Project Deliverable D: **Detailed Design, Prototype 1, and BOM**

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:

In Project Deliverable C, the design team collectively agreed on a promising conceptual design. This was done by performing a functional decomposition, brainstorming, providing three concepts per team member, and analyzing each concept based on target specifications. The concept that best satisfied all the target specifications was chosen. A visual representation (sketch and model) of the concept was then provided, and its benefits and drawbacks were thoroughly analyzed. During the client meet, the team presented this idea to the client and received valuable feedback regarding the design. The next step in the engineering design process is prototype development and testing. However, before building the prototype, the team summarizes the feedback received from the second client meeting and analyzes what needs to be changed or improved in the design. An updated and detailed conceptual design is then provided with visual representations and explanations. The most critical product assumptions to be tested are clearly defined. Prototype 1 is built, its function and purpose is explained, and visual representations of this prototype are provided. Next, the prototype is tested, and its performance is evaluated based on the target specifications developed in Project Deliverable B. In addition, the information that needs to be obtained in the next client meeting is summarized. Finally, a detailed preliminary bill of materials and parts is listed for the team's final prototype.

1. **Client Meeting Feedback**

   The second client meeting provided the team with an opportunity to showcase the design to the client and receive constructive feedback on what can possibly be changed or improved. Overall, the client approved of the design and was quite pleased with it. He stated that it meets all his needs and expectations. In addition, he invited a wheelchair user to the meeting, which was quite helpful because the team was able to obtain the perspective and opinions of a potential user of the design. The wheelchair user was also impressed by the design and was excited to use it as soon as it was completed. However, the client and the user also expressed concerns or possible improvements of certain aspects of the design. For instance, the client mentioned that the rowing machine adapter should not interfere with the chain of the handlebar since this chain constantly recoils and oscillates while the user is performing the workout. This means that the height of the adapter must be carefully considered and should not touch the chain of the handlebar at any time during the workout. The client also gave the team a constraint and stated that the design has to be suitable primarily for manual wheelchairs and not for electric ones. The design team further consulted the client and the user for their opinions as to whether cushion pads or a V-shaped design under the wheelchair is more suitable and comfortable. The client stated that cushion pads are more beneficial, and the user said that the pads are also more comfortable. Even more, the client informed us that the

rowing machine is not bolted to the ground and can be moved around, which was an additional piece of information that the team was seeking. The design team was also given the opportunity to see the rowing machine at the gym and take any necessary measurements for the design. Finally, the client emphasized the importance of the ease of adjustment of the adapter. The design team is eager to take all of these suggestions into consideration and design an adapter that exceeds the expectations of the client and potential users.

2. Updated Conceptual Design

Description:

The updated design is quite similar to the chosen concept in Project Deliverable C. It will be constructed using three separate adjustable pieces. As shown in **Figure 1**, the first piece will connect to the rowing machine itself and extend down to the floor for support (green piece). The next piece (beige) will be an L-shaped bar that attaches to the green support piece. It will move independently from the support piece to allow for vertical adjustment, and it will be locked in a desired place with a pin locking mechanism. The third component (yellow) will be a T-shaped piece that allows for lateral adjustments by sliding over the L-shaped piece. It will also be kept in the desired place with the same pin locking mechanism. This piece will further have a padded soft section (blue) where the user can counter the force of pulling on the machine with their legs or wheelchair frame. This design, however, does not include the additional handlebar holder because the chain needs to move freely when it returns into the rower head, which is a concern that the client posed.

Visual Representation:

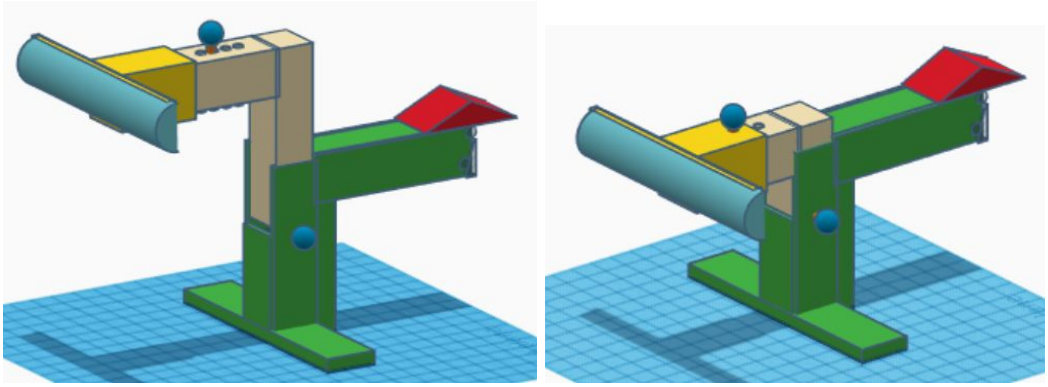

Figure 1. Three-Dimensional Model of Updated Design.

3. Product Assumptions

Clip:

The existing rowing machine consists of two parts. The seat part of the machine is easily attached to the fan part by clipping onto it in the section between the foot pads. The adapter that the team is designing is expected to also clip onto the fan part of the rowing machine in the same way. Therefore, an accurate size of the clipping part of the adapter is crucial. It is essential that the adapter clips onto the machine appropriately without moving or falling in order for it to function properly and for safety purposes. This is one of the product assumptions that must be tested with the prototypes.

Adjustable Height/Width:

One of the core features of this design is that it is expected to be adjustable to accommodate a wide range of wheelchair heights. There are two adjustable bars that fit into each other to allow the user to adjust the height and width of the adapter as necessary. The prototypes will hence be tested for height and width adjustability.

Independent Use:

Another important assumption of the product is that it can be used independently. This is one of the features that the client emphasized. It is expected that staff members do not necessarily need to help the user during the workout. The staff only set up the machine and the adapter. This is also one of the assumptions to be tested with the prototypes.

Safety Features:

The product is expected to be safe for use. To accomplish this, pin locking mechanisms are used to lock the adjustable adapter in place. A padded section is also included in order to ensure that the user is able to counter the force of pulling on the machine. These features help prevent any possible harm caused by the wheelchair moving around. The padded section further adds to the comfort of the user. The prototypes will be tested for these features as well.

4. Prototype 1

The main purpose of prototype 1 is to test the clipping part of the adapter. The exact dimensions of the rowing machine were determined, and, more importantly, the dimensions of the region where the adapter would be clipped were measured. Then, a 3D model of the clipping part of the adapter was created using these dimensions. The ability of the design to clip on to the machine is the basis for the development of the product.

Therefore, this prototype is very important and will be used to test this essential assumption.

Visual Representation:

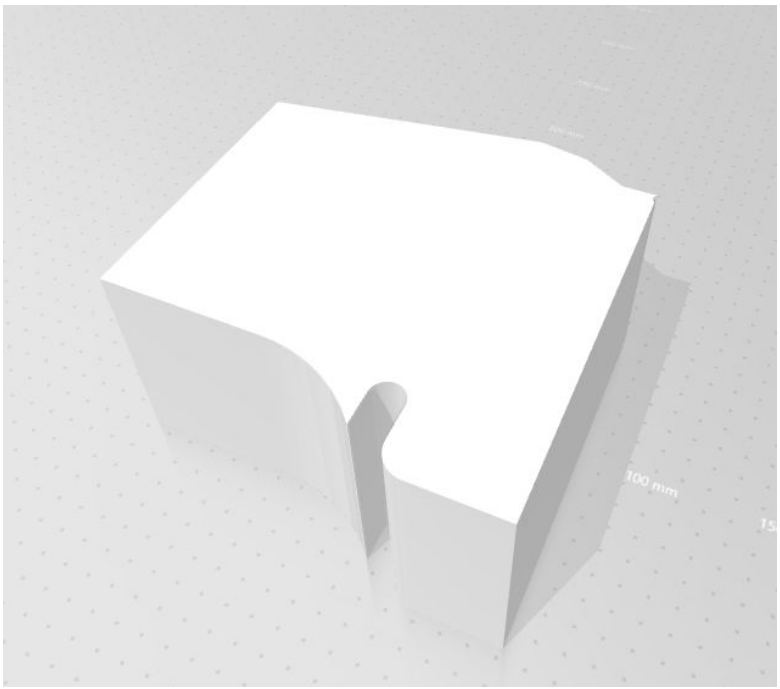

Figure 2. Three-Dimensional Model of Prototype 1.

5. Prototype 1 Performance

For Prototype 1, the team made a low fidelity prototype which consists of a simulated analysis of the mechanical properties of the clipping part of the adapter. This simulation was created using three-dimensional modelling software, including SolidWorks and AutoCAD. The prototype was expected to be 3D printed as well to create a medium fidelity prototype that more closely represents the actual clipping part of the future final design. However, due to time and budget constraints, it could not be 3D printed. This is because such large dimensions are costly, and the team did not receive a budget for this prototype. Also, the printing is lengthy, and the team was unable to print it overnight due to certain restrictions with using the 3D printers at the available facilities. Nevertheless, the simulation was tested for its weight, height range and width range. Its performance was thoroughly analyzed using the target specifications, as shown in the table below. The prototype is expected to clip onto the rowing machine successfully since the dimensions are accurate. In this way, it satisfies the product assumption.

Table 1. Analysis and Evaluation of Prototype 1 Performance.

Target Specifications	Expected Results	Actual Results
Weight	20 lb	6.475 lb
Height range	up to 50 cm	32.94 - 41.79 cm
Width range	up to 20 cm	13.93 - 18.88 cm

Furthermore, it wasn't possible to simulate the maximum load supported by the adapter, but considering that the material is relatively strong (aluminum), it can be assumed that it won't break and will have a long functioning duration. Finally, the consideration of the height range is related to the maximum height that the rowing machine can be held before the back wheels begin to move. This should definitely be avoided because it would not be safe to use.

6. Future Client Meeting

At the next client meeting, the team will present the clip-on mechanism prototype that was built and tested. The members will attach the prototype to the rowing machine and determine whether it fits properly. The team will also gather feedback from the client to determine whether or not it is on the right track and whether it is meeting the client's expectations and needs. Since the client emphasized the importance of ease of use, it will be important to know if he is satisfied with how the clip-on prototype will be attached to the rowing machine. Also, an important piece of information that must be gathered from the client is whether he is satisfied with the strength and stability of the clip-on mechanism. This is because the adaptive attachment must be secured to the rowing machine for proper safety and usage. Thus, if the client feels that the strength and stability is inadequate, the design is not ready to be used. Should the client come up with further modifications, the next client meeting will also be a good opportunity to listen to him and consider his opinions for future development of the design. Once the client expresses his thoughts and opinions, any modifications needed for the design will be made, and the focus of the second prototype will be on another crucial product assumption, such as adjustability of the height and width.

7. BOM of Final Prototype

Table 1. Bill of Materials for Final Prototype.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	COST/UNIT CAD	TOTAL COST CAD
1	L-bar	bar to adjust the height of the T shaped bar	1	20	20
2	T-bar	bar that will prevent the wheelchair from moving forward	1	20	20
3	main part	the main part is attachable to the rowing machine	1	30	30
4	base	welded to the main part to bring stability	1	10	10
5	rubber	the rubber below the base is to create friction so that the machine don't move	1	7	7
6	cushioning		1	5	5
7	bolt	used to fix the height	8	0.50	4
8	nut	used to lock the bolt in place	8	0.50	4
9					100

Conclusion:

The prototype and testing step of the iterative engineering design process was successfully performed. The design team summarized the feedback received from the second client meeting and considered all the clients' suggestions and concerns to develop an updated and detailed design with visual representations and explanations. The product assumptions were defined and the prototype was developed to test those assumptions. The purpose and function of the prototype were then explained, and sketches/models were provided when necessary. Testing of the prototype was later performed and results were clearly presented. The design team then identified the information that needs to be obtained at the next client meeting, and a bill of materials and parts of the final prototype was listed. Further steps will involve a project progress presentation as well as a business model.