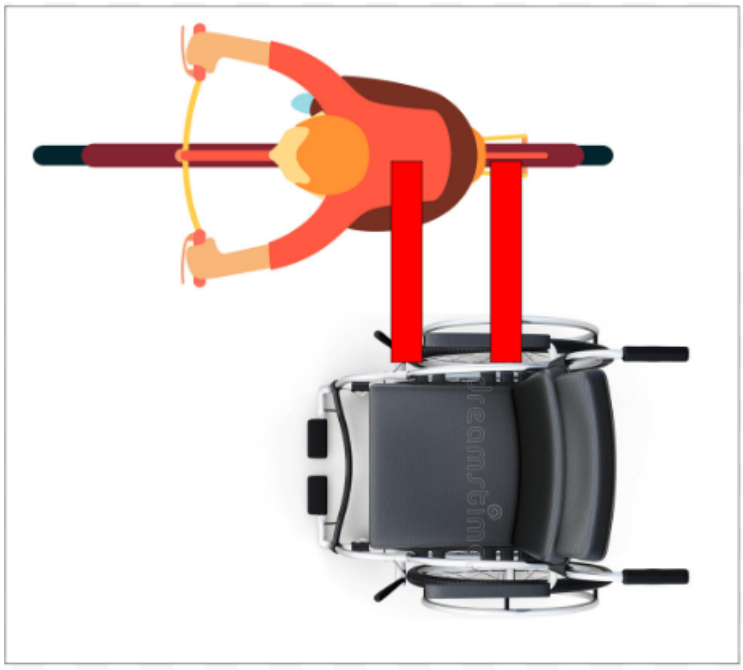

Figure 3.1.2: Brian's Concept 2 Sketch

Pros

- Wheelchair user can give directions on where to go
- Strong frame attaches bike to wheelchair
- Turning will be stable

Cons

- Might have trouble on certain paths where it is narrow

Concept #3:

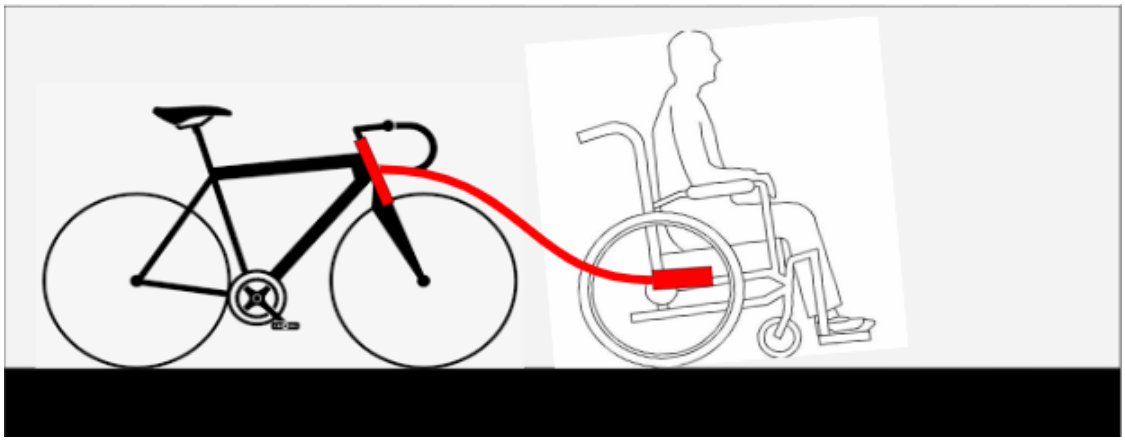

Figure 3.1.3: Brian's Concept 3 Sketch

Pros

- Wheelchair in front to allow person in wheelchair to give directions
- Strong frame attaches bike to wheelchair

Cons

- Harder for the bike user to push wheelchair and turn wheelchair

3.2 Gurjot's Sketches

Concept #1:

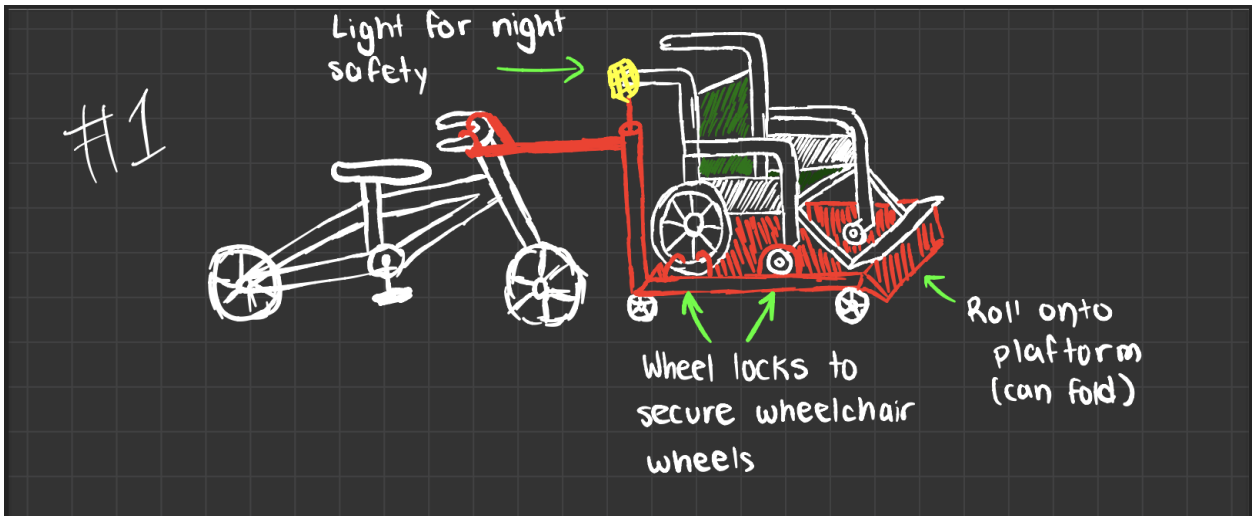

Figure 3.2.1: Gurjot's Concept 1 Sketch

Pros

- The first design is very secure as the wheelchair is secured on a platform. This allows for the wheelchair to avoid being damaged by any harsh terrain
- The wheels are also “locked” so it would not roll off the platform
- The safety is also increased by a light for night-time riding
- The wheelchair is at the front of the wheelchair allowing for a more exciting ride and makes it easier to give directions

Cons

- The design is very heavy which would require a lot of strength from the biker
- The direction of the wheelchair would be controlled by attaching the platform to the bike’s handles. This could prove to be difficult as the platform is large
- Higher cost implementation

Concept #2:

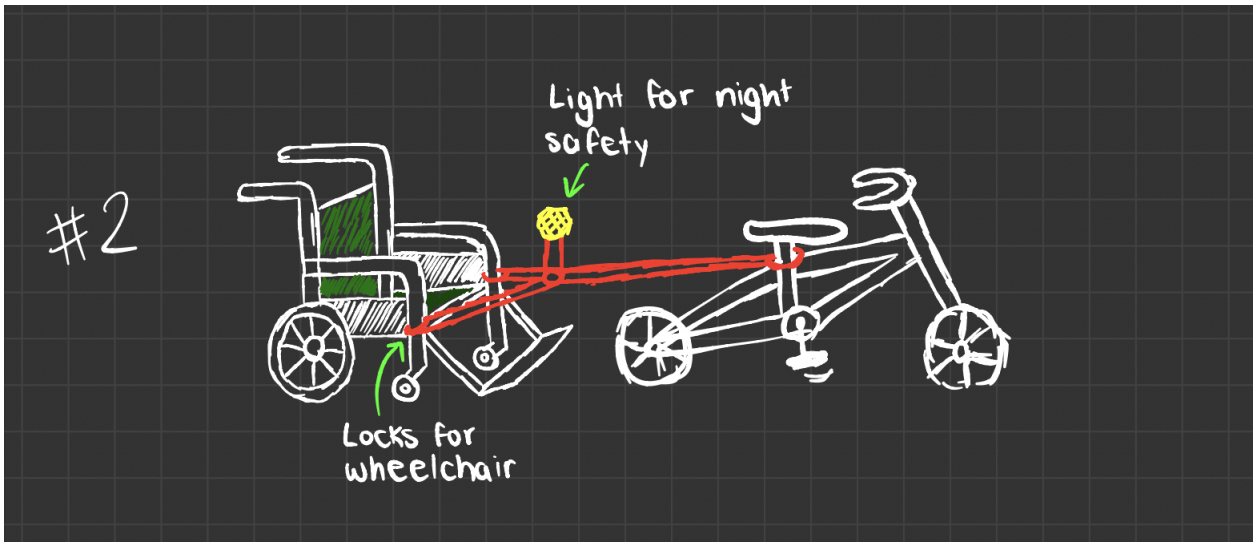

Figure 3.2.2: Gurjot’s Concept 2 Sketch

Pros

- The wheelchair is safely locked onto the bike, which will avoid detachment of any kind
- The safety is also increased by a light for night-time riding
- Easy to assemble

Cons

- The wheelchair is at the back which could block the view in front and make it harder to give directions
- Harsh terrain could cause for a bumpier ride

Concept #3:

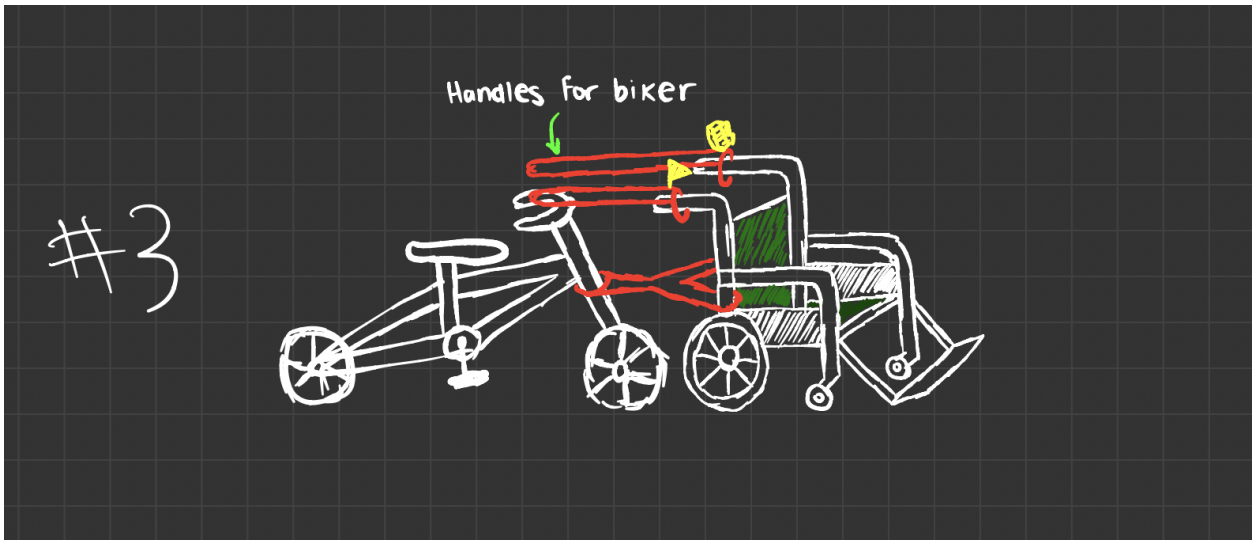

Figure 3.2.3: Gurjot's Concept 3 Sketch

Pros

- Easier to direct angle of wheelchair
- The safety is also increased by a light for night-time riding
- The wheelchair is at the front of the wheelchair allowing for a more exciting ride and makes it easier to give directions
- Easy to assemble

Cons

- Less security of wheelchair
- Harsh terrain could cause for a bumpier ride

3.3 Kevin's Sketches

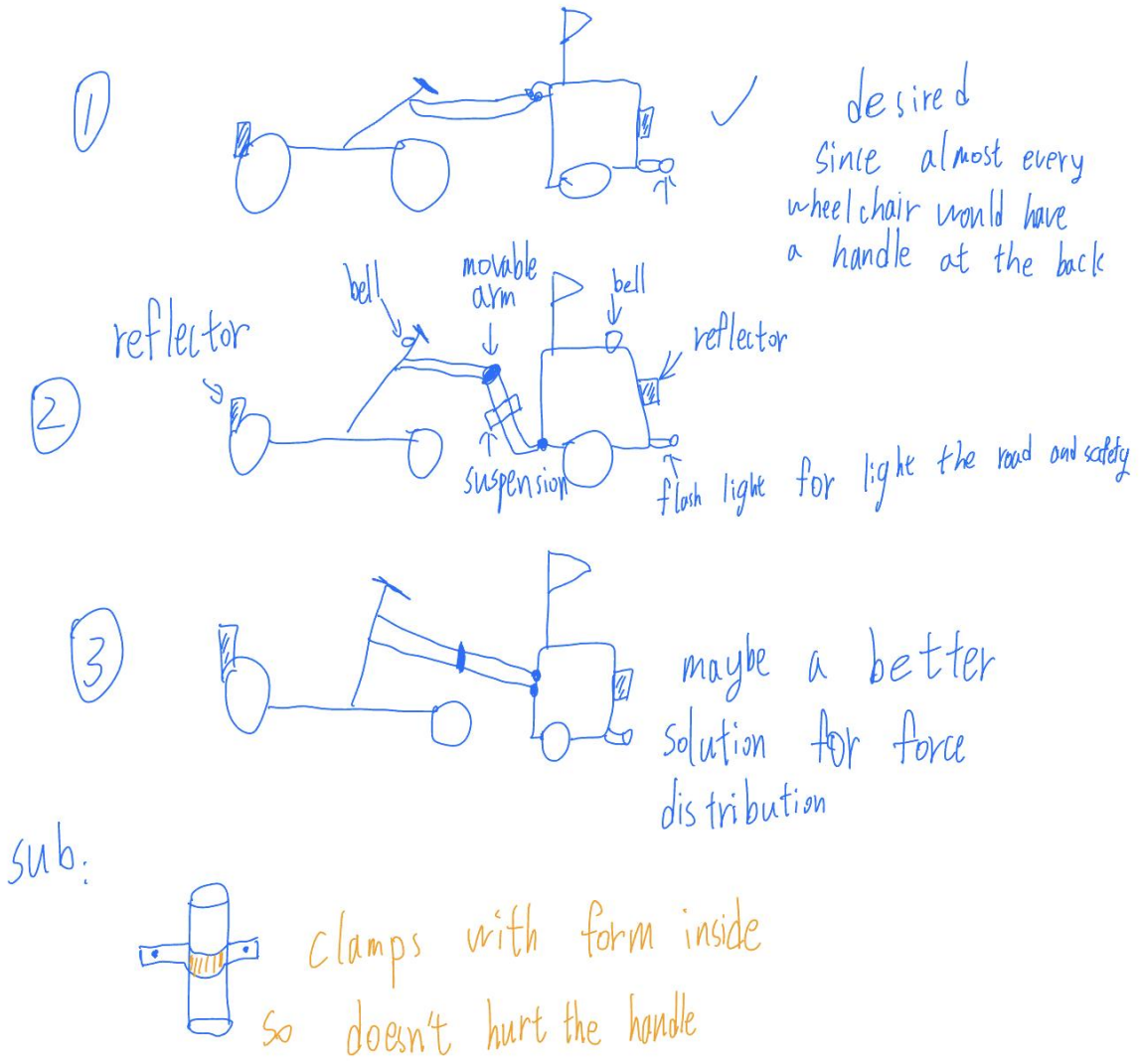

Figure 3.3.1: Kevin's Concepts Sketches

Concept #1:

Pros

- Concept 1 would be a better solution in universal uses, since almost every wheelchair has a handle at the back
- It is more budget friendly

Cons

- The force distribution of Concept 1 may not be very excellent

Concept #2:

Pros

- Concept 2 has a movable arm where the users can adjust the height of the arm for different wheelchairs
- A suspension is also wanted in Concept 2 to provide the user some possibilities to use their wheelchair on hilly terrains

Cons

- Concept 2 would be a bit more time consuming in the design process
- It may cost more money in the design process

Concept #3:

Pros

- Concept 3 is more excellent in force distribution
- Concept 3 would also take less time to implement
- It is more budget friendly

Cons

- Concept 3 lacks universal fitting for other bike and wheelchair models

All the concepts would come with reflectors on the front, side and the back of the wheelchair and the bike; a safety flag on the wheelchair; and a LED light in the front of the wheelchair for lighting the road in the evening and safety reasons.

A conceptual subsystem of the clamper is also introduced in the sketch above. A piece of sticky foam will be placed between the clamper and the handle, so the metal clamper would not hurt the surface of the handle, and it can clamp more tightly.

3.4 Matej's Sketches

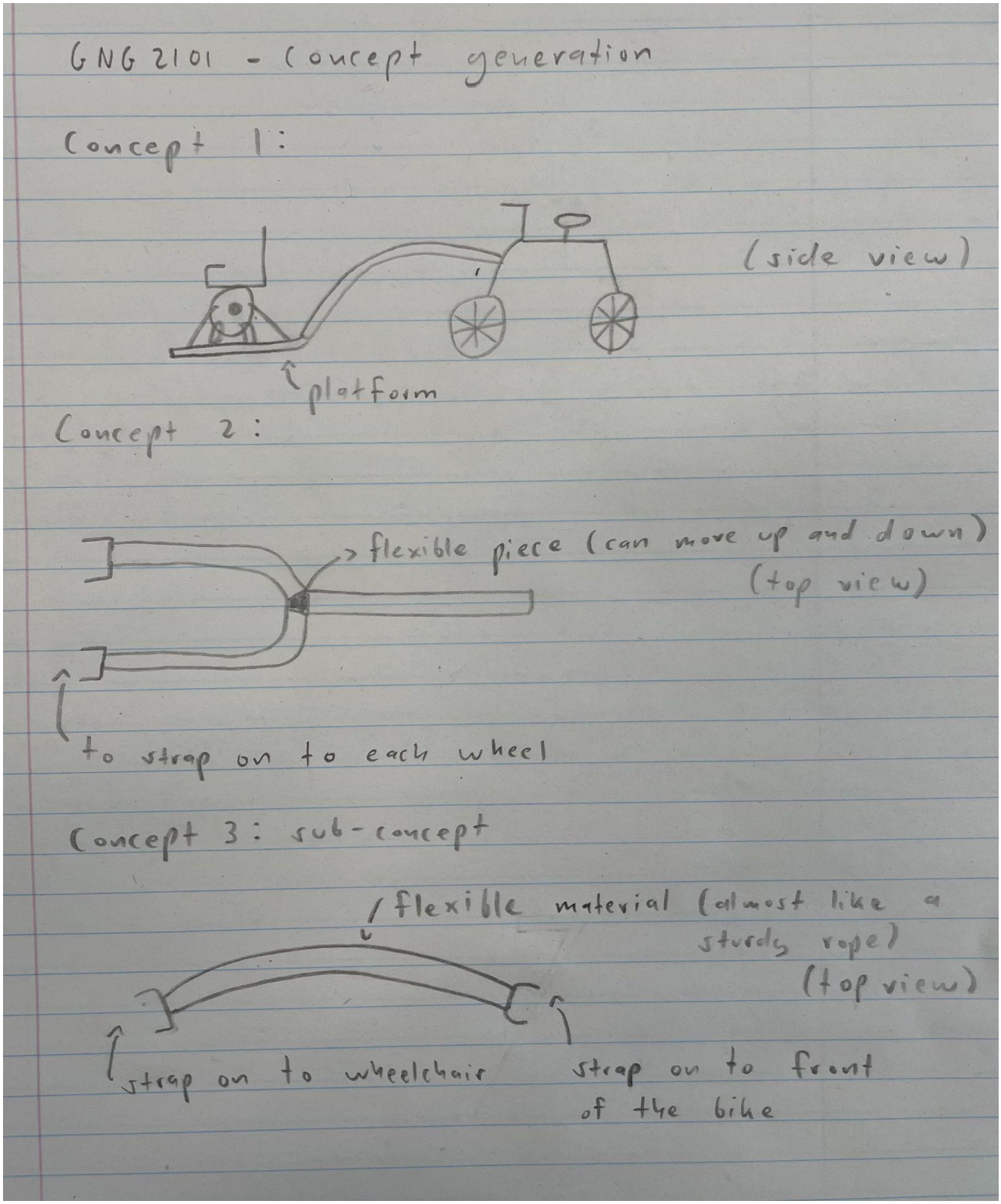

Figure 3.4.1: Matej's Concepts Sketches

Concept #1:

Pros

- Allows for a very sturdy and secure ride for the wheelchair user
- Short assembly time
- Wheelchair is located in the front, which is the preferred position of the user

Cons

- May be too heavy to actually implement (depending on the material used and the weight of the wheelchair user)
- May be difficult to store, and could take up too much storage space
- Might be expensive to create and implement, meaning it could surpass the maximum budget

Concept #2:

Pros

- Easy to store, assemble and disassemble
- When using this device, the wheelchair can be positioned in front of or behind the bike
- Relatively inexpensive to maintain and to manufacture

Cons

- It may be difficult to turn quickly without slowing down or requiring excessive force from the wheelchair user, if they are positioned at the front
- Bumpy terrain could cause a more difficult ride for the wheelchair and bike users
- Not very aesthetically pleasing to the human eye

Concept #3:

Pros

- Wheelchair user can be seated in the front, and can guide the bike user
- Very easy to assemble, requires limited storage space and little maintenance
- Likely the least expensive option, as it is the simplest and cheapest to manufacture

Cons

- Wheelchair user is not very well secured to the bike, so this may be the least safe option in practice

- The weight distribution between the wheelchair and bike users is relatively suboptimal
- The biker cannot pick up speed and pedal very fast, as they may lose control over the wheelchair

3.5 Yendra's Sketches

Concept #1:

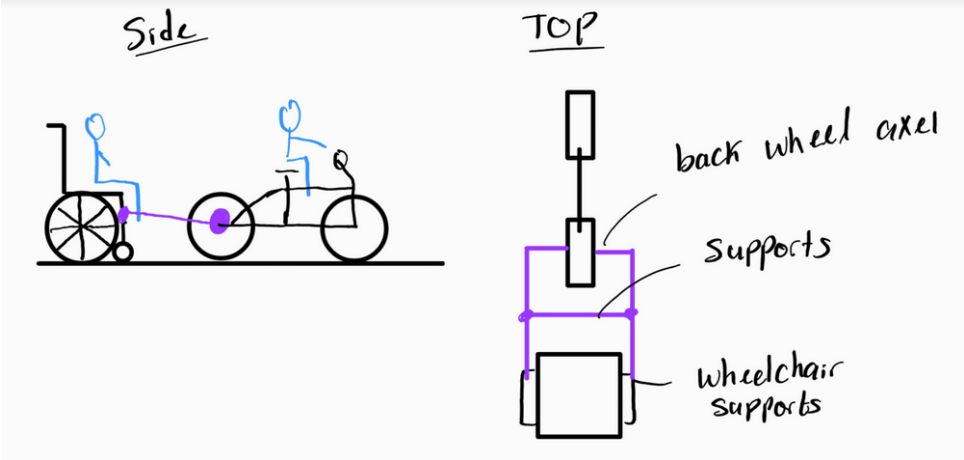

Figure 3.5.1: Yendra's Concept 1 Sketch

Pros

- Secure and sturdy design
- Simple to make
- Easier to perform turns when pulling the wheelchair user from behind the bike

Cons

- Client wants to sit in front
- Could be hard to secure the attachment to the bike gears

Concept #2:

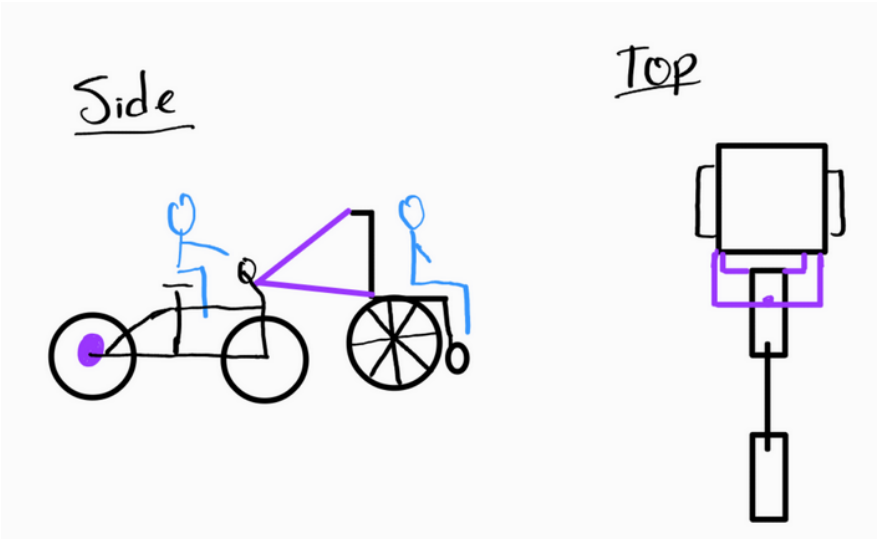

Figure 3.5.2: Yendra's Concept 2 Sketch

Pros

- Client is in front
- Attachment is secured onto more secure areas on the bike and wheelchair

Cons

- Turning could be a potential issue
- The bike rider would require a lot more force to push the wheelchair and user forward than if the wheelchair user was in the back

Concept #3:

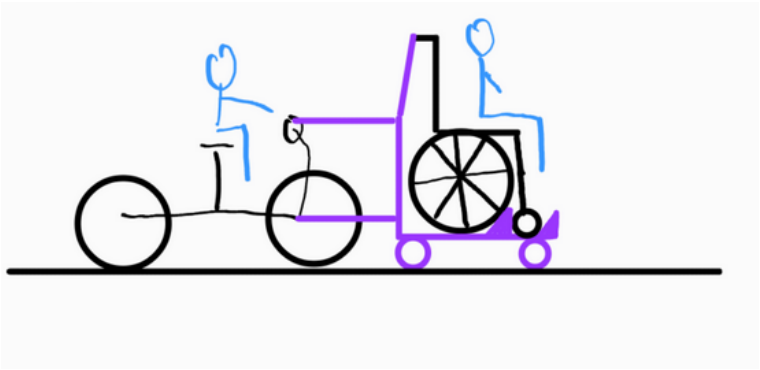

Figure 3.5.3: Yendra's Concept 3 Sketch

Pros

- Client is in front
- Platform is attached to bike handlebars to make turning much smoother
- Wheelchair user is much more secure

Cons

- If the wheel locks fail, wheelchair user can be thrown off the platform making it unsafe
- More complex design and requires more material and machining expertise
- The bike rider would require a lot more force to push the wheelchair and user forward than if the wheelchair user was in the back

4.0 Decision Matrix

Next, the team will analyze all of the concepts that were developed by the members. To do this, we will evaluate them based on the target specifications that were defined in Project Deliverable B. A simple decision matrix will be developed in order to obtain direct comparisons between the various concepts. Based on the previously established criteria that is shown in the below table, each potential design will be ranked from one to five, with 1 being the least desirable and 5 being the most desirable. The overall score, out of a possible total of 35 points, is portrayed in the far right column.

The scoring bases itself upon group discussion regarding the pros and cons of each member's concepts, signifying that the highest overall scores will be seen as the promising ideas. This type of mathematical simulation, although relatively simple, is extremely powerful as a decision-making tool. Since there are several types of target specifications that we are aiming to meet, we are able to evaluate the most effective solutions that seek to best meet our metrics, and therefore, the customer requirements. This is especially crucial for the following step in the process, where our team will need to narrow down and choose one concept that will be developed further.

	Metrics							**Score**
Concept	Cost	Attachment Weight	Maximum User Weight	Footprint Size	Maximum Safe Speed	Assembly Time	Aesthetics	Out of 35
B.B #1	4	4	3	3	3	4	2	23
B.B #2	3	4	4	4	3	3	4	25

B.B #3	4	4	3	3	2	4	2	22
G.G #1	2	2	5	2	3	5	5	24
G.G #2	3	4	3	4	3	3	3	23
G.G #3	3	3	4	4	3	3	3	23
K.Z #1	4	4	3	4	2	4	4	25
K.Z #2	2	2	5	2	3	3	4	21
K.Z #3	4	4	3	3	2	4	3	23
M.M #1	3	2	4	2	3	4	3	21
M.M #2	3	4	4	4	3	4	3	25
M.M #3	4	4	2	4	2	4	3	23
Y.Y #1	3	3	4	3	4	3	3	23
Y.Y #2	3	3	2	3	2	4	2	19
Y.Y #3	1	1	5	2	2	2	5	18

Table 4.1: Decision Matrix of 15 Conceptual Designs

4.1 Analysis of Decision Matrix Results

As is highlighted in the above table, the top scoring designs were B.B #2, G.G #1, K.Z #1, and M.M #2. Here are some of the common findings:

We've noticed that all of the high scoring designs were unique and different from each other. They all brought different strengths and weaknesses to the table. All of the designs made sure to take the difficulty of assembly as well as the time. Our clients need a design that does not require many or any tools at all to assemble. It should also be relatively quick to assemble, meaning it should meet the ideal value of around 5 minutes. All of the designs look sturdy and secure enough to safely transport the wheelchair and bike users in a safe manner. They all have an even center of gravity, making sure the weight is distributed evenly across the whole assembled design.

Some of the common negatives we have noticed amongst the winning designs were that none of the designs seem to be able to travel at faster speeds. This is mainly due to the fact that the bike rider has to pull the weight for two people. To counter this, the group design has to make sure that the attachment is secured to the bike in a manner that the bike rider has the optimal position to transfer and work done into actual motion.

The other common con that we have seen is that they all seem somewhat costly. It is important to make sure that we have a detailed plan and have made low fidelity models before making the detailed prototype. The team believes that it may be close, but we will be able to accomplish the design within the allocated budget of $150 (CAD).

Taking this information into account, the team has a solid foundation of positive and negative qualities which will aid in making an adeuqate, combined group design. We will be sure to take these factors into account when creating the group concept.

5.0 Group Design Concept

5.1 Group Design Choice

Following our in-depth analysis of our individual solutions, our group held discussions and has selected a design concept that we will move forward with. It was discovered that various group members had similar thoughts when it came to this idea, so it will be presented as a thorough integration of the encouraging proposals that were demonstrated previously.

We have decided that it would make the most sense to have the wheelchair pulled from behind, to make it more suitable for turning, as well as for the overall attachment assembly to fit within the average sidewalk width. We've also decided to use a bar with a clamping mechanism on both ends instead of a platform to help reduce the overall load for the cycler to push. We have also added the accessories that the client has requested as of now, which include a light, a flag and a bell. More details regarding our chosen concept are discussed below in Section 5.3: Group Design Analysis.

5.2 Group Design Representation

Below is a detailed sketch of our group design concept. The visual representations are paired with brief descriptions that explain the proposed solution.

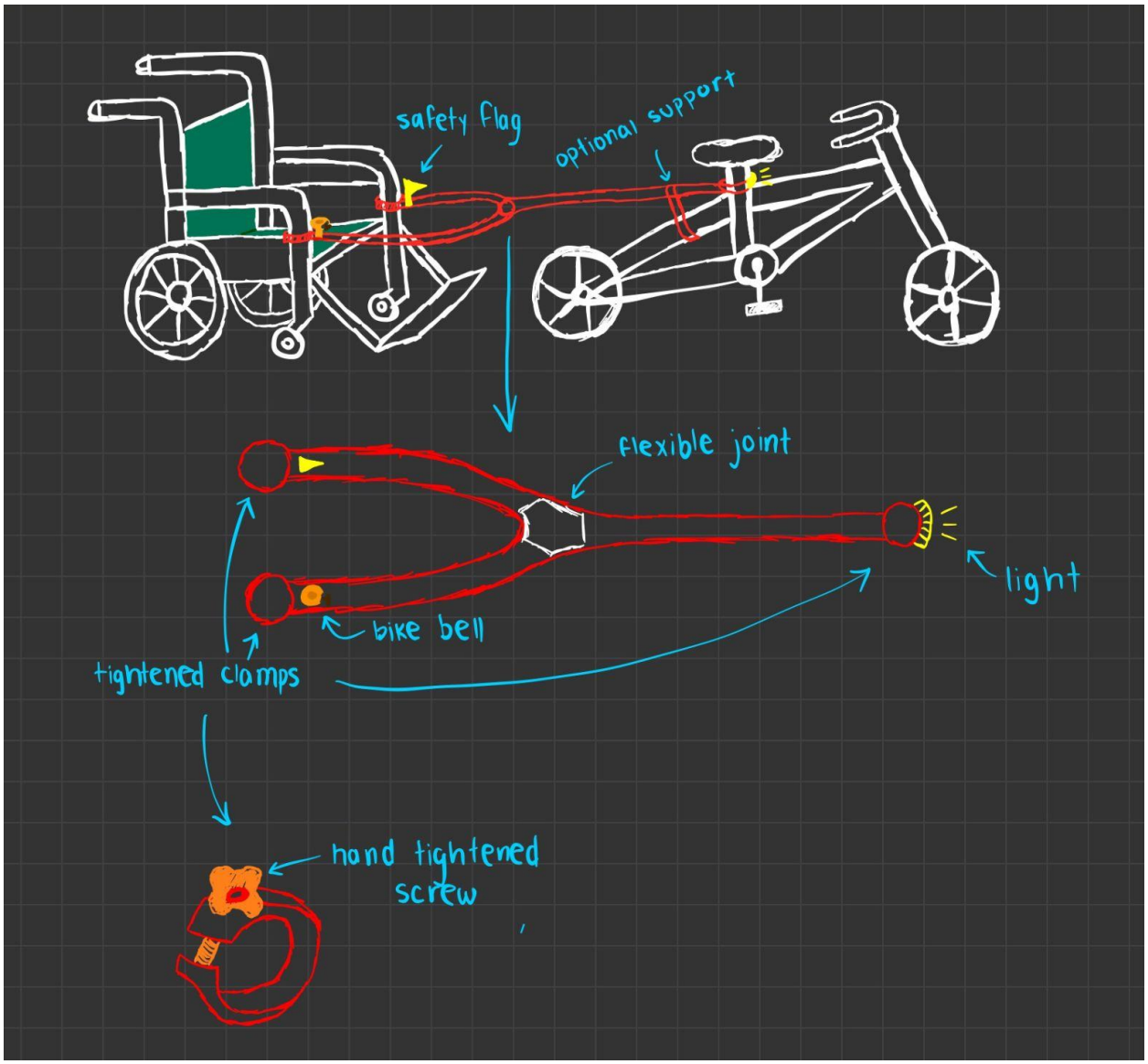

Figure 5.2: Group Conceptual Design Sketch

5.3 Group Design Analysis

As with every potential design, our group concept presents many advantages, but also some drawbacks that should be looked at closely. Some advantages include that this design is lightweight, easy to assemble and store, and can be manufactured in

a basic manner. It also provides the wheelchair user with a high level of security and sturdiness, meaning that the rider can feel in control while they enjoy the bike ride.

Taking a deeper dive into some of the pros of this design, having a lightweight attachment is essential to reduce the strain on the cyler. Ensuring that the joints from the wheelchair and bike are placed in the optimal locations allow for the cycler to be able to push the highest amount of load with the least amount of work.

Having a lightweight design also helps in the attachment assembly. A crucial need that we discovered during our initial client meeting was that the assembly of the attachment should be simple, quick and should not require any complex tools. For our design, we will attempt to use clamping mechanisms that can be tightened without the use of tools, to make the assembling process smoother. In turn, this also helps in disassembling the attachment when not in use and facilitates the storage of the device.

The final benefit of this design is that it is very intuitive and simple to manufacture. The team believes that it would not require any complex machining processes and would be able to be done in a safe and reliable manner.

With regards to the disadvantages that this design possesses, it would require the wheelchair to be positioned behind the bike as an additional safety measure. We believe that this would create a better overall center of balance, and the weight distribution would enable for easier turning. This is mentioned as a drawback because the client requested to sit in front of the bike - we plan to discuss this at the next client meeting. Furthermore, biking in bumpy, slippery or rugged terrain may cause a bit of a more difficult ride for the wheelchair user as well as the biker, and it is also noteworthy to mention that this design is not the most aesthetically pleasing to the human eye.

In many ways, our proposed design also relates to the target specifications that were defined in Project Deliverable B. Firstly, with regards to the cost, the team believes that we would be able to manufacture the design within the allocated budget of $150

(CAD). We will also aim towards having the attachment weight be less than the targeted marginal value of 6 kg: although steel, the material we will likely use for the final design, is heavier than a metal such as aluminum, it is incredibly durable. The simplicity of our design, as well as the amount of parts that we expect to manufacture it with, will contribute to this lightweight aspect. We believe with the use of a strong material such as steel, we would be able to transport a 90 kg load, which is our ideal maximum wheelchair user weight. The use of a hand-tightened clamping mechanism will help keep assembly time low and well within the five minute ideal value. With the lights, safety flag and other visibility precautions, we strongly believe that a car would be able to see the riders within a distance of twenty meters.

6.0 Client Meeting Preparation

Since our last meeting with the client, we have progressed through the concept generation stage and have concentrated ourselves on a few encouraging ideas. Our plan is to present these main ideas to the customer, and to obtain valuable feedback, which can be used to fine tune our design. We have prepared a slideshow to present to the client, so that our team is able to visually show our selected ideas. Furthermore, in order to validate some of our metrics, we plan to 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. What is your opinion about being seated to the side of the bike rather than the front or back?
4. How big of a space do you have to store the attachment?
5. Can we see the bike that you plan to use?
6. Are we allowed to measure the dimensions of your wheelchair? Do you have the model name of the wheelchair?
7. Other than a flag, bell and lights, do you have any additional accessories you would want us to add to the device?
8. What is your favorite overall design? Why do you like it the most?

7.0 Conclusion

Based on the group's conceptual designs, we have put forward the most ideal solution by assembling the best bits and pieces and excluding the least desirable ones. We plan to show the client the chosen design in detail, along with a few other promising proposals, in order to get direct feedback. Taking the client feedback into consideration, we will incorporate the necessary changes into our group design. We will then create initial CAD models to assist the team in establishing a Bill of Materials (BOM). This will also allow us to develop the initial, low fidelity prototype. This product has the potential to revolutionize the way wheelchair users get around and relax in their leisure time.

8.0 Wrike Project Plan

Our team has updated our project plan on Wrike based on the feedback received from Project Deliverable A. We have included detailed sub-tasks based on our new understanding of the project, as well as milestones and dependencies between these tasks. Our up-to-date Gantt chart contains these in-depth tasks for approximately the next two weeks, and we will be continously updating our plan on a weekly basis to include it in our deliverables for the rest of the semester.

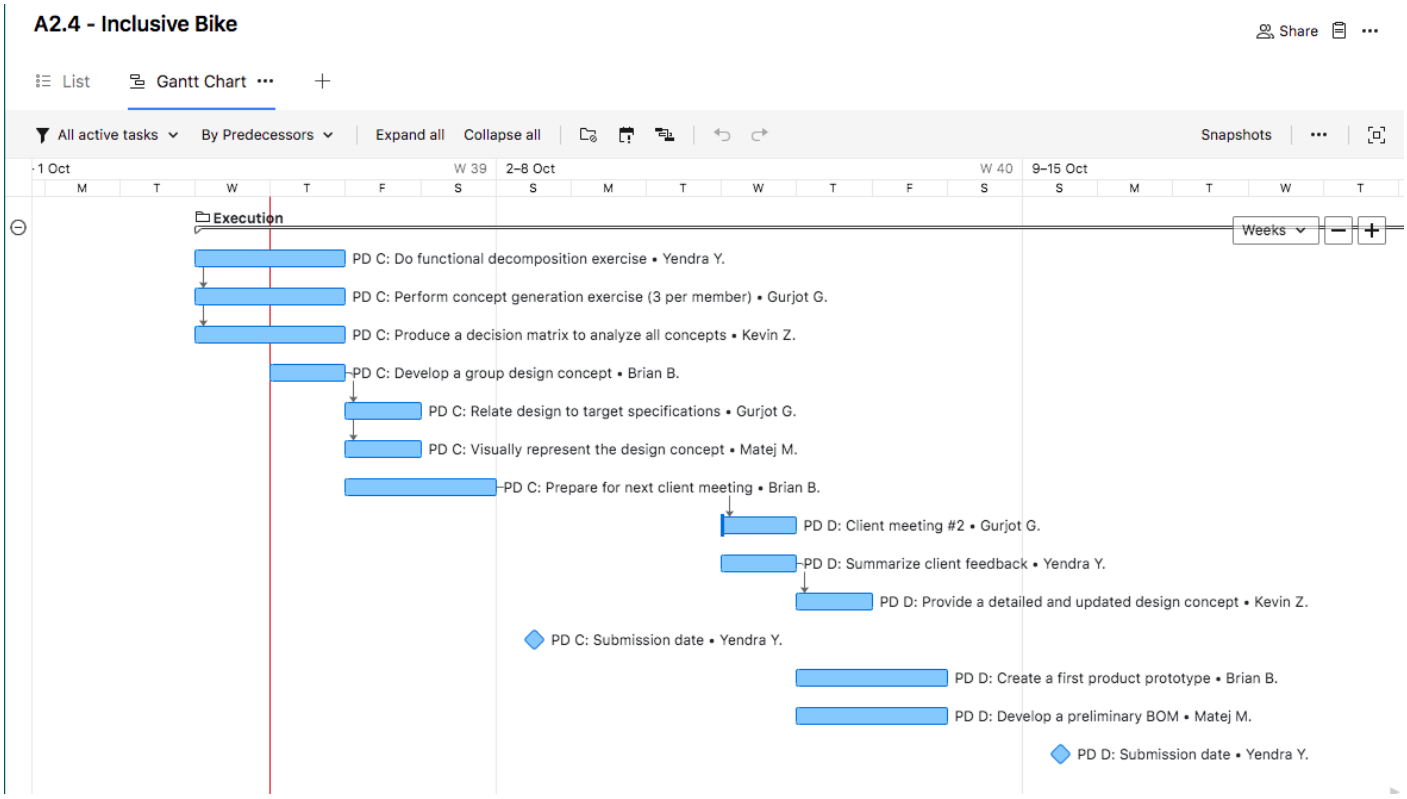

Figure 8.1: Biweekly Project Plan on Wrike

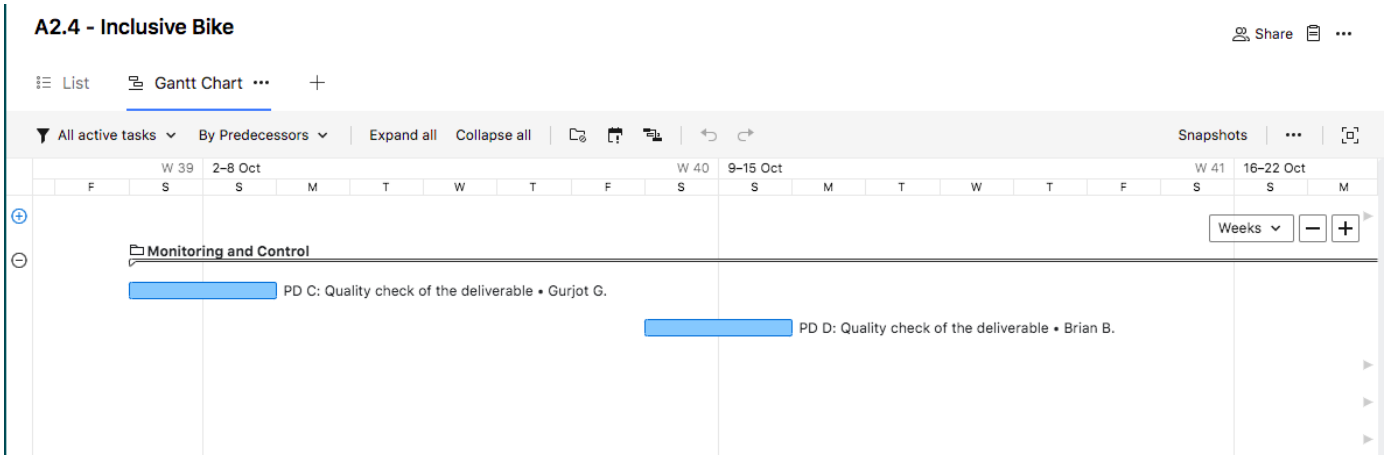

Figure 8.2: Biweekly Project Plan on Wrike