Project Deliverable G: **Prototype 2**

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 Deliverable F, the "Direct Sales Business Model" for the project was chosen, and the reasons behind this choice were clearly stated. A business model canvas that would be well suited to commercialize the product was then developed based on this choice. Core assumptions made while developing the model were also listed, and a feasibility study was performed on the business model and its components. The next step in the project is the development of the second prototype. However, before building it, the team summarizes the feedback received from the third client meeting and analyzes what needs to be changed or improved in the design. Based on this feedback, a second prototype is built, which will help the team in the development of the final product. Prototype 2 is then documented with visual representations, and its purpose and function are clearly defined. Subsequently, prototype testing is carried out, and its performance is analyzed and evaluated based on the target specifications determined in Deliverable B. Testing results and prototype specifications are documented, and expected vs. actual results are shown in organized tables. Finally, a future plan for what the team intends to present on Design Day is provided, and a method to verify that the "Solution Works Really Well" is determined.

1. **Client Feedback**

During the third client meeting, the team presented the first product prototype and received constructive feedback regarding the design and what needs to be changed or improved in the development of the second prototype and the final product. The client was very pleased with the design of the first prototype. He was impressed by how the piece fit perfectly into the rowing machine and greatly appreciated the team's ideas and efforts. The client also tested the prototype using a wheelchair, which was quite useful in determining its functionality. In addition, he gave significant feedback on possible areas for improvement. For instance, the client stated that the adapter will have to be slightly greater in height. This is because, when testing using a wheelchair, his feet touched the foot pads of the rowing machine. This could hinder the functionality of the product and result in discomfort for the wheelchair-user. Another idea is that the adapter should be shorter in length, in order for the user to be able to reach the handlebar and exercise comfortably. When the client tested it, a team member had to hand him the handlebar in order to perform the workout. In the final product, the wheelchair-user should be able to grab the handlebar independently. Also, when testing the prototype, the rowing machine and the wheelchair were slightly moving and rotating, even though the wheels of the wheelchair were locked. This means that the locking mechanism in the final product needs to be strong and stable for the user. Moreover, the shin pad, which will be included in the final product, was another area for discussion. The client stated that it should ideally have a wood or metal base with comfortable material over it. This is because it has to be strong enough to resist the pulling force of the user, while remaining soft and comfortable on the user's shins. The client tested several

pads available at his gym and noted that he was feeling uncomfortable in his shins after testing, which is definitely something that needs to be avoided in the final product. He also suggested that the pad should not be too long that when the user's shins press on it, it rotates and possibly breaks the attachment to the adapter. Furthermore, the client gave a pertinent recommendation to install a 3D printed holder on the adapter in order to make the handlebar closer to the user during the workout. He also stated that the team could paint the adapter with the same colour for improved aesthetics during the Design Day presentation. Finally, he was impressed by the 3D printed material, contending that it is very strong and lightweight. The client even tested the piece to see if it could withhold the rowing force, and it successfully did. This was an indication to the team that 3D printed material is a possible building material for the final product and not just for the prototypes. Overall, the client admired the prototype, and the design team is eager to take all of his suggestions into consideration and design an adapter that exceeds the expectations of the client and potential users.

2. Prototype 2

Based on the client feedback received, the design team decided to develop a comprehensive prototype with most of the requirements and functionalities of the final product. This prototype can help in creating the final product, ensuring that the design will work well, and resolving any potential issues that may arise. The prototype was primarily built using the methods of laser cutting and 3D printing. A detailed documentation is provided below.

3. Documentation of Prototype 2

Visual Representation:

Figure 1. Drawing of the Supports of Prototype 2 for Laser Cutting

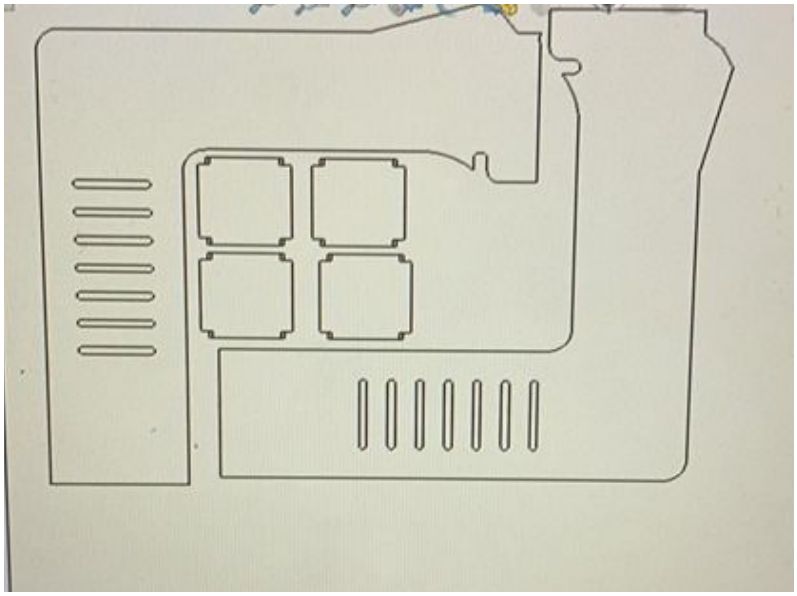

Figure 2. Top View of Prototype 2

Figure 3. Side View of Prototype 2 with Wooden Stand for Support

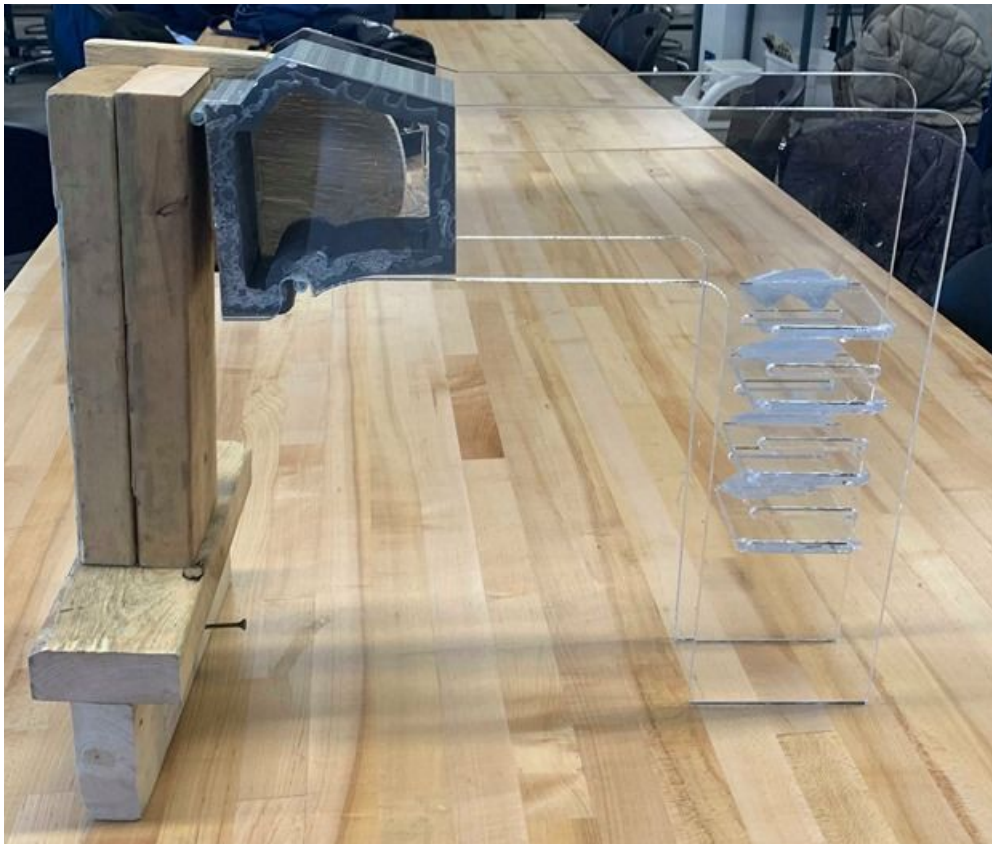

Figure 4. Side View of Prototype 2

Description - Purpose and Function:

Prototype 2 is designed to represent a better functionality in comparison to the first prototype. Its primary purpose is to test the dimensions, stability, and strength of materials used, as well as to discover any potential issues that may arise while developing the final product. For the development of this prototype, the team first created a more accurate 3D model on SolidWorks with proper dimensions, and then made a sketch that was converted into a pdf file in order to be laser cut (**Figure 1**). Acrylic sheets were used to make the two supports since the material is lightweight, strong, and easy to use. Holes were laser cut in the sheets and acrylic pieces were placed in between them to provide strength and support, while keeping it lightweight. A new 3D printed mount was also developed, which is similar to the first prototype, but it is hollow. This is because it makes it lighter, but doesn't result in a loss of too much strength. To finish it off, everything was glued together. In developing prototype 2, the team decided to remove any source of trouble for users during the workout. For instance, in order to reduce the trouble of reaching the handlebar, the team made the second prototype shorter in length. Therefore, the mount was 3D printed in smaller dimensions. Testing the first prototype also showed that the user's feet may collide with the foot pads of the rowing machine; this was fixed by increasing the height of the prototype. Even more, in order to avoid the unsafe movements of both the adapter and the wheelchair of the user during the workout, two supports were made, rather than one. These two acrylic sheets can play a better role in supporting the rowing machine and in preventing it from moving. On the other hand, the adjustability, handlebar holder, and the cushion pads were not included in this prototype. These features will certainly be included in the final product, and they are relatively easy to implement. The design team has a clear plan for their development.

4. Prototype 2 Testing

Prototype 2 was tested primarily for strength, stability, and correct dimensions. The prototype successfully clipped onto the rowing machine; this means that the dimensions are accurate and can be used for the final product. Its length was also appropriate, and the user can definitely reach the handlebar if a holder is placed on the piece. It also withstood the force of rowing, and did not break or fall apart, which indicates that acrylic plastics and PLA are relatively strong materials that could be used for the final product.

As shown in the table below, the second prototype satisfies the time required to assemble/dismantle since it only took 20 seconds to clip the piece onto the rowing machine and ensure that it is stable and secure. This prototype was also made from readily available and free-of-charge materials, as well as tools and machines available to the team at no cost; the cost constraint is hence satisfied. Also, staff members will have to clip the adapter into the rowing

machine and give the handlebar to the user because this prototype did not include a handlebar holder. This means that 2 actions have to be performed by staff members, satisfying this particular target specification. It is also estimated that the prototype can last for approximately 2 years due to the strength and type of materials used. Hence, the expected functioning duration is greater than 1 year, which is the marginal value of the target specification. Moreover, the space taken up in storage added up to 0.013 m^3, which is better than the expected result. Furthermore, the total mass of the prototype was not accurately measured with a scale, but it is expected to be less than 10 kg since 3D printed material and acrylic plastics are quite lightweight. However, certain specifications were not perfectly met. For instance, the foam roller is 60.96 cm long, meaning that this is the maximum possible wheelchair width that can be accommodated. The target specification, conversely, is >70 cm. In addition, safety features were not included in this prototype, but the team will implement them in the final product.

Table 1. Testing Results of Prototype 2 Compared to Target Specifications

Number	Metric	Unit	Marginal Value (Expected Results)	Ideal Value	Actual Results
1	Total mass	kg	<20	<15	<10
2	Time to assemble/dismantle	s	<30	0	20
3	Unit manufacturing cost	$	<100	<761.25	0
4	Actions that need to be performed by a staff member	list	<3	None	2
5	Size of wheelchair that can be accommodated	cm	>70	any	60.96
6	Expected functioning duration	yr	>1	>3	2
7	Space taken up in storage	m^3	<0.100	<0.0742	0.013
8	Safety features	list	>2 features	>4 features	0

5. Future Plan

The construction of the two prototypes led to the development of a final plan of what the team intends to present on Design Day. After testing the strength and durability of the acrylic material with the second prototype and being satisfied with the results, the team has planned to implement the concept of laser cutting the acrylic sheets to form each surface of the support and then easily assembling them together in the same manner. It will essentially create a skeleton shell frame to offer maximum strength, while being made out of minimal material. The design team plans to use PLA, 3D printed blocks fixed in between the two main acrylic supports on each side of the design in order to provide additional support and proper spacing. The team also intends to make the adapter fully adjustable as previously stated; the plan is to use a combination of strategically designed connectable 3D printed blocks that can slide up and out of the acrylic sheet shell. These blocks will be formed into supports running through the entire design, ensuring that the adapter will resist any force applied to it by the rowing machine. The pieces will be secured by a 3D printed spring lock pin (similar to commonly seen exercise equipment), allowing for the user to adjust at ease. The team has yet to implement a handle holder that is closer to the wheelchair-user to account for easier use. However, since this aspect is lower on the list of client needs and is a relatively easy piece to install, it did not have the highest priority when building the prototypes. Finally, the team plans to have a knee support made from an athletic foam roller (shin pad) that is cut in half and supported by wood (most likely). The purpose of the pad is to provide comfort for users, while helping to resist the rowing force.

To verify that the final solution works well, the team intends to display the adapter with a rowing machine and a wheelchair-user. This will be executed during Design Day, since the client has informed the team that he is willing to provide a demonstration using a rowing machine and wheelchair-user on that day. Therefore, an indication that the product works “really well” would be the satisfaction and approval of the client and wheelchair user. The solution must meet the client’s needs, be lightweight, easy and safe to use, stable and secure for the user, and adjustable in height. The product must also be used independently by the user; the only action performed by staff members should be the attachment of the adapter onto the machine. If all of these core features are successfully met, the target specifications are satisfied, and the client and user are pleased with the product, then the design team can confidently conclude that the “solution works really well.”

Conclusion:

The prototype and testing process was successfully performed. The design team summarized the feedback received from the third client meeting and considered all the client’s suggestions and concerns to develop an improved prototype and final design solution. Prototype

2 was built, its purpose and function were defined, and visual representations were provided. Prototype testing was then performed, results were tabulated, and performance was evaluated based on target specifications. Finally, an updated and detailed solution for Design Day was provided, and a plan for measuring the success of the product was developed. Further steps will involve an economics report and a video pitch.