# Team Deliverable E

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## Introduction

People all around the world face different types of disabilities which affect their day-to-day tasks. Currently there are existing and developing devices to help people with disabilities to not worry about their limitations and live a 'regular' life. However, there is always room for more improvements and innovations to ease daily tasks. The client is a company of occupational therapist that are looking to facilitate the lives of their clients. Currently, they are looking for an adaptive care tool to mitigate the difficulties of people with mobility limitations. This project will aim to aid people with mobility disabilities, specifically to allow them to take care of toddlers and children. Ideally, the stroller and walker combo will ease the user's life while being as discreet and efficient as possible. The tool will allow the user to navigate and complete their childcare tasks despite their limitations.

This report consists of 6 main sections: design constraints, updated detailed design, client feedback, prototypes, prototype testing and updated project plan. In the design constraints section we will identify various non-functional design constraints that play a role in the development of our prototypes. In this section we will identify the design constraints, discuss various changes that should be made in our design to satisfy the constraints and provide proof demonstrating how making these changes effectively satisfies the constraints. The client feedback section will provide a reflection on our most recent client meeting and highlight some of the main takeaways to be considered moving forward. Next, the detailed design section will present an updated detailed design of our concept in response to the feedback received in client meeting, and in response to the identified design constraints. In the prototype section we will document the second round of prototypes developed to test critical assumptions. These prototypes will be documented through sketches and images taken of the physical models. In the prototype testing section, we will carry out prototype testing to analyse and evaluate the performance of each prototype compared to the target specifications. In this section of the report, we will document our findings in an organized table. Finally, an updated version of our project plan will be included, outlining the next steps of our project.

## Design Constraints

Functional requirements define what a system is supposed to do and non-functional requirements define constraints which affect how the system should do it. Non-functional design constraints also play a role in guiding functional requirements. They work together to ensure that the system not only works but also meets the needs of the users and our clients. The two non-functional design constraints that play a significant role in the development of our prototypes are safety and usability.

We chose safety as one of the non-functional design constraints because our design must safely sustain the weight of an adult and the weight of a child. Our design must prioritize their safety when the stroller is being braked, being pushed, and at a complete stop. Safety is an important non-functional constraint for us because the implications of neglecting this can be deadly. It is also important to consider that our device will be used on different terrains in different weather conditions. The adult and the child should be safe no matter the environmental conditions. It is important that our design makes the ride comfortable for the child and the adult.

Table 1. Design Constraints

| | **Subsystem / part** | **Safety considerations** | **Proposed changes** |
|---|---|---|---|
| S1 | Braking | Make sure the brakes and locking mechanisms work well | Extensive testing at varying speeds |
| S2 | Seating System | The system must be always in total balance. No tipping. | Add the seat to the back of the stroller |
| S3 | Full/Slow Braking | Make sure that they are visible and in an obvious spot | Add a color indicator for the brakes and place it in an obvious spot |
| S4 | Wheels | Make sure that the wheels are attached securely | Extensive testing in varying environments |
| S5 | Packaging | Make sure that the device come with instructions of use. | Add clear weight limits to instruction manual |
| S6 | Full system | Make sure that if the adult sits down or hangs a bag on the device, it does not tip over. | Add horizontal support bars to counterbalance weight |
| 7 | Storage space | Ensure that the system has adequate space to store emergency items for the baby | Add a basket to the walker that is easy to reach for emergency situations. |
| 8 | Walker | Ensure that the adult always has full control of the device no matter the weather. | Add extra hand grips on the handles for the adult to grab onto in rainy weather |

Additionally, we chose usability as our other non-functional design constraint because our design must be easy to use for an adult with mobility, stability, and endurance difficulties. It must be intuitive and non-bothersome for the user. If this non-functional constraint is not met, we would not be helping the user but adding to the challenges they already face. Usability also includes the constraint that the device should be easy to maneuver.

Table 2. Usability Considerations

| | **Subsystem / part** | **Usability considerations** | **Proposed changes** |
|---|---|---|---|
| U1 | Slow Braking | Ensure the brakes can perform its required functionality quickly | Have 2 brakes that work independently.<br><br>Add a bike brake for each handle instead of just one to allow for advanced steering |
| U2 | Full Braking | Ensure the braking functionality is intuitive | Add full stop breaks to rear wheels only |
| U3 | Packaging | Ensure that first-time users can easily and quickly understand the basic navigation and functions | Add a succinct and easy to use manual or quick steps tag |
| U4 | Full System | Ensure adequate error tolerance: What errors do users make, and how severe are they? How quickly and easily can users understand and recover from those errors? | |
| U5 | Full System | Ensure the device is easy to maneuver | |
| | | | |

3. Provide proof (e.g. analysis, simple calculations and/or simulations, research) to demonstrate the effectiveness of your changes in satisfying the constraints. Justify the process and methods you used.

**Proof of Safety**

file:///Users/ifeoluwaoyetoran/Downloads/A_Guideline_for_the_Design_of_a_Four-Wheeled_Walke.pdf

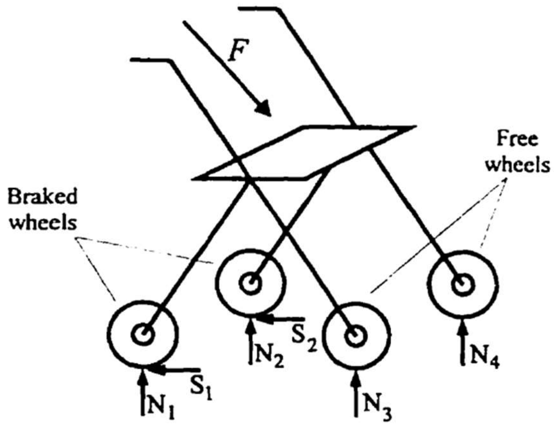



Figure 1. Force Diagram of Wheels

**Adding The Seat to the back of the Stroller to avoid tipping**

To prove that having the seat at the back of the stroller instead of the side will be better for safety, we will conduct a linear displacement analysis on the walker legs. This involves relating the moment (M) to the moment of inertia (I) and the angular acceleration (α):

$$M = \frac{I}{\alpha}$$

Assume the displacement of the wheels from the ground to be linear since they only rise 2 cm over a 45 cm base. The mass distribution of the walker is approximated by five lumped masses totaling 10 kg (22 Ibm.) If a moment of 4.5 N m is applied about the contact point between one set of wheels and the ground. the linear and angular displacement of the other wheels can be compared.

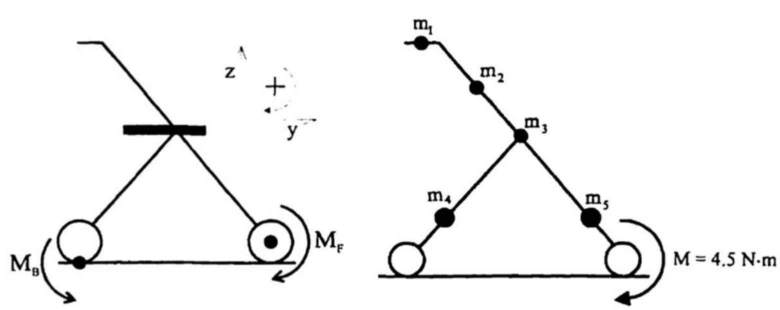



Figure 2. Moment Diagram of Wheels

**Proof of Usability**

U1 – Adding a brake for each handle on the stroller for advanced steering.

The left and right brake levers apply the brakes independently to each side of the walker. Pull up on the left hand lever, and you apply the brake on the left wheel. Pull up on the right hand lever, and you apply the brake on the right wheel. To slow the walker down while moving in a straight line it is important to apply both brakes equally. If you use only one of the brakes, or use one much more so than the other, the walker will turn to the side with most of the brake force applied. (See "How to use the brakes to make tight turns" below to use this as an advanced steering technique.)

Because the brakes on a rollator work independently of each other, there is an advanced steering technique you can learn to help you make tight turns. If you would like to make a tight left turn then apply only the left-hand brake while keeping the right side un-braked. This will cause the walker to pivot sharply around the braked wheel, resulting in an extremely tight turn. Likewise, if you need to make a sharp right turn, apply only the right brake.

## Client Feedback

During our most recent client meeting, we presented our updated detailed design in response to the feedback received in previous client meetings. Additionally, we were able to present the various prototypes we developed and discuss results obtained from prototype testing.

During our client meeting, we presented our folding and adjustable chair design where the seated part of the walker can be folded up and attach to the side of the stroller when not in use. The client praised the idea of seating beside the stroller, rather than behind the child and mentioned that this concept hadn't been brought up yet. We presented the "Seat Testing" prototype we developed to test the feasibility of having a seat that adjusts in height, this prototype is highlighted in figure 4. The client appreciated that we researched the average height of the user, average height of chairs and considered possible mobility restrictions that the user might experience and how this may impact them seating and lifting from the seated position.

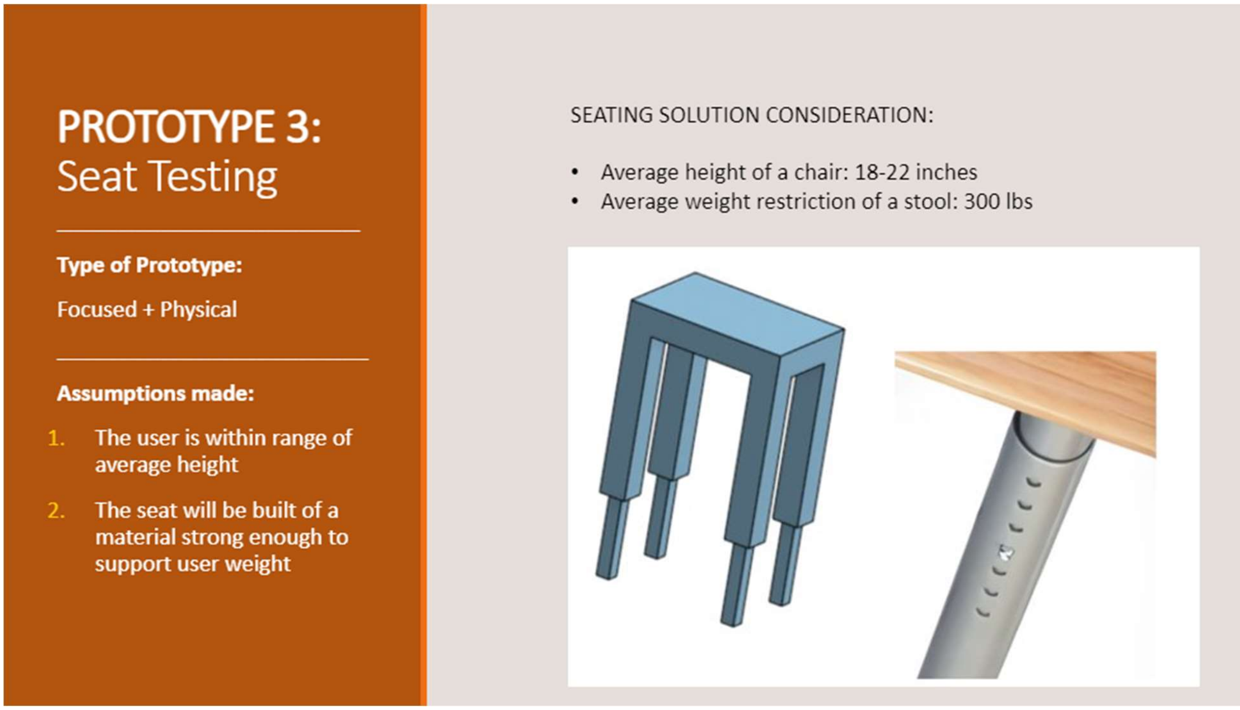


Figure 4. Seat Testing

In our meeting, we also presented the force analysis and physical testing we performed on the hand brakes (Figure 5. Force analysis, Figure 6. Physical Testing of Hand Brakes). When in the brainstorming stage of the design process, we researched different braking systems and concluded that a hand brake (like that on a bicycle) would be the most feasible and reliable option for our system. When researching different types of hand brakes, we discovered that different amounts of grip strength would be required to “trigger” the brakes, depending on the orientation of the brake with the handle (as seen in Figure 5). At the end of the client meeting, we were able to ask some questions to the client to ensure we were proceeding on the right track moving forward. One of the questions we asked was “how much grip strength does the average user have, and are their any hand mobility challenges that may make it difficult to use a hand brake”, the client confirmed that the typical user should be able to physically “trigger” the hand brake, and some are even using hand brakes in their current walker / mobility systems. In figure 6, Physical Testing of Hand Brakes, we attached a bike brake to a shopping cart wheel to test that a typical bike brake would be capable of slowing the movement of a large body such as a cart or a stroller. Further, this prototype helped us conclude that a bike braking system would be able to attach to a larger wheel, like that of a shopping cart or a stroller.

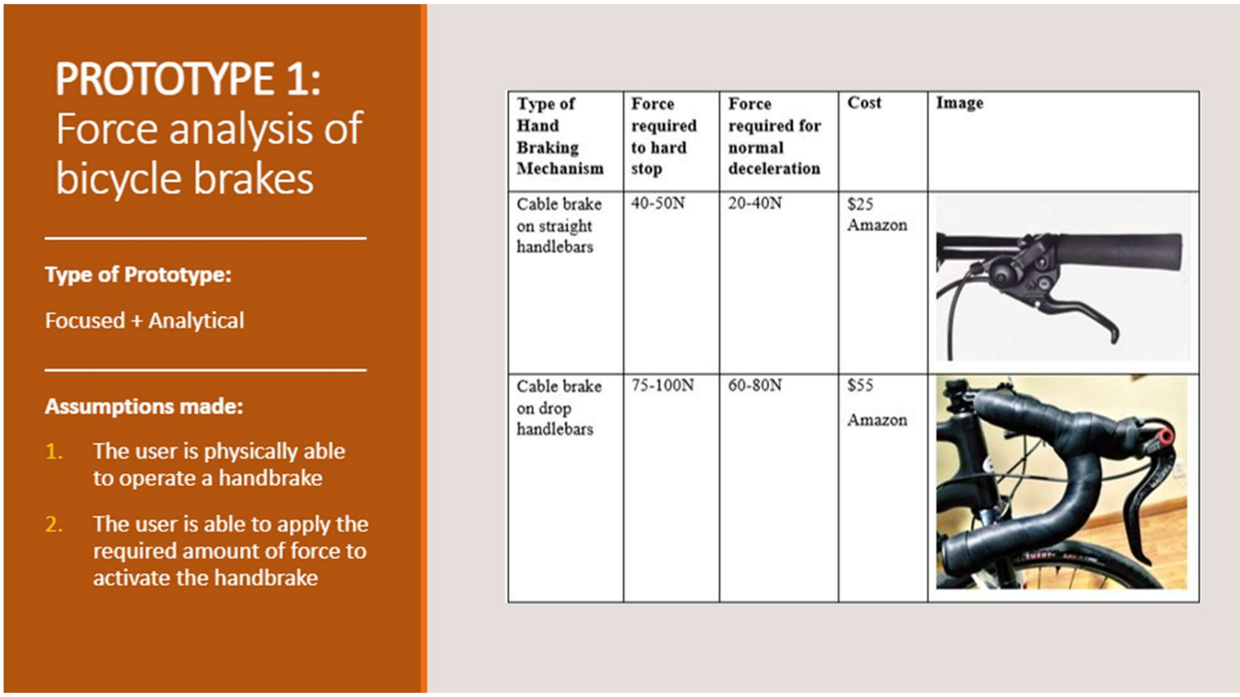



Figure 5. Force Analysis of Hand Brakes

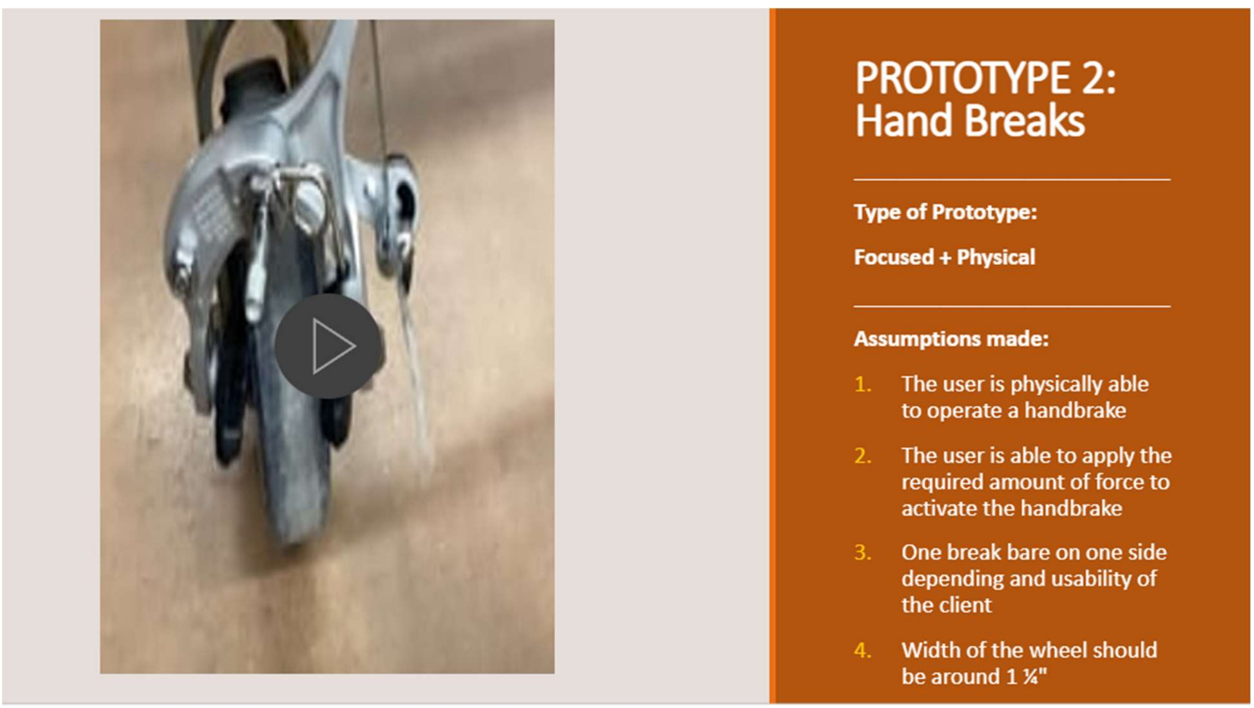



Figure 6. Physical Testing of Hand Brakes

As a follow up to our previous client meeting, we presented our updated junction and connection design. During client meeting 2, the client expressed concern about the strength of our proposed junctures as the user would be applying much of their body weight onto the supports. We took this feedback and considered different materials that could be used to construct the “Walker” component of our system. Figure 7. Shows our updated proposition, PVC pipe connection pieces to build up the walker components. We selected PVC junctures as they can be purchased at a reasonable price, and can connect together to build the walker structure we need. The client was receptive to our idea and liked the idea that the PVC junctures could be purchased in bulk (from a manufacturing standpoint) and locally to them.

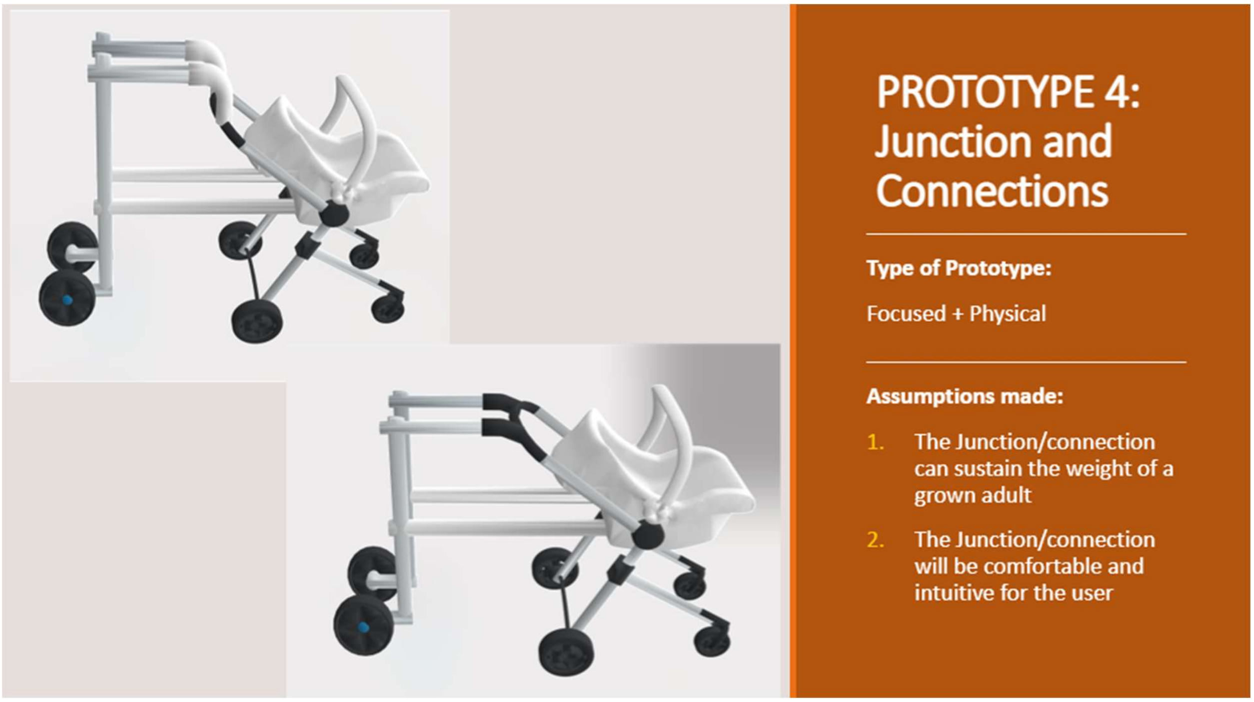



Figure 7. Junctures and Connections

Finally, we presented a comprehensive, physical prototype encompassing all the main features of our design. The popsicle stick prototype featured in figure 8 allowed us to better understand cohesion between the system components and show the overall vision of our design to the client.


Figure 8. Comprehensive Prototype

After discussing our design process thus far and presenting our detailed design to the client, we were able to ask some questions to ensure we proceed on the right track moving forward. We asked about what mobility limitations the user may be experiencing and if this will inhibit them from using the seating component comfortably. The client expressed that the user should be able to seat and stand up despite their mobility concerns, but that adding an aid such as a handle may be beneficial for added support. Additionally, we discussed ethical constraints of our system, and if there were any ethical considerations that we hadn't taken into consideration. The client expressed appreciation towards the question, and valued that we were taking on an ethical lens in the design process alongside the technical perspectives. The client suggested that in the next steps we focus our attention on stability, and ensuring that all the components of the system are secure. The client liked the various elements we've presented for our system, but wanted to makes sure the components would be fully secure and safe for a real user.

Overall, the response from the client during our most recent client meeting was positive, assuring us that our design meets the project needs as we move forth in the design process. One main advice given from the client was to keep in mind mobility and stability of the system (eg. Smooth turning, navigation of curves, uneven terrain and ensuring all components are secured together in a secure and safe manner) as we move forth in our concept development.

## Updated Detail Design

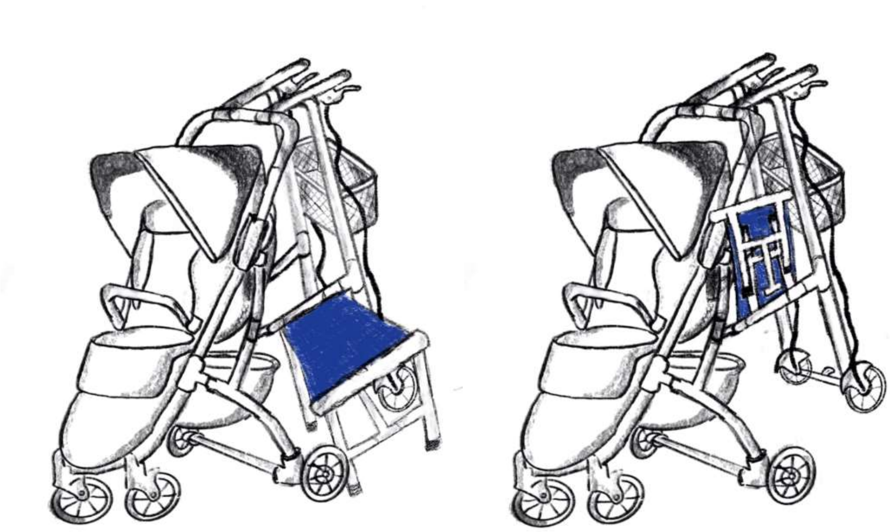


Figure 3. Updated Detailed Design

The client's feedback was positive and not many changes were necessary. It was emphasized that we should focus on functionality over aesthetics. As a result of the comments made by the client, extra storage will be added in the second stage of prototyping, if after the main aspects there is still resources (time and money). Additionally, to test functionality of our design, the next prototype will have a walker component made of PVC instead of the ideal end material, steel. We decided to build this component out of PVC to save on costs, weight, and eliminate the need of welding materials together. Additionally, the portable chair will be moved forward to reduce length of device and to be closer to child. Both the chair and stroller were bought to adhere to FDA specifications and ensure the safety of both the adult and child.

## Prototypes

After developing prototypes for brake analysis, seat testing, juncture and connection strength testing, and a comprehensive prototype to present the cohesion between the various elements of our system, we've begun the development of our physical, fully functional, and comprehensive prototype.

The main purpose of our physical comprehensive prototype is to show how the various elements of our design correlate together, and test the usability of the system as a while. In the development of our prototype, we purchased a stroller to simulate one that the customer would already own, as well as materials to construct the walker and seating component of our system.

The walker supports on our prototype were constructed out of PVC pipes. While PVC doesn't have the same weight bearing capabilities as a metal (eg. Steel), for the purpose of developing a simulating and cost-effective prototype, we chose to use PVC instead. In deliverable D, we presented a force analysis of the junctures, and were able to confirm that using PVC pipes and junctures would be suitable to support the weight of the typical user, and would be sufficient in our comprehensive prototype. Further, we connected the PVC components together using PVC junctures. While an alternative method to achieve the specific angles and bends we wanted in the PVC pipe was to heat treat and bend the PVC plastic… using prefabricated junctures allowed us to achieve the same result, while conserving time.

In the construction of our prototype, we noticed that the PVC pipes bent slightly when weight was put upon them. This posed a significant concern as the purpose of the walker component is to provide support and allow the user to rest their weight. When we noticed this design flaw, we considered various methods of increasing support, such as changing the PVC pipes to metal, purchasing a predesigned walker, or filling the PVC pipe with a supporting material. To increase the rigidity of the walker supports, we filled the PVC pipes with metal rods. The metal rods made it so that the walker supports wouldn't bend when load was applied and increased the weight of the walker component, thus, increasing the overall stability of the system.

At the bottom of the walker supports, we've included medical grade walker wheels. We wanted to incorporate wheels to the walker component to allow the user to roll the entire system, rather than having to lift the walker section while pushing the stroller. Further, we were sure to implement medical grade wheels as these have been used on similar supporting systems (ie. Walkers) before and give us security in knowing that they will be just as supportive in our design. By attaching wheels to the walker supports, this allows the user to roll the entire system, and tackle any terrain they may encounter.

At the side of our system, we attached a foldable seat to give the user a place to rest if need be. As mentioned in previous deliverables, we attached the seat to the side of the system (rather than the back) so that the user was facing the same direction as their child, and could tend to the child if need be. The foldability of the seat was an asset, as it allows the user to fold the seat up and out of the way when not in use. To attach the seat to the system, we first fastened the seat to a metal plate that would be able to support the weight of the user, then fastened this plate to the side of the stroller. By attaching the seat in this two-step process, we were able to ensure that the seat was properly attached, and at a suitable height for the typical user.

Finally, we attached hand brakes onto the system to give the user a method of slowing and stopping the system if needed. In Deliverable D, we performed force analysis and a physical testing of hand brakes to confirm that a traditional hand braking system (like that on a bicycle) would be 1. Able to slow / stop the motion of the system 2. Would be easy to use by the user. The hand brakes are attached to the walker supports close to where the hands would rest, and can be pulled easily in need of emergency. The brake pads attach to the wheels of the stroller, to stop the motion of the whole system in a smooth manner.

## Prototype Testing

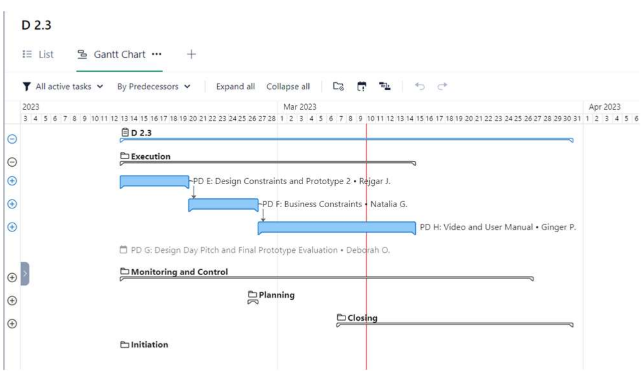
Building our physical, comprehensive and fully functional prototype, we encountered various design challenges that we were able to learn from during the process. For example, when constructing the walker supports, we discovered that hollow PVC pipes weren't rigid enough to support the weight of a user. To increase the rigidity of the supports, we filled the pipes with metal rods that are 1. more rigid than the PVC and would resist bending stresses and 2. Heavier than the PVC, increasing the weight of the system, thus overall stability. Secondly, in constructing our prototype and actually seeing the materials of our BOM in real life, we realized that while materials such as PVC were more cost effective to use in our situation, using stronger and more rigid (while more expensive) material such as metals, might be more attainable by the client and should be considered moving forward. Building a full-scale prototype has also given us the opportunity to test the prototype in real life situations. While more focused prototypes help us gain information about specific elements of our design… putting them together allows us to test them on a more realistic scale. For example, in the testing of our prototype, we pushed the stroller over different terrains to test the durability and performance of the wheels. Further, after attaching the walker component to the stroller, we tested how mobile the system was by subjecting it to a closed course with tight turns and curbs to simulate those in real life. In the prototype testing stage, we were able to see the functionality of our design in a real-life setting, and will use this information to improve our prototype, and present our findings to the client.

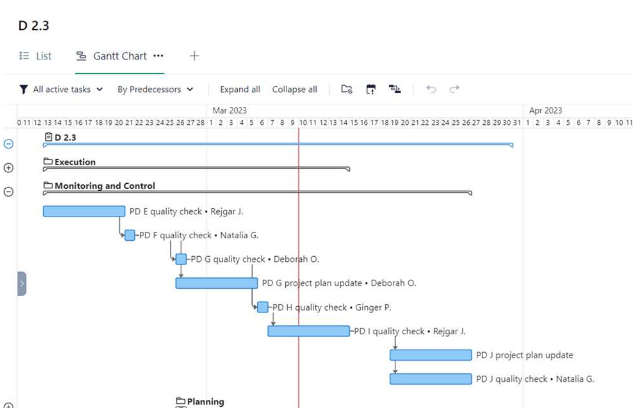
Our physical, comprehensive and fully functional prototype was tested against our target specifications to ensure it met the criteria of the project brief. In comparing the prototype with the target specifications (included below), it was found that the prototype satisfied the target specifications, or have the potential to meet the target specifications (i.e.. At this stage, we can't determine if the prototype matches the target specifications, but as further developments and testing is performed, we can ensure that the design meets them.

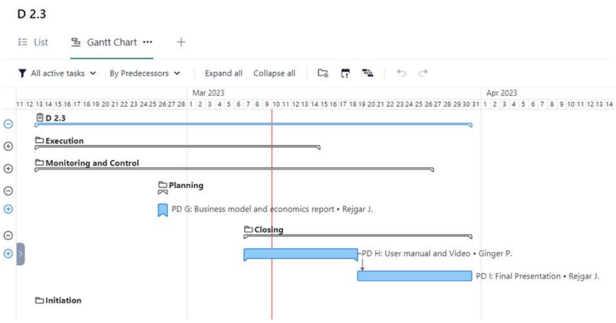
| Characteristic | Unit | Prefer | Relation | Target value |
|---|---|---|---|---|
| *Width* | Inches | lower/equal | ≥ | 20-27 |
| *Length* | Inches | Lower | > | 43-52 |
| *Item weight* | kg | Higher | < | 22 |
| *Max Weight* | Pounds | Lower | > | 50 |
| *Max height* | Feet | Lower | > | 3 |
| *Storage* | Kg | equal | = | 20 |
| *Breaks* | N | Higher | < | Depending on the weight |
| *Cost* | $ | Lower | > | 50-1600 |
| *Curb height* | Inches | Higher | < | 6-18 |

Table 3. Target Specifications

## Updated Project Plan






Link to updated gantt chart:

https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=OCgOPSnhOLWleDz180Te02Tug8UMc9at%7CIE2DSNZVHA2DELSTGIYA

## Conclusion

In conclusion, technologies abound to make life easier for people with diverse types of disabilities. As the world advances, so do their needs and desires. We hope to leverage these technologies to develop an adaptive stroller that is conformable and safe for the parents. Strollers are an essential part of parenthood. It is only fair that parents with endurance, mobility, and or stability difficulties also have the right to participate in this fundamental aspect of their child’s life. The adaptive stroller we develop should be a source of normalcy for these parents and should adapt to their needs.