Project Deliverable C1: **Conceptual Design**

GNG 2101- Introduction to Product Development and Management for Engineers

Faculty of Engineering - University of Ottawa

Submitted by:

Group C2

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Introduction:

Previously, the design team followed the problem definition process and determined customer needs and the problem statement. A benchmarking analysis was also performed, and appropriate metrics and target specifications were developed. The next step in the engineering design process is the generation of solutions and conceptual design. First, a functional decomposition is performed based on customer needs in order to clarify core functionality of the design. Then, each team member provides three product concepts with sketches/models and thorough descriptions. These concepts are analyzed and evaluated based on the target specifications that were developed in Project Deliverable B. As a result of this evaluation, a promising solution is chosen collectively by all the team members. A group design concept is then developed with a justified approach, and the design team provides a visual representation of the group concept. Finally, the concept's relationship to the target specifications is explained, and the benefits and drawbacks of the conceptual design are provided.

1. **Functional Decomposition**

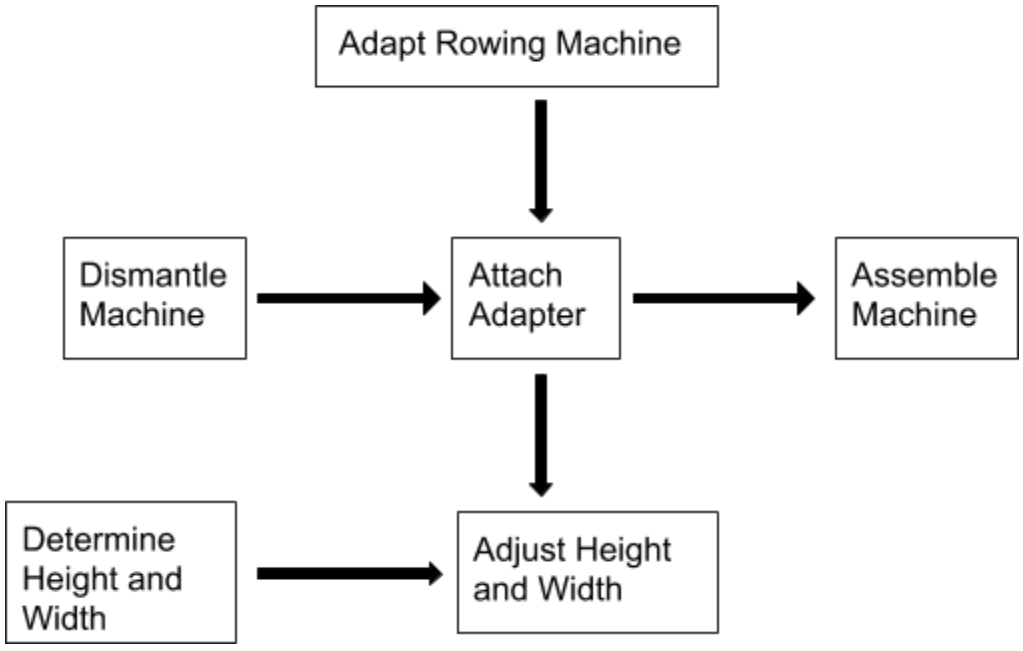


Figure 1. Functional Decomposition of Rowing Machine Adapter.

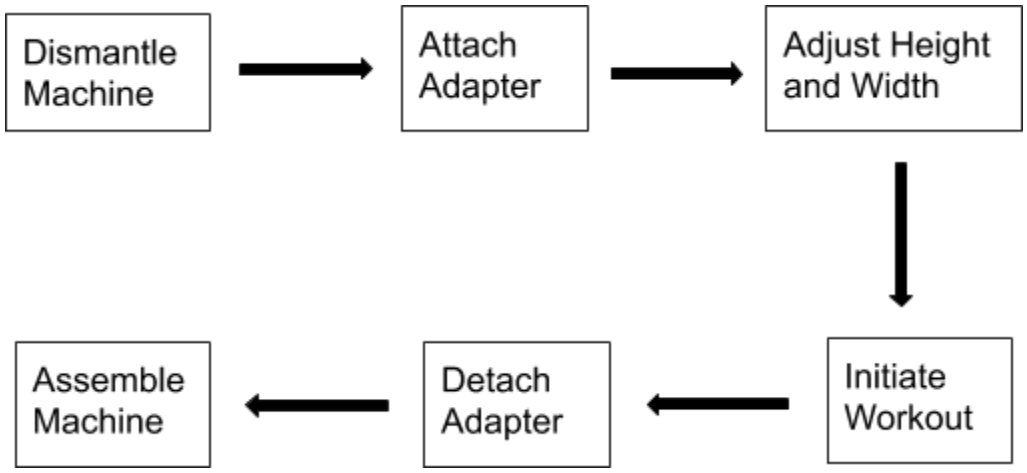
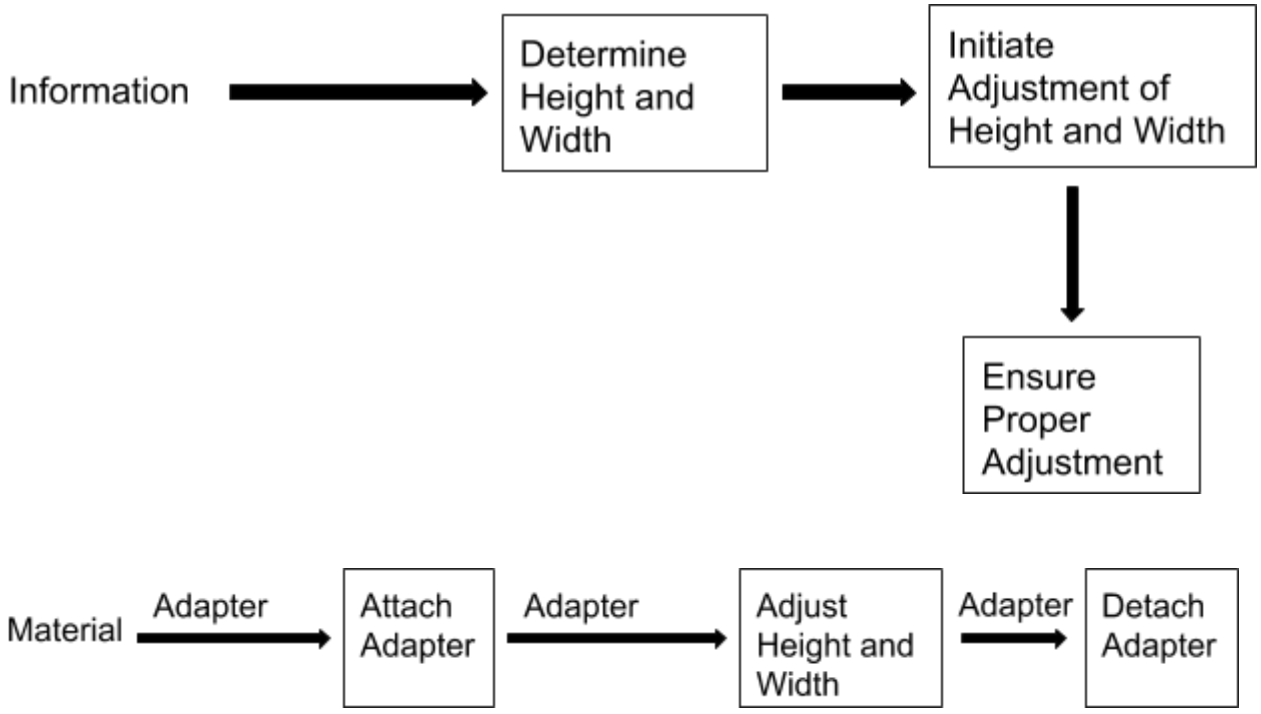


Figure 2. High-level Decomposition of Rowing Machine Adapter.



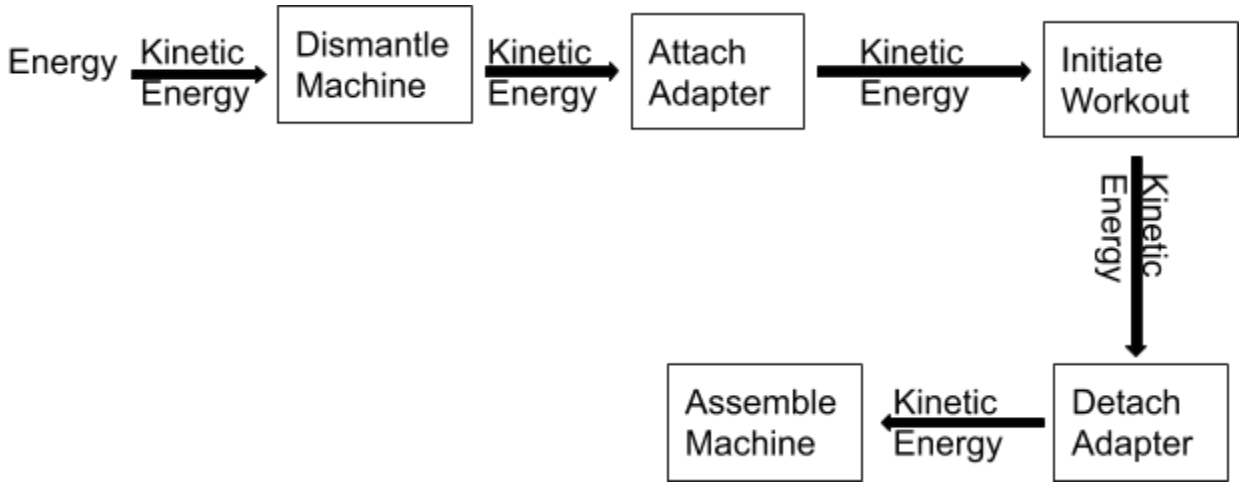


Figure 3. Detailed Functional Decomposition of Rowing Machine Adapter.

2. Individual Product Concepts

Team Member 1: Roxel Fouego

Concept A:

This design resembles a ladder, and it can be folded for storage (to save space). The chain on the side is attached to adjust the height for the different users. The rowing machine will be attached in the designated area, avoiding motion in all directions and helping to keep the wheelchair in place at all times during the workout.

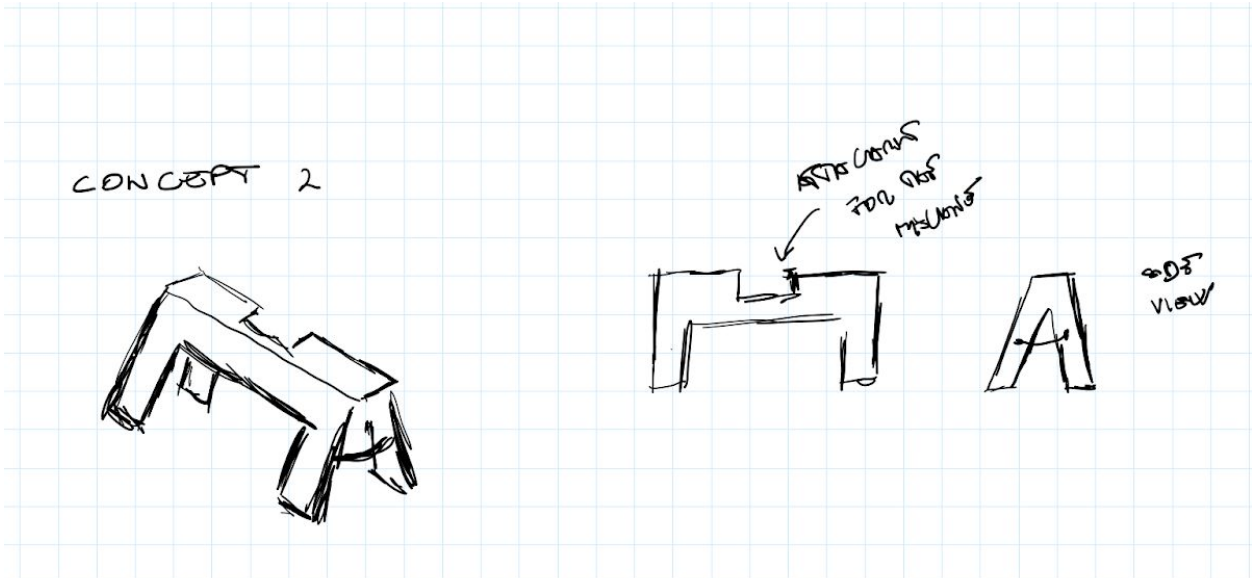


Figure 4a. Concept A Sketch - Team Member 1.

Concept B:

This concept is very basic. It simply attaches to the rowing machine, ensures stability, and is lightweight. There is also room for users' legs under it.

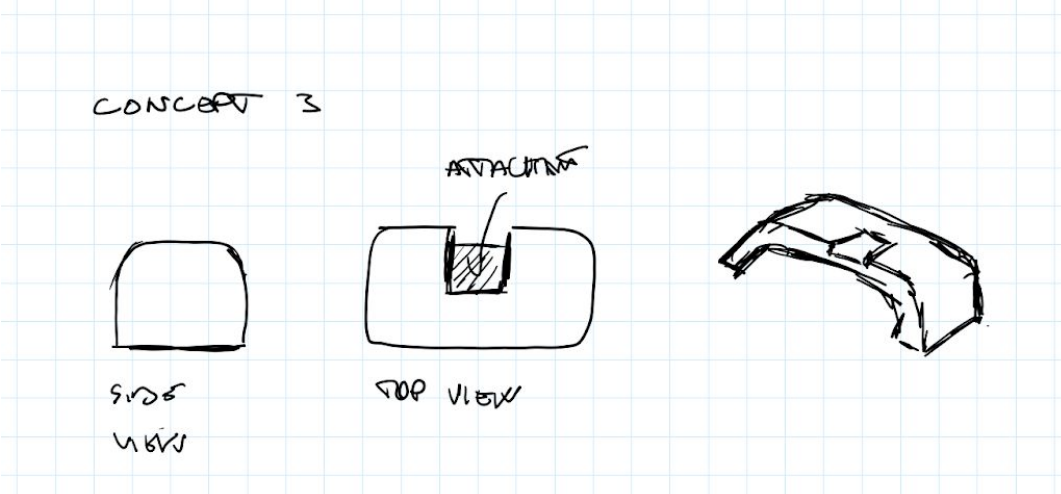


Figure 4b. Concept B Sketch - Team Member 1.

Concept C:

Concept C is similar to Concept B, but it is heavier (more stable). Also, it is easy to carry because a set of two wheels can be attached to the back.

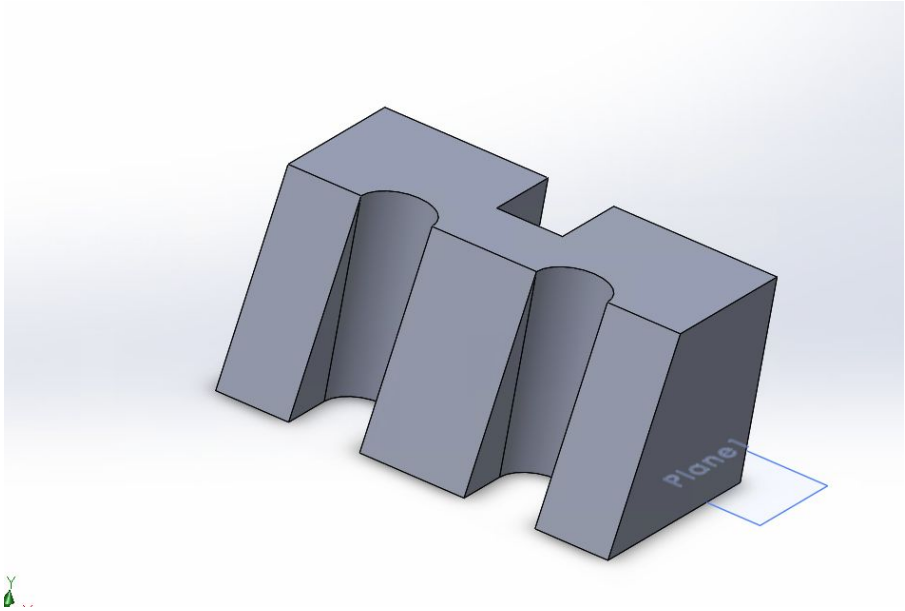


Figure 4c. Concept C Model - Team Member 1.

Team Member 2: Sireen Hallal

Concept D:

This design involves an adjustable stand with rails on the ground for the wheels. The stand is attached to the rowing machine, enabling height adjustment, and has locks at the back to ensure that the wheelchair is secure during the workout. Moreover, in order for users to be able to reach the handlebar easily and more comfortably, chains/ropes can be attached to the ends of the handlebar. This will allow users to hold the chains/ropes to bring the handlebar closer to them. Then, they can grab the handlebar and perform the workout successfully on the rowing machine. **Figure 5a.** below illustrates this design.

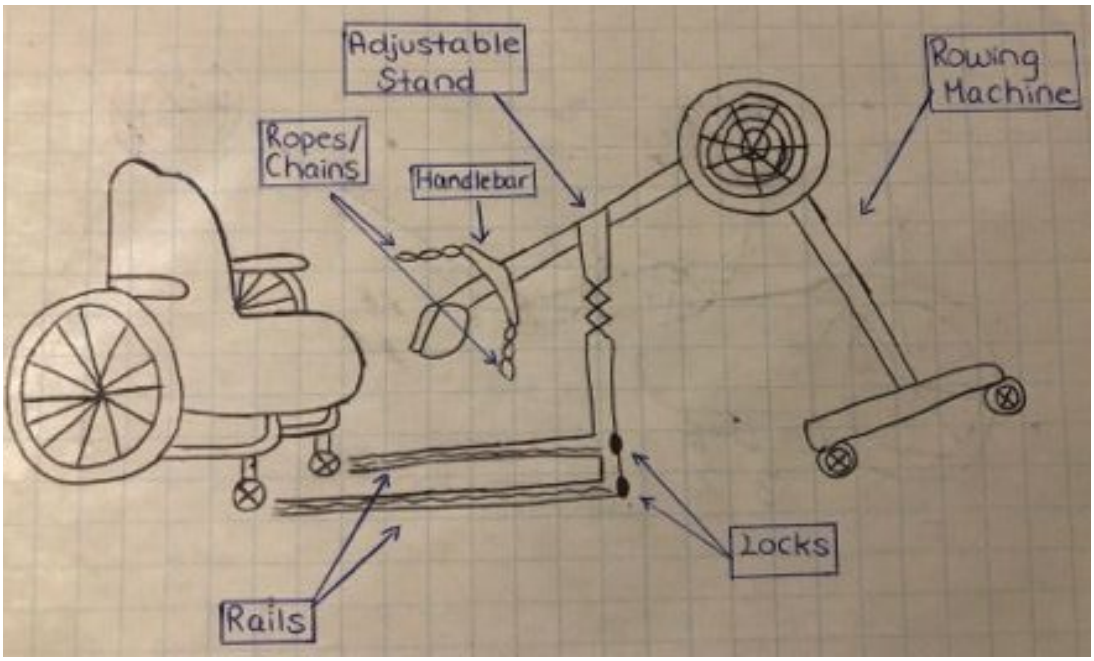


Figure 5a. Concept D Sketch - Team Member 2.

Concept E:

This design involves an adjustable bench/table that is attached to the rowing machine to allow the height to be adjusted. To keep the wheelchair in place during the workout, strong ropes/chains can be attached from the legs of the bench/table to the wheelchair legs. Finally, to ensure that the handlebar can be reached easily, the same idea from Concept 1 can be implemented. Chains/ropes can be attached to the handlebar, allowing users to bring the handlebar closer to themselves. Once the handlebar is close to the users, they are able to grab it and initiate the workout on the rowing machine. **Figure 5b.** below illustrates this design.

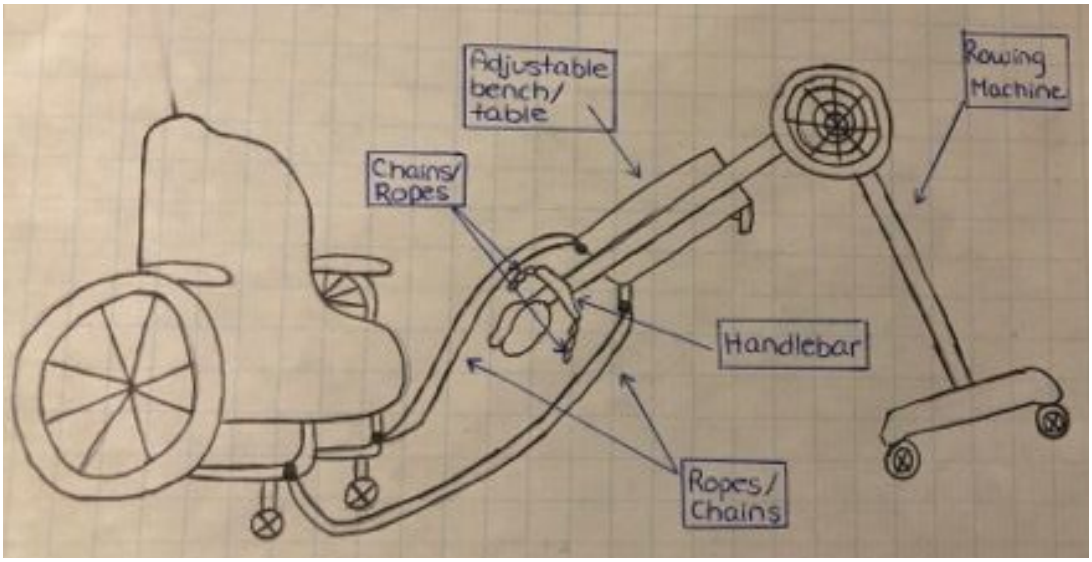


Figure 5b. Concept E Sketch - Team Member 2.

Concept F:

In this design, metal/plastic bars can be attached from the inside of the connection point between the two parts of the rowing machine to each handle on the wheelchair. This can be used to ensure that the wheelchair is secure during the workout. Also, holders for the handlebar can be 3D printed and placed on these bars in order to have the handlebar closer to the wheelchair and, hence, to the user. **Figure 5c.** below illustrates this design.

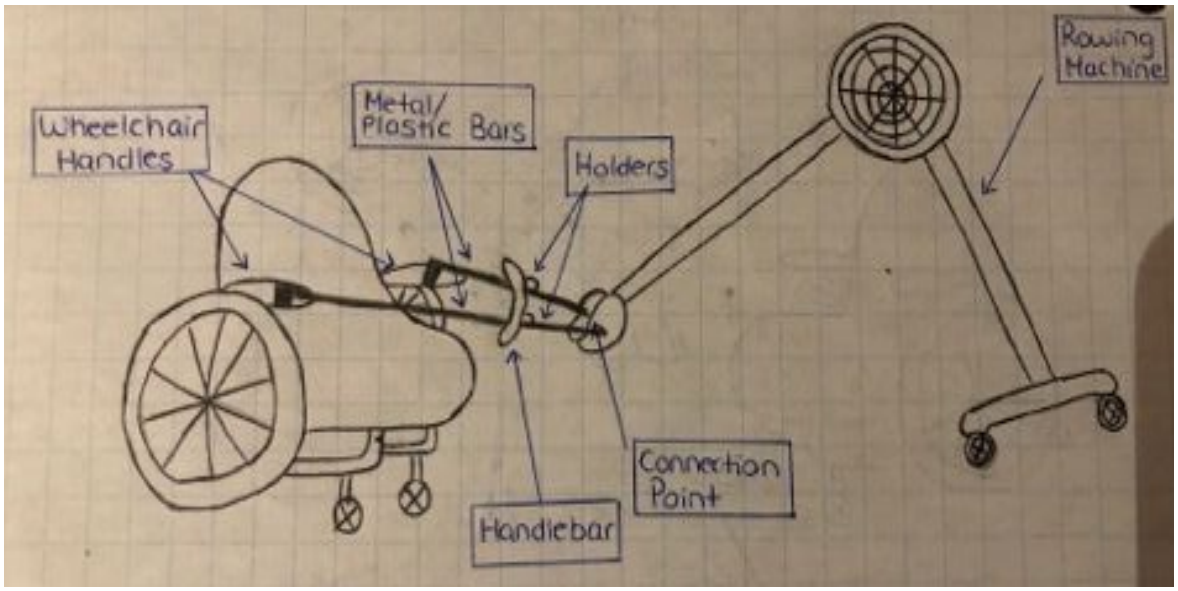


Figure 5c. Concept F Sketch - Team Member 2.

Team Member 3: Isabel Benke

The costs and weights of all three designs were calculated approximately by determining the volume of each part of the machine using software and calculating their masses based on the density of each material. The average cost per pound of these materials was used to estimate the designs' costs. These factors helped in assigning a score to each concept in **Table 2**.

Concept G:

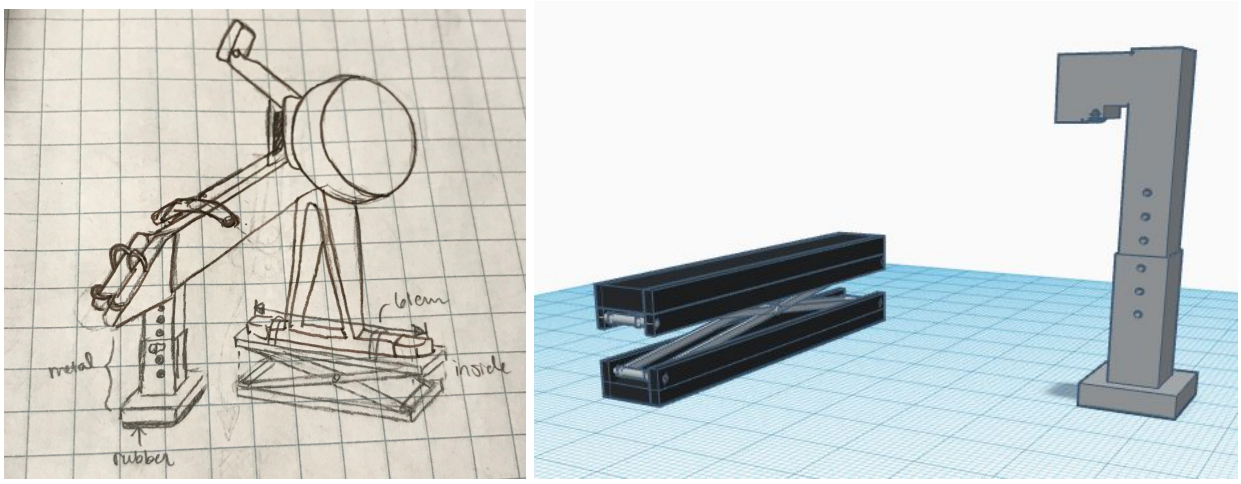


Figure 6a. Concept G Sketch and Model - Team Member 3.

The base of the rower is placed within the top part of a specially-fitted scissor jack capable of lifting up to 50 kg, which can be adjusted like a laboratory jack. This allows for the height of the rowing bars to always be at the user's chest height, as sitting on a wheelchair can result in the user being higher off the ground than they would be on the Concept 2 rower's seat. The front part of the rower hooks into the adjustable hollow stainless steel stand. The base of both pieces of equipment is lined with rubber or a similar material to increase the friction between it and the ground, preventing the rower from sliding. In order to move the adapter(s), wheels would be fitted on them similar to those on the rower itself. The major drawback of this design is its cost, which will be over budget. It is also more complicated to assemble and may be over our target weight limit.

Concept H:

This concept involves a very similar adjustable frame to Concept G, but it is fitted with a joint with adjustable height. Its angle is adjusted with a lever, so it can accommodate a wide range of wheelchair widths. It fits onto the legs of the chair (which are attached to its front wheels) with adjustable rubber straps. A plastic frame on the end of the bar hooks into the rubber, attaching

the wheelchair to the machine. Drawbacks of this adapter include its complexity in terms of assembly and the additional time it would take for a gym employee to adjust it.

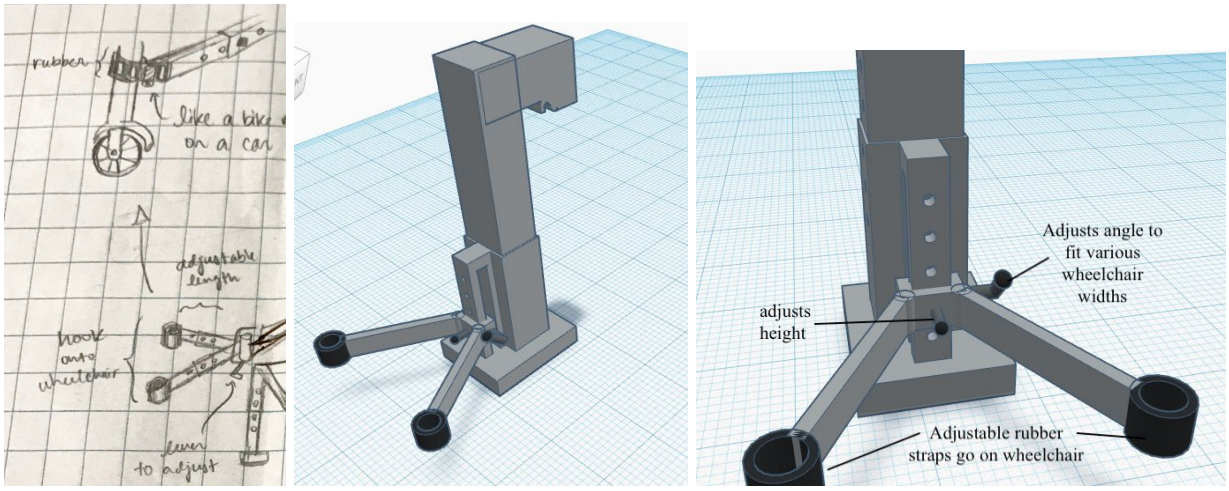


Figure 6b. Concept H Sketch and Model - Team Member 3.

<u>Concept I:</u>

This machine is primarily made of stainless steel. It hooks into the rower like in Concepts G and H. To change the height of the front part of the machine, the latch pictured below can be adjusted. The front of the rower can fit into the frame of adjustable height; it consists of two hollow pieces that can slide up or down and a knob that can be tightened to fix it in place. Since the frame at the front of the machine would be inefficient to adjust, this attachment is not ideal. Its design is not sufficiently simple to assemble either.

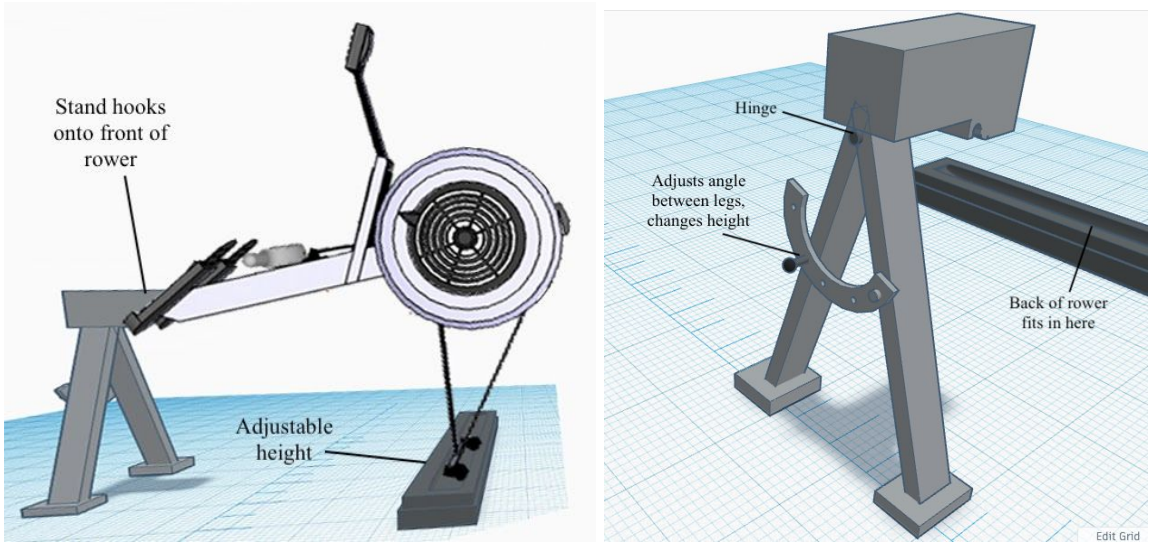


Figure 6c. Concept H Model - Team Member 3.

Team Member 4: Peter Huang

Concept J:

New adaptive attachment for the rowing machine will clip-on like how the regular rowing machine model does. This new attachment will replace the seat attachment that the regular rowing machine uses. The adaptive attachment is an elevated cushion pad, and the user can simply roll up to the cushion, lock the wheelchair in place, place their chest against the cushion, grab the handles, and start exercising, as they would on a regular rowing machine. As a result, they can work their arm and back muscles. In theory, the attachment can be installed and removed with ease at any time, can adapt to wheelchairs of all sizes, can be used by all people that are able to move their upper bodies and gives users a decent upper body workout. Apart from installation assistance by the staff, users can use the machine on their own. However, the design only works based on the assumption that the wheelchair can lock in place on its own. There are also no safety measures in place for this design.

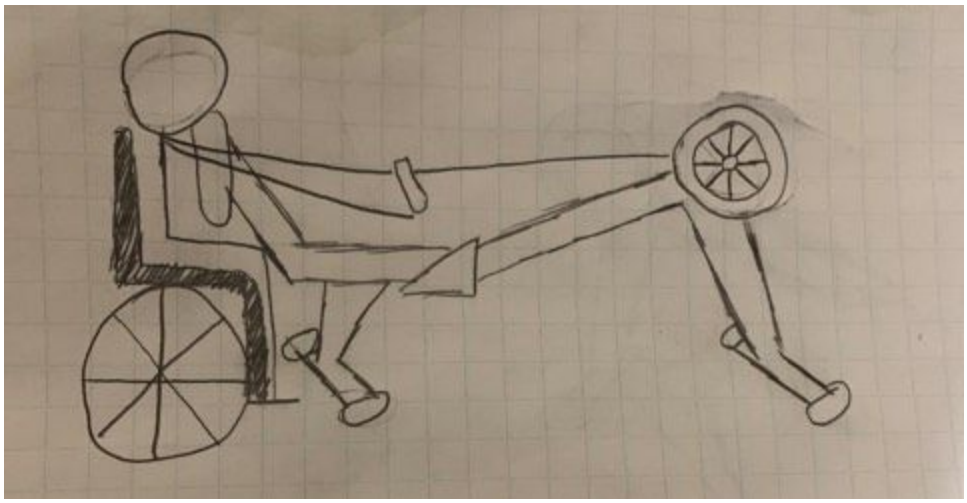


Figure 7a. Concept J Sketch - Team Member 4.

Concept K:

New adaptive attachment for the rowing machine will clip-on like how the regular rowing machine model does. However, instead of providing a seat, it is a floor attachment with adjustable barrier spikes to help lock the wheelchair in place. Once the wheelchair is stable in the desired position, the user can grab the handles and begin moving his upper body as he would on a regular rowing machine. In theory, the attachment can be installed and removed with ease at any time, can adapt to wheelchairs of all sizes, can be used by all people that are able to move their upper bodies and gives users a decent upper body workout. Apart from installation assistance by the staff, users can use the machine on their own. However, the design only works based on the assumption that the barrier spikes are enough to hold the wheelchair in place and, at

the same time, withstand the force of the user's pulling motion. Furthermore, there are no safety measures in place.

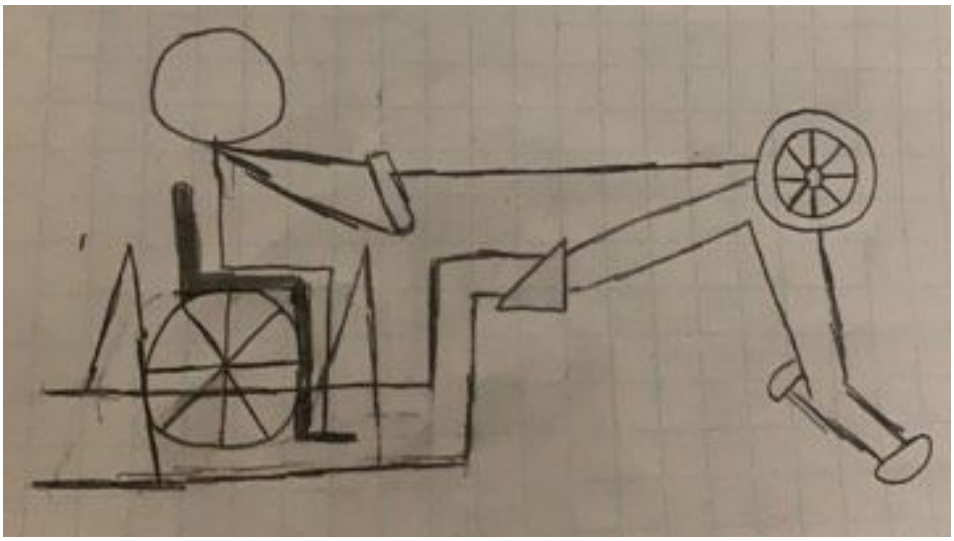


Figure 7b. Concept K Sketch - Team Member 4.

Concept L:

New adaptive attachment for the rowing machine will clip-on like how the regular rowing machine model does. The attachment has two hooks that can securely attach onto the wheelchair and lock it in place. Similar to the previous two concepts, once the wheelchair is stable in the desired position, the user can grab the handles and begin moving his upper body as he would on a regular rowing machine. In theory, the attachment can also be installed and removed with ease at any time, can adapt to wheelchairs of all sizes, can be used by all people that are able to move their upper bodies and gives users a decent upper body workout. Apart from installation assistance by the staff, users can use the machine on their own. However, the design only works based on the assumption that the hooks are enough to hold the wheelchair in place and, at the same time, withstand the force of the user's pulling motion. Furthermore, there are no safety measures in place.

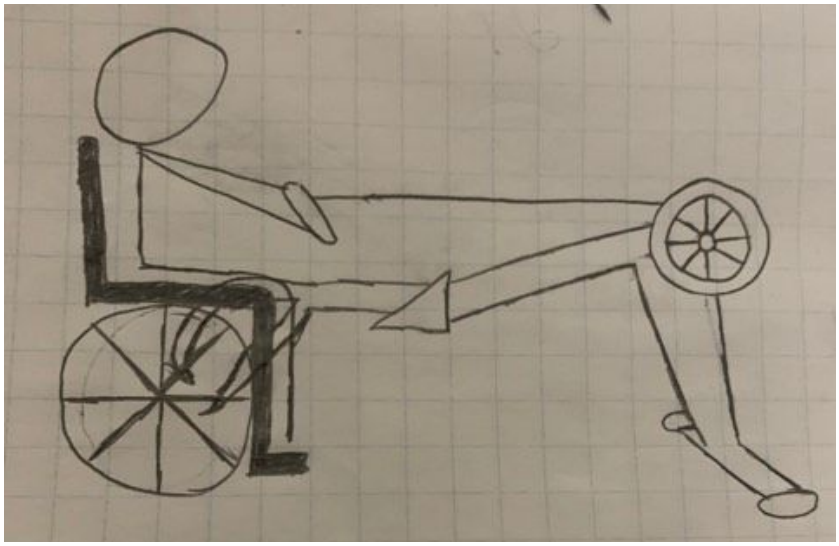


Figure 7c. Concept L Sketch - Team Member 4.

Team Member 5: Fatemeh Omidi

Concept M:

The original rowing machine has to be split in two parts at the sitting point. The front/fan section of the rowing machine will be used. An adjustable ramp can be placed for the wheelchair. However, use of this design requires staff assistance because the wheelchair and, therefore, the user will be far from the handlebar.

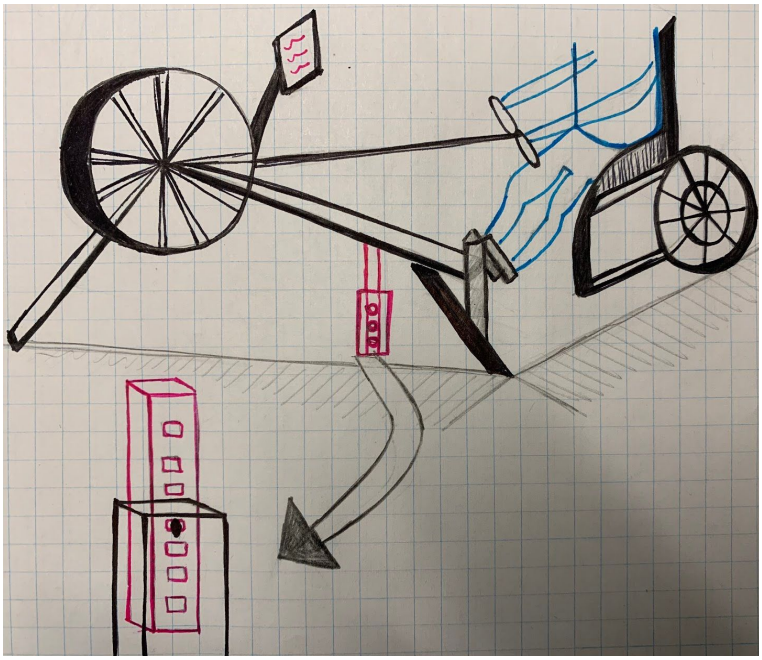


Figure 8a. Concept M Sketch - Team Member 5.

Concept N:

The second design consists of two attachable parts. The first part is an assembled chair suitable for disabled individuals which replaces the original seat of the rowing machine. The second part includes attached equipment, keeping the handlebar closer to the user. However, use of this design not only requires staff assistance, but it is also not safe for the targeted user to sit on the chair and perform the workout.

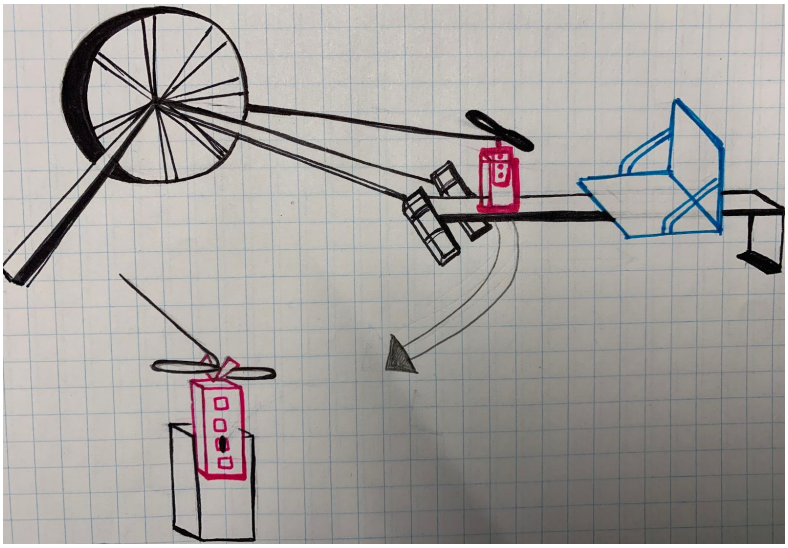


Figure 8b. Concept N Sketch - Team Member 5.

Concept O:

Another approach to solve the problem is to have a standing rowing machine which is bolted to the ground. The height of the fan can be adjusted accordingly, and the wheelchair can be fixed to the machine using hooks and ropes. Since it is an uncommon training machine, the manufacturing cost of this design could be extremely high.

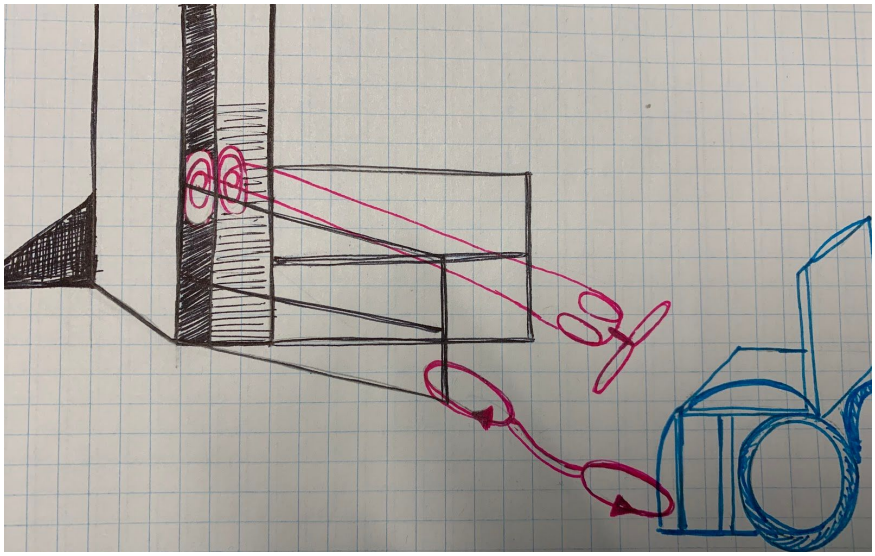


Figure 8c. Concept O Sketch - Team Member 5.

Team Member 6: Liam Vannest

Concept P:

This adaptation of the rowing machine consists of individual pieces that allow for the adjustment to better fit users ranging in size and movement capabilities. There will be a piece that acts as a base for the rower, and connects the attachment to the rowing machine. Inserted in the vertical hollow portion of this connecting piece will be an independently moving arm, it will branch out and allow for vertical adjustment. The end of the arm of the vertically adjustable piece will be inserted into a T-shaped piece, this will allow for the adjustment of how close the user is to the rowing machine. Extending out from the other ends of the T-shaped piece will be two small metal bars with knee pads fixed onto the ends of them, allowing for adjustments to be made depending on leg width of user. Over all this design will allow a user in a wheelchair to pull on the rowing machine securely and with ease, by matching the pulling force with the pressure against the leg rests. There will also be a handle holder made of two rollers that will make it easier for the user to rest the handle if needed, located on top of the rower connection piece.

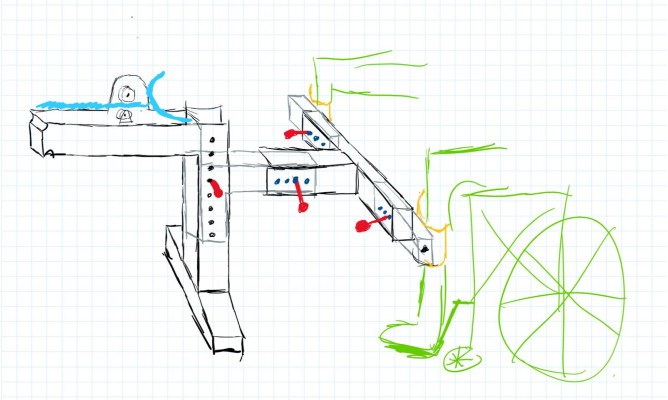


Figure 9a. Concept P Sketch - Team Member 6.

Concept Q:

This adaptation will have a T-shaped piece that attaches directly to the current rowing machine. On the other two branches of the T there will be an adjustable arms that supports the rower. These arms will allow for height adjustment to better fit individual users. On the top of the T-shaped piece will be a foam pad that will provide the resistance needed so the rower can securely pull against the machine.

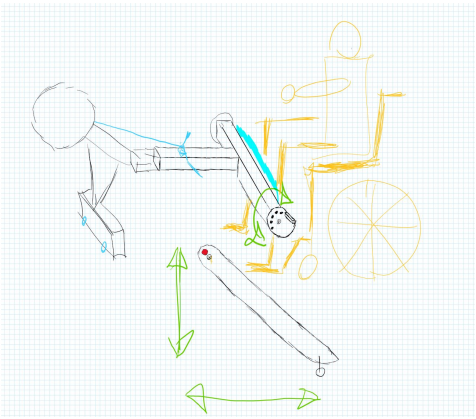


Figure 9b. Concept Q Sketch - Team Member 6.

Concept R:

This piece is a design for securing adjustable parts. It is essentially a pin that when pulled back allows for two pieces to slide freely for easy adjustment but when left at rest locks the pieces in place. It will consist of a metal pin secured perpendicularly to the plane of movement of ,by a 3D printed housing. There will be hollowed out section of the housing that will allow a washer fixed to the pin slide up and down, with a spring holding it in the down or ‘locked’ position.

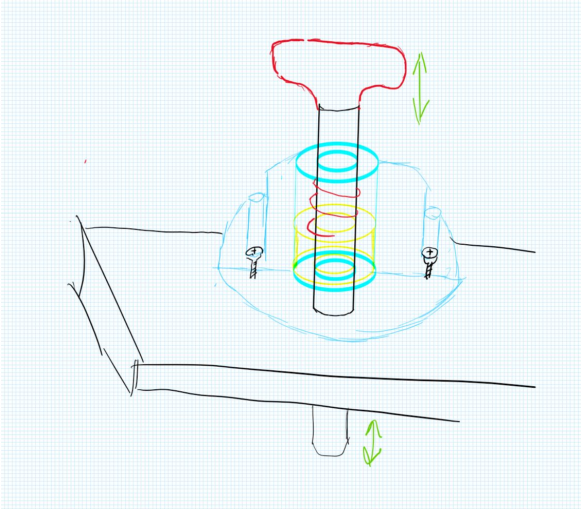


Figure 9c. Concept R Sketch - Team Member 6.

3. Screening of Solutions

To analyze and evaluate each of the 18 concepts, 3 decision matrices are formed. Each target specification is given a weight based on its relative importance, which was determined in Project Deliverable B. There are two columns for each individual concept. The left hand column contains a score from 1 to 6 that is determined based on how well the concept matches that particular target specification. A score of 1 indicates that it does not meet the specification adequately, and a score of 6 indicates that it perfectly meets the target specification. In the right hand column, the weighted score is provided. This is found by multiplying the individual scores by the weight of each specification. Finally, the last row gives the total score, which is obtained by adding the weighted scores of each concept. The concepts with the highest scores meet the target specifications better and are therefore the best solutions.

Table 1. Decision Matrix for Concepts A to F.

Target Specifications / Selection Criteria	**Weight**	**Concept A**		**Concept B**		**Concept C**		**Concept D**		**Concept E**		**Concept F**	
Total mass	0.09	5	0.45	3	0.27	1	0.09	2	0.18	4	0.36	3	0.27
Time to assemble/dismantle	0.09	3	0.27	4	0.36	4	0.36	3	0.27	3	0.27	3	0.27

Unit manufacturing cost	0.2	3	0.6	2	0.4	1	0.2	1	0.2	5	1	4	0.8
Actions that need to be performed by a staff member	0.2	3	0.6	5	1	5	1	2	0.4	2	0.4	3	0.6
Size of wheelchair that can be accommodated	0.15	4	0.6	2	0.3	1	0.15	1	0.15	5	0.75	3	0.45
Expected functioning duration	0.05	3	0.15	2	0.10	1	0.05	4	0.2	1	0.05	1	0.05
Space taken up in storage	0.02	5	0.1	1	0.02	1	0.02	2	0.04	4	0.08	5	0.1
Safety features	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
	Total Score		2.97		2.75		2.07		1.64		3.11		2.74

Table 2. Decision Matrix for Concepts G to L.

Target Specifications / Selection Criteria	**Weight**	**Concept G**		**Concept H**		**Concept I**		**Concept J**		**Concept K**		**Concept L**	
Total mass	0.09	2	0.18	4	0.36	3	0.27	4	0.36	5	0.45	2	0.18
Time to assemble/dismantle	0.09	4	0.36	3	0.27	4	0.36	5	0.45	5	0.45	4	0.36
Unit manufacturing cost	0.2	2	0.4	5	1	3	0.6	5	1	5	1	5	1
Actions that need to be	0.2	2	0.4	1	0.2	4	0.8	4	0.8	3	0.6	3	0.6

performed by a staff member													
Size of wheelchair that can be accommodated	0.15	5	0.75	2	0.3	5	0.75	5	0.75	5	0.75	5	0.75
Expected functioning duration	0.05	5	0.25	4	0.2	3	0.15	1	0.05	1	0.05	1	0.05
Space taken up in storage	0.02	5	0.1	5	0.1	6	0.12	4	0.08	4	0.08	4	0.08
Safety features	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2	1	0.2
	Total Score		2.64		2.63		3.25		3.69		3.58		3.22

Table 3. Decision Matrix for Concepts M to R.

Target Specifications / Selection Criteria	**Weight**	**Concept M**		**Concept N**		**Concept O**		**Concept P**		**Concept Q**		**Concept R**	
Total mass	0.09	4	0.36	4	0.36	1	0.09	6	0.54	4	0.36	2	0.18
Time to assemble/dismantle	0.09	5	0.45	3	0.27	6	0.54	5	0.45	3	0.27	4	0.36
Unit manufacturing cost	0.2	5	1	3	0.6	1	0.2	5	1	4	0.8	3	0.6
Actions that need to be performed by a staff member	0.2	4	0.8	3	0.6	5	1	6	1.2	4	0.8	5	1

Size of wheelchair that can be accommodated	0.15	4	0.6	1	0.15	5	0.75	6	0.9	4	0.60	5	0.75
Expected functioning duration	0.05	1	0.05	1	0.05	3	0.15	5	0.25	4	0.2	4	0.8
Space taken up in storage	0.02	3	0.06	3	0.06	1	0.02	4	0.08	5	1	4	0.08
Safety features	0.2	1	0.2	1	0.2	3	0.6	5	1	5	1	5	1
	Total Score		3.52		2.29		3.35		5.42		4.23		4.77

4. **Concept Selection**

   Based on the evaluation, Concept P results in the highest score. It has a relatively low total mass and assembling/dismantling time. The estimated unit manufacturing cost is also below $100, and it can be adjusted to accommodate almost any wheelchair size. The design can be used independently, and only a few actions need to be performed by a staff member. It also has a reasonable size and, hence, takes up small space in storage. Finally, it has a long expected functioning duration, and it is equipped with certain safety features. All the target specifications and customer needs are sufficiently met with this design, and it is therefore a promising solution.

5. **Final Concept**

   The final concept is a modification of Concept P chosen in the previous step. It will have the same connection and will support the rower in the same manner. It will also have a vertically adjustable piece that branches out of the support along with the T-shaped segment allowing for a wide range of adjustment. It will differ, however, by having a foam pad across the top of the T-shaped piece (similar to concept Q) that will secure the user when pulling, countering the motion by having their legs or wheelchair against the machine. This modification in the design will still account for the variability of leg width but at the same time require less materials and an easier construction. The handle holder from Concept P will also be implemented in a similar fashion.

6. **Concept Representation**

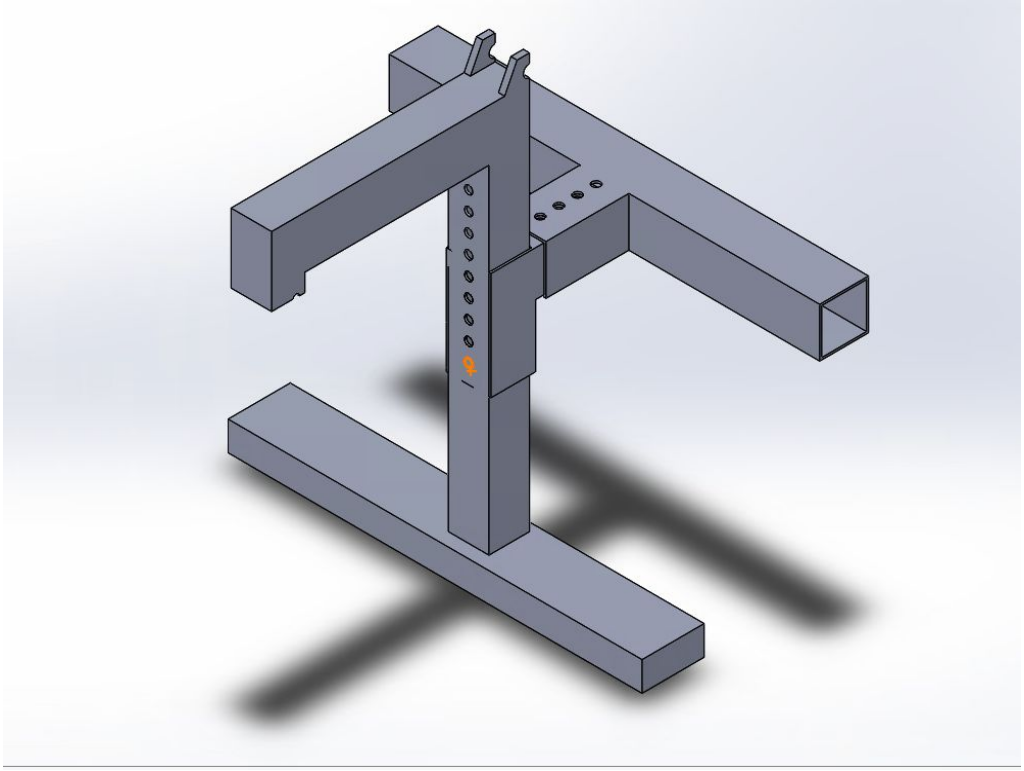


Figure 10. 3D Model of Final Concept.

7. Rationalization Behind Concept Selection / Benefits and Drawbacks

The main reason why this concept was chosen as the final one is because it meets the target specifications almost perfectly. It has a relatively low estimated total mass (8.62 kg) and low assembling/dismantling time (approximately 30 seconds). The estimated unit manufacturing cost is also below $100, and it can be adjusted to accommodate almost any wheelchair size. The design can be used independently, and only a few actions need to be performed by a staff member to adjust the height/widtph and attach the adapter to the machine. It also has a reasonable size (1.09 cubic meters) and, hence, does not take up much space in storage. Finally, it has a long expected functioning duration, and it is equipped with certain safety features such as the foam pad. These matches to the target specifications provide the rationalization behind why the team chose this concept, and these are all benefits of the design. Another benefit is the fact that it includes a handle holder which will bring the handle closer to the user and will therefore make it easier to use. A drawback of the design is that it will be on the higher end of the $100 budget, considering it will mostly be made out of metal. As for implementation concerns, the actual construction may be difficult and issues may arise due to minimal experience with metal among the group members.

Conclusion:

The solution generation step and conceptual design in the iterative engineering design process were successfully performed. A functional decomposition was completed by breaking down required product functions into smaller basic sub-functions to understand and clarify the core functionality of the design. Each team member successfully developed three innovative design solutions. The eighteen concepts were then evaluated based on target specifications by using decision matrices. According to this evaluation, the concept with the highest score was chosen to be developed further. A modified final concept was then selected and visually represented using a 3D model. Finally, the benefits and drawbacks of the final concept were mentioned, and the rationalization behind the concept selection was provided. Further steps will involve a detailed design and the initiation of prototype 1.