Project Deliverable I: **Final Prototype Update**

GNG 2101 - Introduction to Product Development and Management for Engineers

Faculty of Engineering - University of Ottawa

Submitted by:

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Introduction:

In Deliverable H, an economics report and one-minute video pitch were successfully completed. The design team first listed and classified the variable, fixed, direct, and indirect costs associated with the business based on the manufacturing and sales of the product. A three-year forecasted income statement was then developed based on the "Direct Sales Business Model" that was chosen in Deliverable F. The break-even point was subsequently determined using an NPV analysis, and all the assumptions made while developing the economics report were clearly described and justified. According to the report, the potential company will be profitable with a positive operating income in the second and third years as long as the assumptions made are valid and realistic. Also, the design team created a one-minute video pitch that would be used to promote investments in the potential company. The video pitch included a brief introduction to the project and team members, an explanation of the problem being solved, an emphasis on its importance, and a discussion of the proposed solution with its competitive advantages. The team ensured that the presentation of visual information was professional and clear, and all the members were confident, relaxed, and organized. In addition, facial expressions and body posture were taken into consideration. These measures ensured the production of a high-quality and professional video pitch. The next step in the engineering design process is the development of the final prototype update. Theoretically, the final prototype would have been completed at this point and presented on Design Day to the client and judges. However, due to the COVID-19 outbreak, this was unfortunately not possible. The final product could not be completed without 3D printers, laser cutters, and other facilities available at the University of Ottawa, and Design Day was further cancelled. For these reasons, a detailed final report on the prototype is presented instead, with a plan on what would have been done to complete the prototype under normal conditions. To develop the report, the design team first documents the prototypes developed so far as well as the intended state of the final prototype using sketches, diagrams, pictures, and descriptions. The purpose and function of the final prototype are then clearly stated, along with a description of the client interaction with the product. Moreover, all the aspects of the final prototype that were not completed due to the COVID-19 facility closures are listed and explained in detail. Next, a step-by-step action plan is provided, which is what would have been followed if the design team had the regular 1.5 weeks to complete the prototype with the required materials and facilities. A Gantt chart is also included to illustrate this plan. Finally, since the prototype could not be developed and tested, a systematic testing and analysis plan is described instead, as well as an explanation of how the final prototype specifications would have been documented. This is the plan that the design team would have followed to evaluate the final prototype's performance compared to the target specifications developed in Deliverable B. The team is inevitably affected by the cancellation of Design Day and the inability to complete the final prototype; however, the final report is an accurate and detailed description of the intended prototype, which can be a useful resource if the team plans to develop the prototype at a later time when it is safe to do so.

I.1 Final Prototype Status Update

1. **Documentation of Prototypes**

Prototype 1:

<u>Visual Representations:</u>

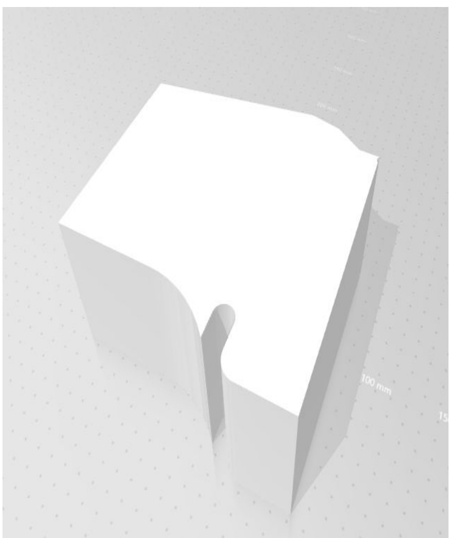

Figure 1. 3D Model of Prototype 1

Figure 2. Prototype 1

Figure 3. Testing of Prototype 1

Description:

The main purpose of Prototype 1 was to test the part of the adapter that clips onto the rowing machine. The exact dimensions of the rowing machine were determined, a 3D model was created, and the prototype was 3D printed from PLA material.

Prototype 2:

Visual Representations:

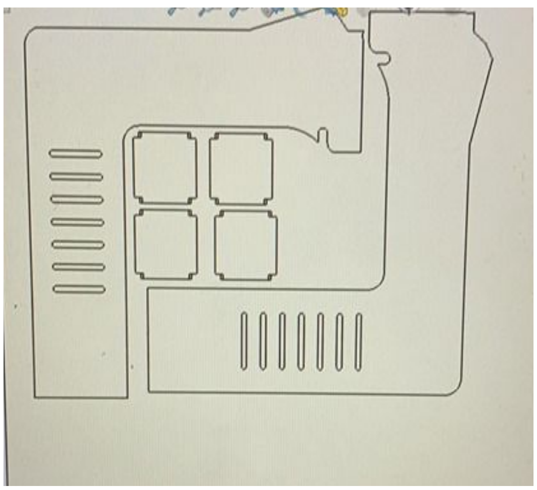

Figure 4. Laser Cutting Diagram of Prototype 2

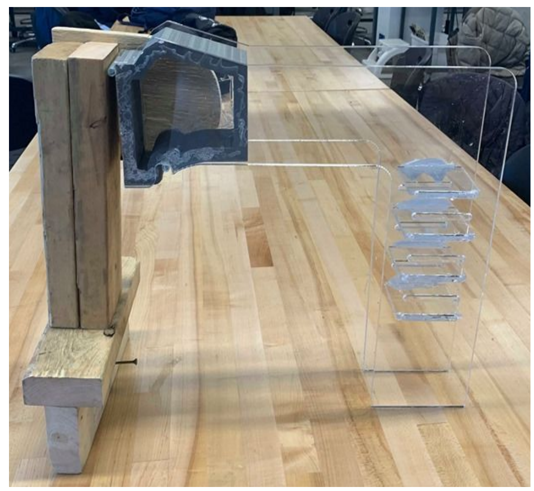

Figure 5. Prototype 2

Description:

Prototype 2 was designed to be a more comprehensive prototype that better represented the final product. Its primary purpose was 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 4**). Acrylic sheets were used to make the two supports since the material is lightweight 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 attached using an adhesive.

Final Prototype:

As mentioned previously, the final prototype was not developed; however, a detailed 3D model of the intended product is shown below.

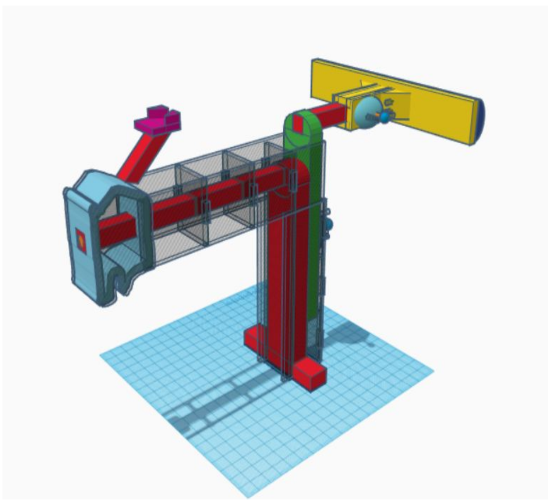

Figure 6. 3D Model of Final Prototype (Side-view)

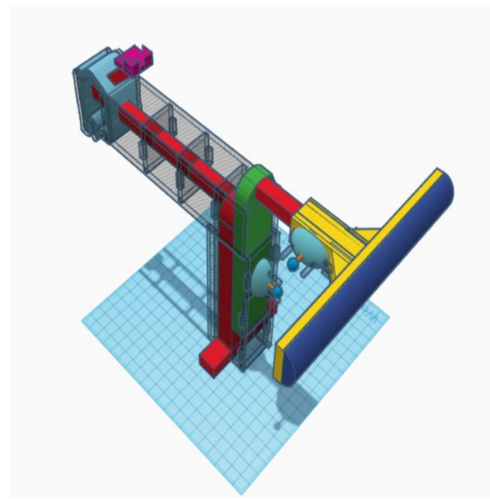

Figure 7. 3D Model of Final Prototype (Top-view)

2. Purpose and Function of Final Prototype

The final prototype was intended to be the complete representation of the final product that the design team was working towards. This is the prototype that would have been presented to the client and the judges during Design Day. The primary purpose of the product is to enable wheelchair-users with lower body disabilities to use rowing machines at fitness centres comfortably and independently.

In order to find the best solution, the team built two preliminary prototypes as described above. While developing the first and second prototypes, the design team had the chance to experiment with different materials and dimensions. This allowed for the choice of the best design, material, and building method for the final prototype.

The final product would consist of a 3D printed attachment head that would clip onto the rowing machine in the same way as the first prototype. When testing the first prototype, the dimensions were found to be exact, and it fit perfectly into the rowing machine. Therefore, the same dimensions would have been used for the attachment head in the final prototype. However, the head would be hollow in order to make the product more lightweight. Moreover, when testing the second prototype, it was found that bare acrylic sheets were not strong enough to hold the assembly together. For this reason, the final product would include a steel support bar that would be inserted into the attachment head (another reason why the attachment head would have to be hollow). Acrylic sheets would still be used on the sides, mainly for aesthetics. Also, 3D printed support blocks would be placed in between the two acrylic sheets in order to provide additional support. The base, which makes the product stand on the ground, would further be 3D printed. All of these measures are to ensure that the product will be stable and rigid during the workout. Strategically-designed connectable 3D printed blocks that can slide up and out of the acrylic sheet shell would be used to make the adapter adjustable in height. The pieces will be secured by a spring lock pin (similar to the ones commonly seen in exercise equipment), allowing for the user to adjust at ease. There would also be a 3D printed part that sticks out of the adapter (yellow part in **Figure 6**). This is where the user's shins will be pressed upon. However, to make it more comfortable, a foam pad (dark blue part in **Figure 6)** would be placed onto this 3D printed base. This base can be moved horizontally in order for the user to place his/her shins appropriately on the foam pad. To do this, another spring lock pin would be used to adjust this length from the green part in **Figure 6** to the yellow base. Finally, a small 3D printed block would stick out of the attachment head with a 3D printed handle-holder. This is to solve the problem of not being able to reach the handlebar comfortably during the workout, which was an aspect that was discovered when testing the first and second prototypes.

3. Client Interaction with Final Prototype

The client intended to use the final product for wheel-chair users at his gym. In order to use the adapter, the rowing machine must first be detached by a staff member. The staff member would then clip the adapter easily onto the rowing machine as described above and as was shown while testing the first prototype. Next, the staff member would remove the handlebar from the holder on the rowing machine and place it in the new handlebar-holder on the adapter. Wheel-chair users would then approach the adapter and adjust its height as needed. Subsequently, they would place their shins onto the foam pad, adjust the length of the foam pad base, and lock their wheelchairs in place. They would then grab the handlebar from the handlebar holder and begin pulling it towards their chests, performing the workout independently. Once the exercise is done, users would return the handlebar to the holder on the adapter. A staff member would return the handlebar onto the original holder on the rowing machine and would detach the adapter and reassemble the rowing machine. This process of assembling/dismantling should not take more than 30 seconds, and the fact that the adapter would be quite lightweight is advantageous since staff members will not have to exert too much force to attach/detach the adapter.

I.2 Planned Execution Under Normal Conditions

1. **Uncompleted Aspects of Final Prototype**

Uncompleted aspects of the final prototype mainly include multiple 3D printed parts and a laser-cut acrylic frame. The team was able to print over half of the 3D printed parts required for the final prototype (the attachment head piece, the main horizontal/vertical supports, the pin lock adjustment pieces, and the foam pad base). However, some 3D printed parts were not yet developed, which include three pieces for the vertical sliding support, one for the horizontal section of the sliding support, the elbow pieces for connecting the slide pieces, two handle attachments, and the base where the adapter touches the ground. The acrylic frame was also not developed yet; it had to be laser-cut. The foam pad further had to be cut according to the appropriate dimensions. Finally, the team would have had to perform the bending of the reinforcement steel rod, the attachment of the lock pin, and the full assembly of the product using the PVC adhesive cement to glue the frame, foam pad, and 3D-printed pieces together.

2. **Action Plan**

The following is a step-by-step action plan that the design team would have followed under normal conditions during the 1.5 weeks leading up to Design Day (March 16th to March 26th) in order to successfully complete and test the final prototype. As mentioned above, some parts were already developed before March 16th and are hence not included in this plan.

<u>March 16:</u>

- Begin 3D printing the three pieces for the vertical sliding support - Liam, Roxel, Peter
- Begin 3D printing one horizontal section support - Fatemeh, Sireen

<u>March 17:</u>

- Collect and check the previous 3D printed parts - Fatemeh, Sireen
- Begin 3D printing elbow pieces for connecting the slide supports - Liam, Peter, Roxel

<u>March 18:</u>

- Collect and check the previous 3D printed parts - Peter
- Begin 3D printing 2 handle attachments - Fatemeh, Sireen
- Begin 3D printing the base - Roxel, Liam

March 19:

- Collect and check the previous 3D printed parts - Peter
- Using the laser cutting machine, cut the acrylic sheets according to the appropriate dimensions - Roxel
- Cut the purchased cushioning pad according to the proper dimensions - Sireen, Fatemeh
- Bend the steel support bar to fit into the attachment head - Liam, Peter

March 20:

- Assemble the product completely using PVC Cement - collectively
- Attach the spring lock pins for height and length adjustments - Liam

March 21:

- Fix any potential issues with the product - collectively
- Write the script for the Design Day pitch - collectively

March 22:

- Fix any other issues with the product - collectively
- Review the script for the Design Day pitch - collectively

March 23:

- Test the product at the uOttawa Minto Sports Complex Gym - collectively
- Amend issues (if any) discovered during testing - collectively
- Begin working on a Design Day poster - Sireen, Fatemeh

March 24:

- Test the product once again at the uOttawa Minto Sports Complex Gym and record a video demonstration - collectively
- Continue working on the Design Day poster - Sireen, Fatemeh

- Practice the Design Day pitch - collectively

March 25:

- Edit the video demonstration of the product as necessary - Roxel
- Finalize the Design Day poster - Sireen, Fatemeh
- Practice the Design Day pitch - collectively

March 26:

- Perform any final touches - collectively
- Final practice of the Design Day pitch - collectively
- Showcase the product at Design Day!

3. Gantt Chart

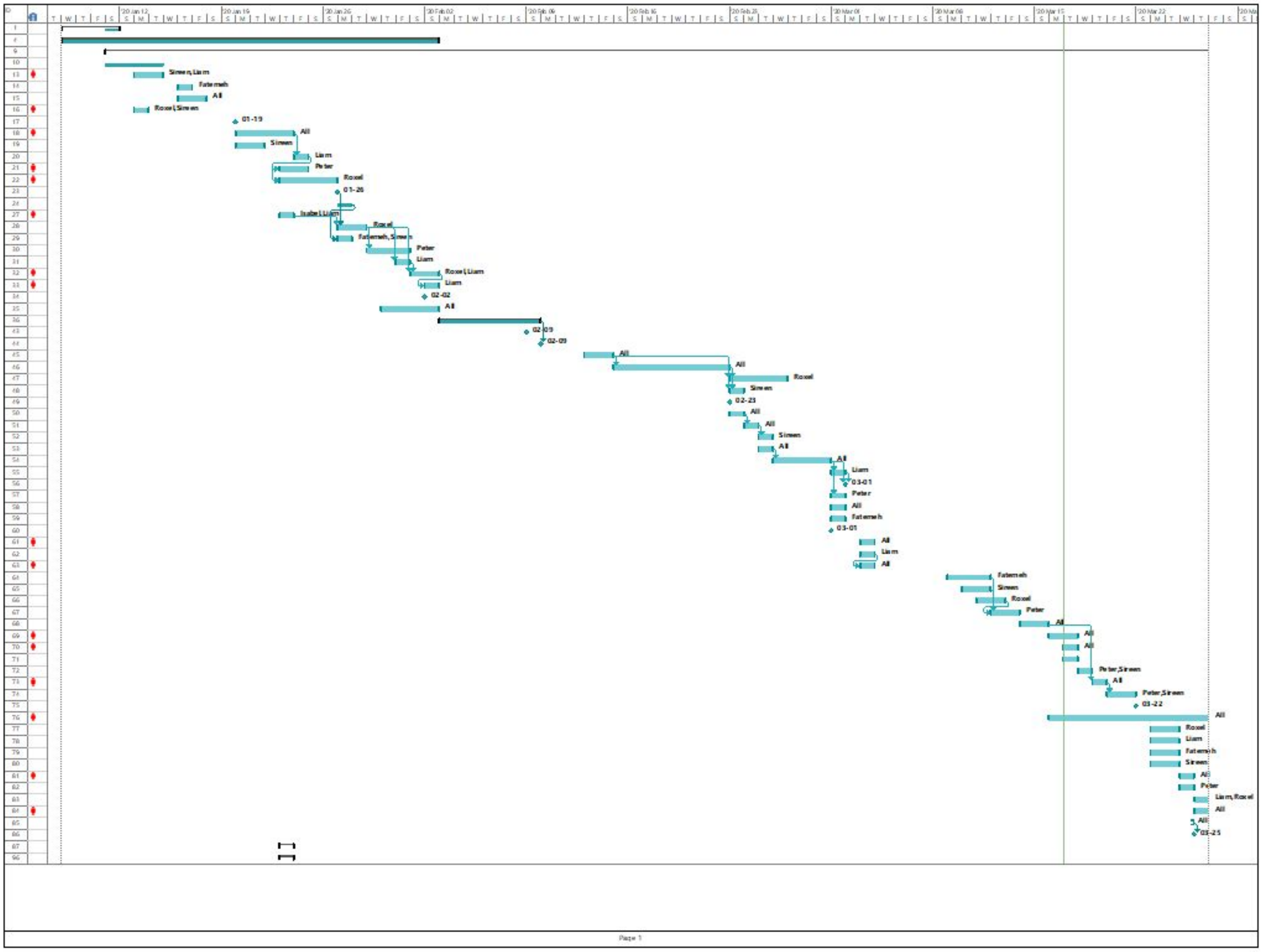

Figure 8. Gantt Chart illustrating the intended action plan under normal conditions.

4. Systematic Testing and Analysis Plan

<u>Systematic Testing:</u>

Systematic testing would include a full and comprehensive test of all individual components as well as the whole unit to ensure that everything works as intended and meets the target specifications (shown in **Table 1)**.

This would include:

- Strength testing to ensure safety and reliability for users (ensuring that the prediction that the unit will function for over a year with minor maintenance and repairs is realistic).
- Testing of the adjustable pieces to make sure that the prototype accommodates the widest possible array of wheelchairs (marginal value of 70 cm) and is easily adjustable by the user.
- Test for ease of installation of the product with a test subject by giving him/her only three basic instructions (remove current slide rail, insert the adaptive prototype, and place handle in holder). This is in order to verify that it is an intuitive design that can be installed in under 30 seconds.
- Measure the size of the dismantled product in order to ensure that it occupies minimal space (within 0.1 m^3 and ideally less than 0.0742 m^3).
- Testing and ensuring that there are at least 2 safety features (foam pad and handle holder).
- Weigh the prototype to ensure that it is under 20 kg.

Table 1. Target Specifications for the Final Prototype.

Number	Metric	Unit	Marginal Value	Ideal Value	Reasons
1	Total mass	kg	<20	<15	This ideal value is chosen since the competitive Product 1 has the lowest mass (15 kg). The marginal value is <20 kg because the team's design is more complex than Product 1 and can therefore weigh more.
2	Time to assemble/dismantle	s	<30	0	The ideal value is 0 s since Product 2 does not require assembling and dismantling. The marginal value, however,

					is less than 30 s because the team's design requires assembling and dismantling. This value was chosen to remain competitive with Product 1 (60 s).
3	Unit manufacturing cost	$	<100	<761.25	The ideal value is <761.25 dollars because that is the lowest cost between the benchmarking products (Product 1). However, the marginal value is <100 dollars since that is a budget constraint in the team's design.
4	Actions that need to be performed by a staff member	list	<3	None	The ideal number of actions is 0 because the benchmarking products all have 1 or 2 actions. To remain competitive with them, 0 actions would be ideal. The marginal value is <2 because, realistically, a staff member will have to perform at least 2 actions to assemble the equipment for the user since the design is detachable.
5	Size of wheelchair that can be accommodated	cm	>70	any	To be competitive with Product 2, the design will have to accommodate any wheelchair size (ideally). The marginal value is >70 cm because there is a limit to the amount of space that the adapter can occupy. To

					accommodate bigger sizes of wheelchairs, a much bigger adapter would be needed.
6	Expected functioning duration	yr	>1	>3	The ideal value is more than 3 years. This is chosen to compete with Product 3. The marginal value, however, is more than 1 year since there are certain constraints for the team's design (such as budget constraints) that could lead to a lower functioning duration.
7	Space taken up in storage	m^3	<0.100	<0.0742	The ideal value is chosen as <0.0742 m^3 since that is the least space taken up between the 3 benchmarking products (Product 2). The marginal value, though, is <0.1 m^3 because, in order to develop an adapter suitable for many wheelchair sizes, a slightly bigger adapter that takes up more space is needed.
8	Safety features	list	>2 features	>4 features	The ideal value is more than 4 features since Product 2 has 4 safety features. However, the marginal value is >2 features since, in order to add more features, a greater budget is needed.

Analysis Plan:

If the prototype passes all the above tests, the team would feel confident in saying that the prototype met all the target specifications and, therefore, satisfies the client's needs. If a test were to fail, there would be two options. One would be to improve the design, and the other would be to dismiss that aspect of the product. Depending on the importance of the aspect that has not been satisfied and the size of the task needed to be done to fix this aspect, the design team would choose a solution. Ideally, the team would redesign the product. However, if the failed aspect was of low importance or there were major time/money constraints, the product would remain as is. According to the design team's best predictions, all tests would be easily passed with the exception of the storage space, which might not be within the target specifications. However, given that this is of low importance on the list, the client would still likely be fully satisfied with the result even if it was slightly larger than desired. Overall, the product would be perfectly successful if it passes all the specifications with the exception of the storage space.

Documentation:

Documenting the results would be done through an organized table comparing actual results with expected results according to the target specifications as was done for the second prototype in Deliverable G. The design team would also make comments and suggestions for future amendments and work .

Conclusion:

A detailed report on the final prototype was successfully completed. The first and second prototypes, as well as the intended state of the final prototype, were clearly documented with visual representations and descriptions. The purpose and function of the final prototype were also explained thoroughly, along with the intended method of client interaction with the prototype. The uncompleted aspects of the final product due to the COVID-19 outbreak were then described, and a step-by-step action plan that would have been followed under normal conditions was developed. A Gantt chart was further included to demonstrate the action plan. Finally, a systematic testing and analysis plan was described, along with an appropriate method for documenting the final prototype specifications. Further steps will include a final presentation and user manual for the intended final product.