GNG2101

Design Project Progress Update

Group #14: Bob's Skates

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Acronym	Definition

Table 2. Glossary

Term	Acronym	Definition

0 Introduction

The purpose of this document is to reestablish the goals regarding our design by comparing our critical assumptions to our five x-factors. The deliverable then delves into the two prototypes done so far, the 3D printed method and the sheet metal model. This is done by conducting tests both physically and analytically to compare the results to the initial target specifications for this project. Finally, a decision is made between the two prototypes and next steps are discussed.

1 Prototype 1, Project Progress Presentation, Peer Feedback and Team Dynamics

1.1 Prototype 1

One assumption was that a sheet metal product would be easy to manufacture. It was also assumed that this would be especially true in the context of mass production. To validate this assumption, not only could we conduct tests during the manufacturing process to see if our design would be feasible to machine, but we could also ask experts in metal working for their inputs on the design. The technicians often know best when it comes to the actual creation of products. To be more specific, while we are creating our prototype, we could utilize equipment that might simulate what a proper automated machine could do. For example, there exist milling machines which are programmed to conduct the same task over and over again. If we were to use a milling machine to create this sheet metal prototype manually and everything goes smoothly, our assumption would be validated. This assumption relates to the manufacturability DFX factor which was considered. It was stated that the product needs to be manufacturable with existing machining processes, it needs to be inexpensive, and it needs to be environmentally friendly. It is obvious how this assumption relates to the DFX factor.

Prototype A is a CAD Model which has been 3D printed using PLA (10% infill), its purpose is to:

- To test feasibility of printing the geometry we have designed
- To test the different materials and infills of the 3D printer
- To test the features of our design and if it's the best model for what we want to achieve


Figure 1: Prototype A Model Top View


Figure 2: Prototype A Model Bottom View

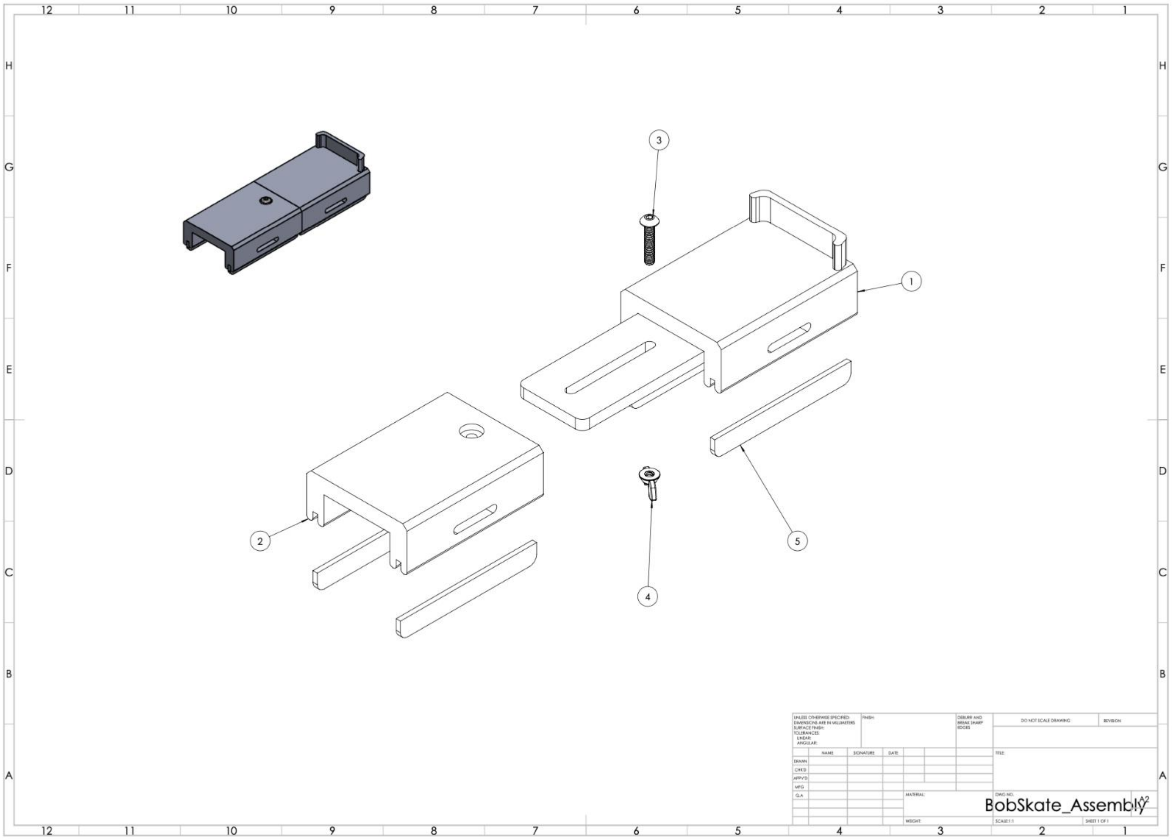


Figure 3: Prototype A CAD Model

Prototype B is a CAD prototype, its purpose is to:

- Demonstrates the geometry and scale of components
- Mass can be calculated using the material properties
- Can be utilized to develop detailed design drawings
- Mathematical/analytical testing methods can be used

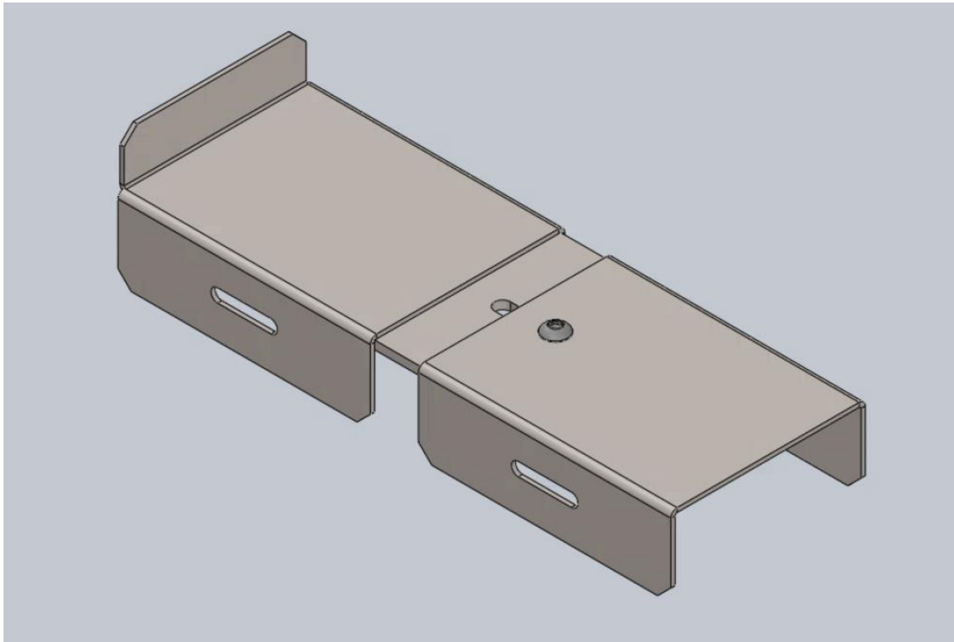


Figure 4: Prototype B CAD Model

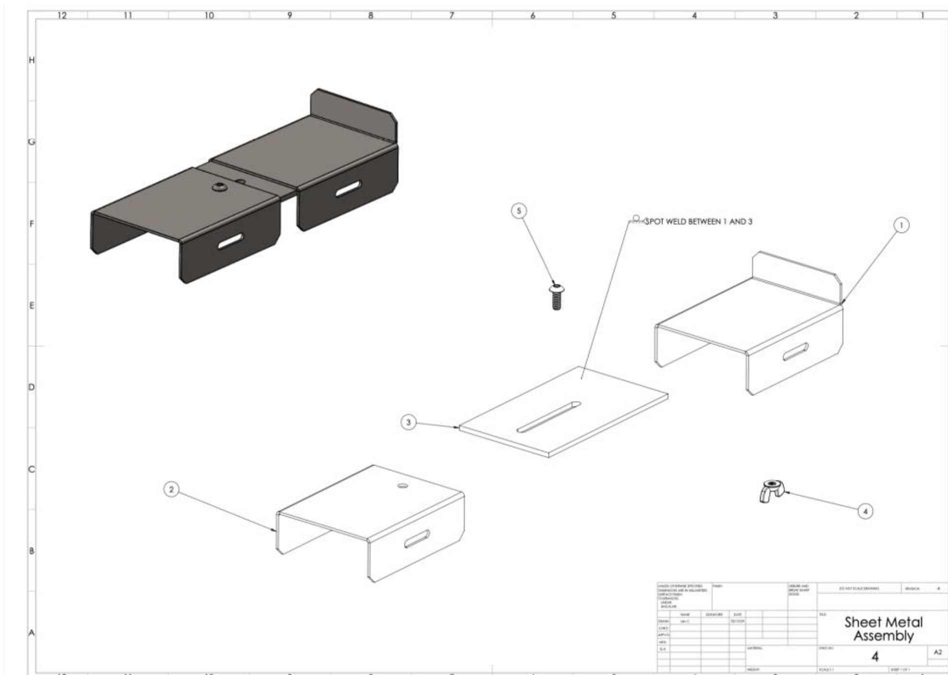


Figure 5: Prototype B Assembly Drawing

PLA 3D Print Results:

After receiving the 3D-printed half of the skate, we realized there are a few problems with this prototype.

1. PLA with a 10% infill will be too weak to sustain the weight of our client, we tested this by stepping on the part and heard cracking.
    i. If we were to continue this approach, we would try using a higher infill, and if that does not work, we would try a different material.
1. Stress Points in Design
    i. We also realized there are points of stress in the way we have it initially designed, such as at the inner 90-degree corners, we can fix this by adding chamfers to these corners or an arc shape.

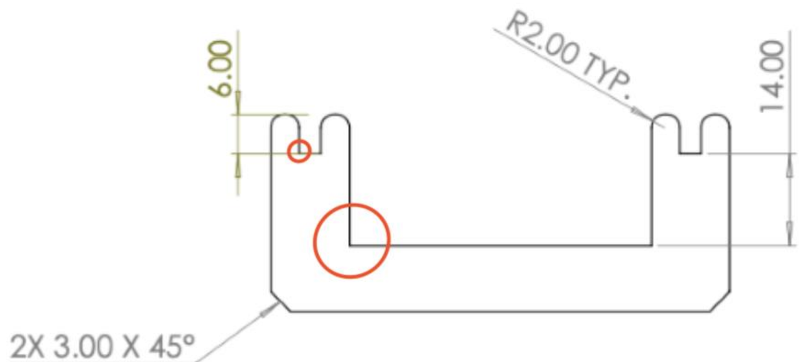


Figure 6: Prototype A Problem Areas

Sheet Metal Mass Analysis:

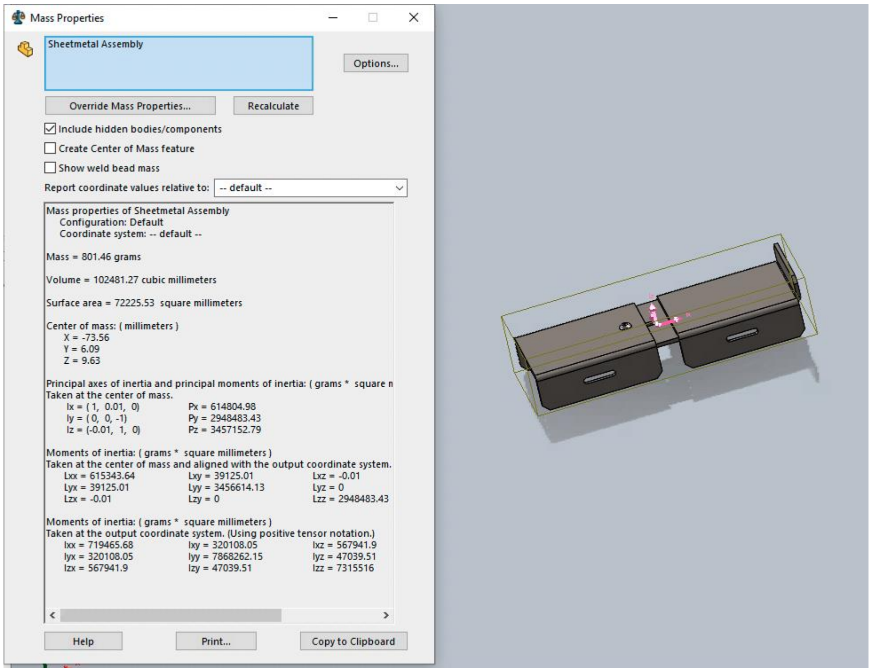


Figure 7: Cold rolled AISI 1020 t = 0.12 in

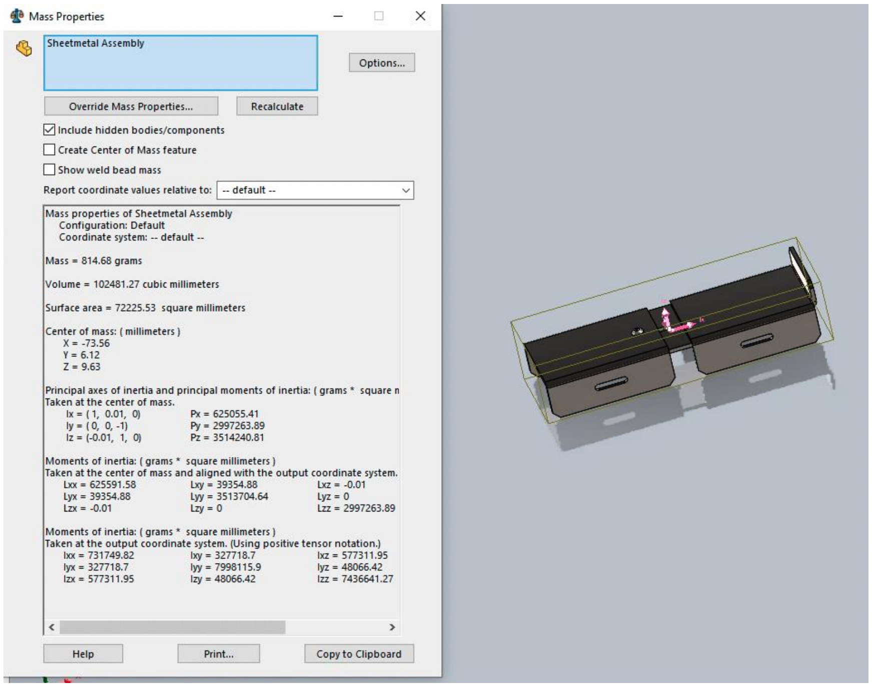


Figure 8: Stainless steel sheet AISI 316 t = 0.12 in

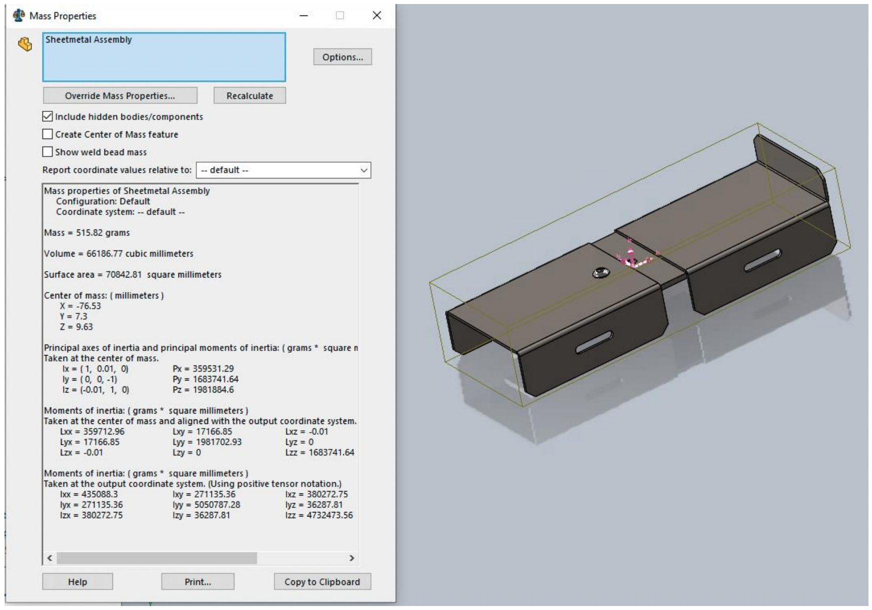


Figure 9: Cold rolled AISI 1020 t = 1/16in

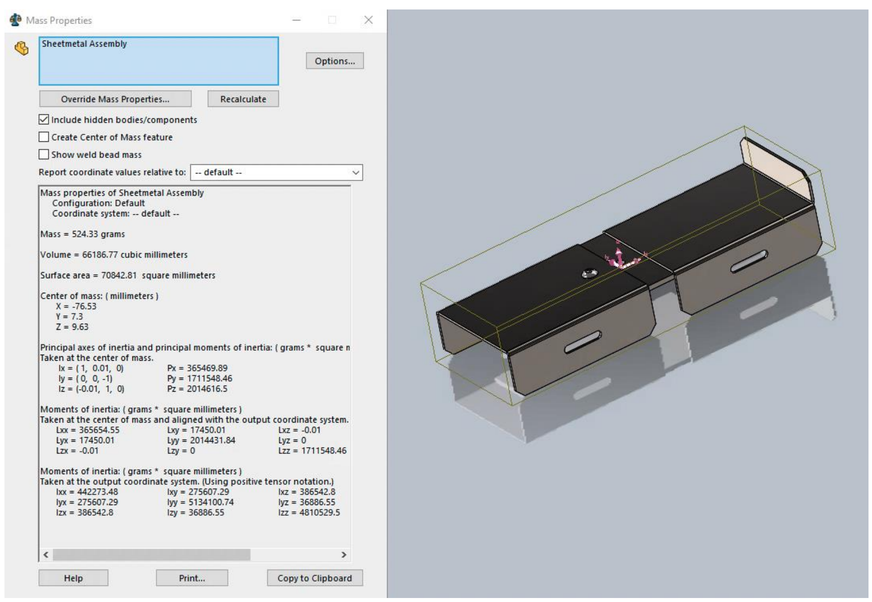


Figure 10: Stainless steel sheet AISI 316 t = 1/16 in

Given that AISI 1020 cold rolled steel is a lighter and a cheaper alternative to AISI 316 stainless steel, we will evaluate the mechanical properties of AISI 1020 cold rolled steel to see if they are sufficient.

Sheet metal simple load analysis

By treating our design as a pin-supported beam (pins where the blades would be), we can analyze the load capacity in respect to bending, shear and deflection. We can also compare applied stress with the material ultimate strength to determine if the part will experience failure.

- For this evaluation, we will consider the front and back parts as a single member and omit the adjustment section.
- Beam with length of 3 inches with pin support at each side
- Rectangular cross section, height of 0.0625 inch (1/16 in) and width of 7.5 inches
- Given the approximate dimensions, moment of inertia I = 0.00015259 in^4
- For cold rolled steel AISI 1020, elastic modulus E = 27000 ksi

The weight can be represented as a distributed load of 58.33 lbs/in or an equivalent point load of 175 lbs

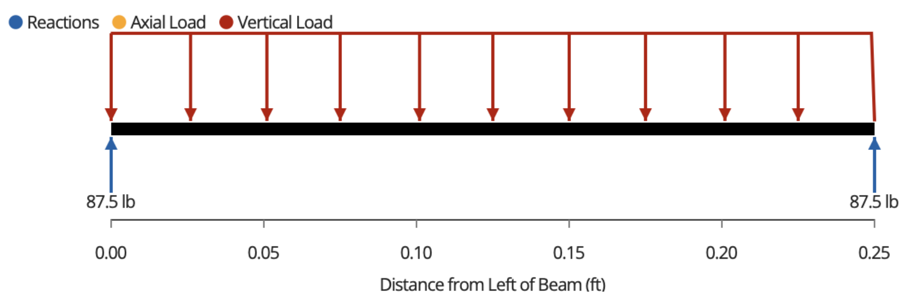


Figure 11: Prototype B Load Diagram

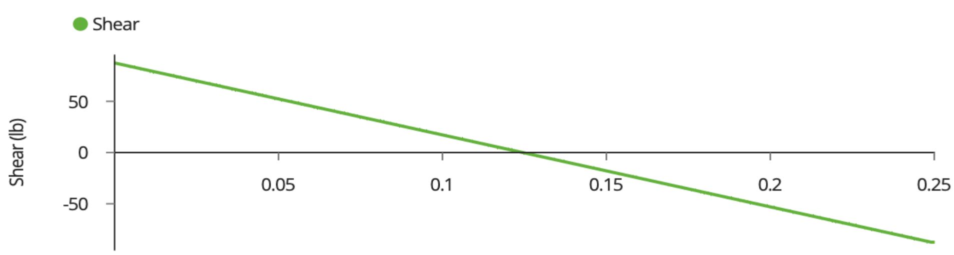


Figure 12: Prototype B Shear Force Graph

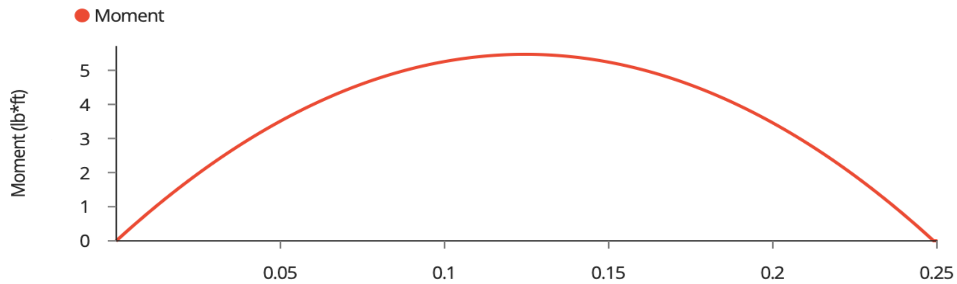


Figure 13: Prototype B Moment Graph

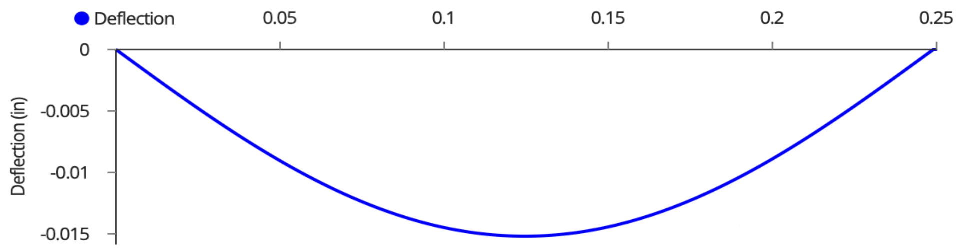


Figure 14: Prototype B Deflection Graph

Summary

- Moment Demand $M^* = 5.47 \text{ lb} \cdot \text{ft}$
- Shear Demand $V^* = 87.5 \text{ lb}$
- Deflection $\delta = -0.0152 \text{ in}$

We can calculate the bending stress in the member as –My/I.

The max bending stress is – 5.47 lb ft (12in/ft) (0.03125 in) / 0.00015259 in^4 = -13442.886 psi (negative since compression is on bottom)

We can also calculate the shear stress in the member as 3V/2A (for rectangular cross section)

The max shear stress is 3 (87.5lb) / 2 (7.5in) (0.0625in) = 280 psi

Comparing these max stresses with the ultimate tensile strength = 60000 psi, we can see that the member would not fail in shear or bending. Even though it is more likely to fail in bending, it has a SF of almost 5.

This testing model is a large oversimplification due to all the assumptions. However, it still provides a general understanding of the system's capabilities.

Table 3: Prototype performance compared with target specifications

Metric	Units	Ideal Specification	3D Printed Prototype Results	Sheet Metal Prototype Results
Size	inch	**7.5 inches**	7.5 inches	7.5 inches
Durability	Years	5 years	NA	NA
Total Weight	lbs	<1 lb	NA	1.1 lbs - 1.8 lbs
Cost	CAD	<$75	Free	Free
Weight capacity	lbs	175 lbs	<175 lbs	>175 lbs
Adjustability	inches	> 2 inches	2.2 in	2.2 in
Balance Support	Yes/No	Yes	Yes	Yes

Conclusion:

After analyzing these 2 different prototype materials, we have decided to stick to the 3D printed part approach to be able to focus all our time and energy on maximizing the best results. After our design review, we learned that with the sheet metal model, there is a chance we won't have all the tools needed to make this model at Brunsfield and would need to send it off to be machined elsewhere. This could be expensive and take away from our involvement in the making of our skates. Moreover, during our second client meet, our client showed a preference for the 3D printed method over the sheet metal since he was happy with the skates he had from before. Moving forward with the 3D printed approach, we are next going to try a higher infill with an improved model and if that still isn't strong enough, we will look into a different material.

1.2 Project Progress Presentation

[GNG2101 Midterm Presentation]

1.3 Project plan update

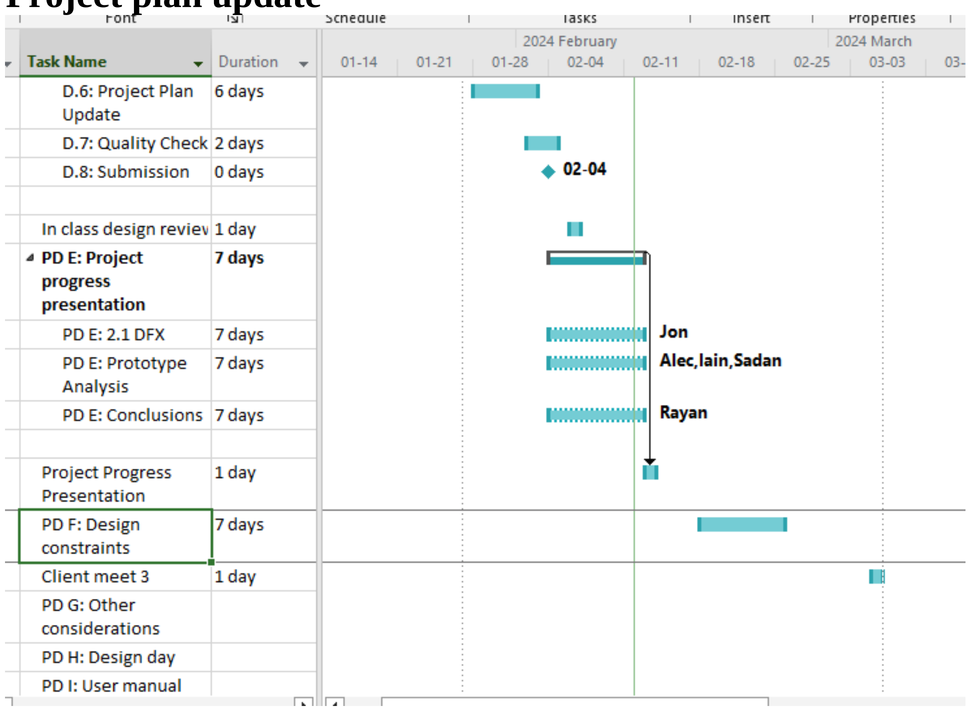


Figure 15: Project Plan Update

2 Design Constraints and Prototype 2

2.1 Design constraints.

Non-Function Design Constraints

Durability and Weight Capacity

- Skate must stay intact for it to function as intended.
- The client is hoping these skates will be useable for multiple seasons as she grows so they must be able to last and stay intact for a long time.
- Our main issue with the first prototype is that it was not durable or sturdy enough, in both its geometry and the material it was made of.
- Our goal with the second prototype is to improve this and carry out further durability and weight capacity testing.

Unit Weight

- Skate must be sufficiently lightweight for the user to move freely.
- The client has difficulty with muscle strength, so the skates must not be excessively heavy to the point where they pose an additional challenge to the user.
- In the first prototype, we were not able to test the unit weight of the 3D printed design since the prototype was only one component of the overall design.
- Our goal for the second prototype is to print both base pieces and carry out initial unit weight testing.

Design Changes

Durability and Weight Capacity

- Changes to design Geometry
  - Implementing chamfered edges along the blade supports to decrease the concentration of bending stresses applied to the skate
- Changes to material
  - Try materials with more desirable characteristics such as higher strength, water resistance, resistance to cold temperatures
  - We are currently still printing with PLA and testing the extent of its mechanical properties since it is free and responding well to initial testing
  - We will also be printing with PETG which should have theoretically better properties (similar to ABS) since a team member has access to printing with it
- Changes to printing settings
  - Skate will be printed with a higher infill of 30, which will increase the design strength

Unit Weight

We will not be making any changes from prototype 1 to 2 based on unit weight, since we have not been able to test the first prototype for this constraint. However, consideration is being given to the following points:

- Changes to design of geometry
  - May need to consider removing excess material in locations that take less load.
  - Cannot remove too much or else it will impact the weight capacity and durability.
- Changes to material
  - All prototype material choices have and will continue to be made with heavy consideration on material density.
  - Higher density will result in a higher weight.
- Changes to printing settings
  - We are increasing the infill, but this will also increase the weight.
  - Weight is a limiting factor for our infill adjustments

In summary:

- Design changes are being made to the geometry, material and print settings, but the extent of the changes is limited by unit weight.
- Must optimize for highest weight capacity and durability at the lowest possible unit weight

Proof of Changes

In a 2019 study, researchers conducted tests on 3D printed objects at different infill densities as well as different infill patterns to see how this would affect tensile strength. The study concluded that there is a correlation between higher infill density and greater tensile strength. “In general, the results showed that increasing the infill density increases tensile properties for the three infill patterns”. (Rismalia, 2019). Additionally, seeing as there is a lot of information regarding 3D printing on the internet, the research that has already been done should be used to save time.

Regarding the chamfered edges on the second prototype, they appear to have had an impact on the load distribution. “While chamfers can help reduce stress concentration, they do not distribute as well as fillets to.” (Xometry, 2016) This information confirms that the chamfers will aid in distributing the load. However, fillets would help distribute the load to a greater extent. We chose not to implement fillets into our design because they are harder to 3D print. However, we will consider implementing the fillets into the final prototype.

Updated Detailed Design

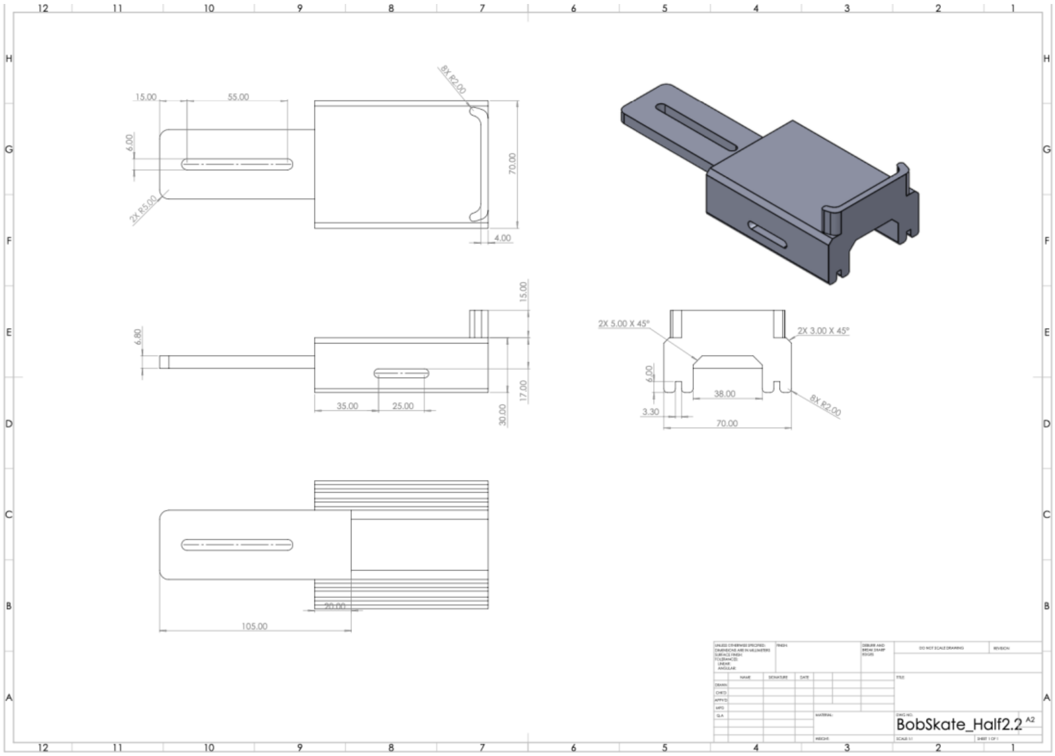


Figure 16: Updated Detailed Design Back Half

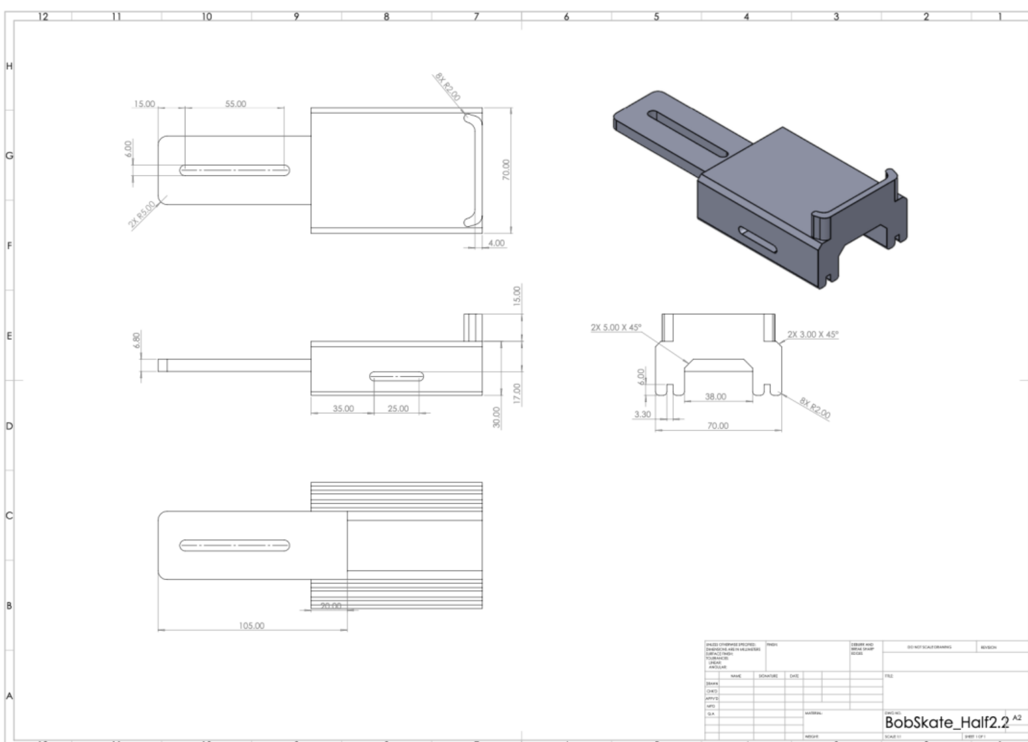


Figure 17: Updated Detailed Design Front Half

2.2 Prototype 2

Client Feedback Summary

During the last client meeting we had, we were still deciding between the two different approaches to our design, the sheet metal model and the 3D printed model, the client was happy with the 3D printed idea, but we still have not gotten specific feedback on our prototype yet.

However, we received feedback from other people to change the geometry of our model to make it more durable which is one point we focused on for this prototype. We also received feedback about our 3D printing technique and how to position the skate while printing to make it stronger.

Critical Product Assumptions and DFX

One critical product assumption was that the skates need to be adjustable up to a length of 7.5 inches. This directly relates to one of our DFX factors where we stated that we would design the product for adjustability. We still need to print the adjusting piece and back end of the skate to test how well the skates can be adjusted.

Another DFX we highlighted in the earlier deliverable was manufacturability, this can relate to our ability to machine the steel blades to fit into the 3D-printed body. We haven't tested these blades yet and if we're able to make them here on campus. However hopefully, the geometry of the blades is simple so it should be feasible.

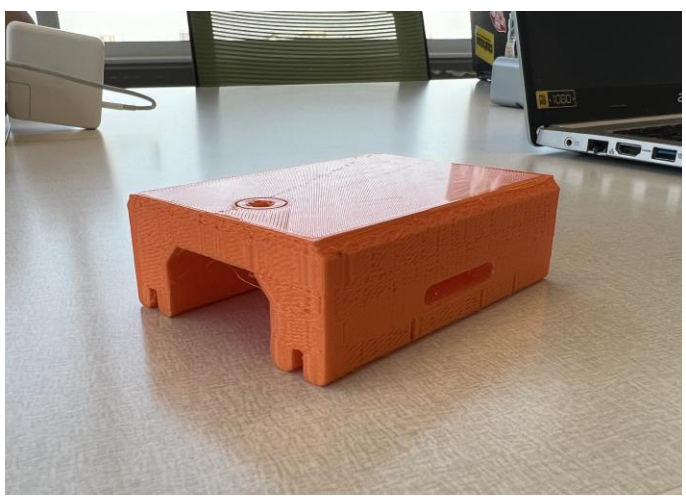


Figure 18: Prototype 2 View 1

Figure 19: Prototype 2 View 2

Table 4: Prototype Testing

Test type	How	Result	Comparison
Weight Capacity	Standing on the prototype which would subject it a load of 160kg	Was able to hold my weight with out and cracking or bending (160kg)	Prototype 1 when I stood on you could hear creaking and bending compared to prototype 2 which has no visible bending or cracks forming prototype 2 is a success

Durability	Put it in the snow (1.2° C) for 30 minutes and then standing on it to see if it has weakened	When standing on prototype 2 it had similar results to the weight capacity test. No creaking, cracking, or bending was observed.	Prototype 1 could not handle my full weight without immediate cracking being heard, crack lines became visible, and testing had to be stopped. Prototype 2 on the other hand did not creak or crack and any point and was able to handle the 160kg with no visible or audible strain
weight	Weighing it on a food scale	41g	When weighted prototype 1 weighed in at 29g compared to prototype 2 being weighed at 41g, this is most likely since prototype 2 has more material and higher infill compared to prototype 1

Figure 20: Prototype 1 (Red) and 2 (Orange) Durability Test

Client Meet 3

For the second client meeting, we plan on showing the client our previous model and the current updated model (both CAD and 3D printed prototypes) to highlight the improvements. We will also show him the different supplies we will be using to bring the product to life. Those being the Velcro straps, steel blades, and adjustable body.

2.3 Project plan update

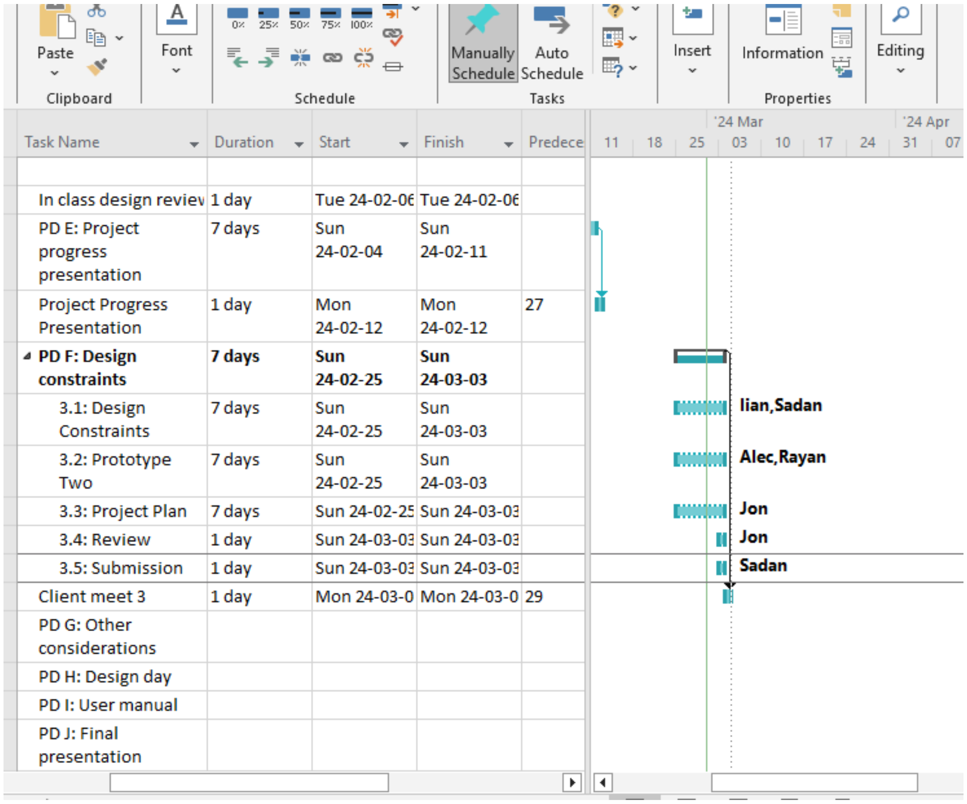


Figure 21: Updated Gantt Chart

3 Other Considerations

3.1 Economics report

1. Include a list of variable/fixed, direct/indirect, and material/labour/overhead costs associated with your business, based on the manufacturing and sale of your product. Make sure that you distinguish between price and cost and realize that prototyping and higher-volume manufacturing costs will probably be different.

Preface:

Our company does not manufacture any components of the product in-house. Instead, pre-manufactured parts are ordered specially from manufacturers and assembled on site. 3D printing is not feasible for large-scale manufacturing, so the body of the skates are injection molded instead. The following is a list of costs associated with our business, based on the manufacturing and sale of our product during the first year of full production.

Cost	Description	Amount	Variable /Fixed	Direct /Indirect	Material /Labour /Expense
Advertising /Marketing	Tiktok add campaign	$20,000.00	fixed	indirect	expense
Utilities	Faciclity electricity and heating	$50,000.00	fixed	indirect	expense
Salaries - Assembly line	Workers who assemble product (hourly)	$500,000.00	fixed	direct	labour
Salaries - Other	HR, finance, marketing staff (hourly)	$800,000.00	fixed	indirect	labour
Pre-Manufactured Parts	Skate base, straps, blades	$600,000.00	variable	direct	material

Facility Rent	Cost to use facility	$200,000.00	fixed	indirect	expense
Shipping	Transportation of pre-manufactured parts to/from assembly facility	$40,000.00	variable	direct	expense
Assembly equipment	System that joins blades with base	$300,000.00	Fixed /variable	direct	expense
Assembly connectors	Epoxy, screws, nuts	$50,000.00	variable	direct	material
Equipment depreciation	Decrease in equipment value from use overtime	$10,000.00	fixed	indirect	expense
Overhead	Other ongoing operating costs	$20,000.00	fixed	indirect	expense

2. Develop a 3-year income statement, which includes sales revenue and costs of units sold for each year, gross profit, operating expenses and operating income (no need to include interest and taxes).

Income Statement:

	Year 1	Year 2	Year 3
Sales Revenue	$150,000	$400,000	$800,000
Cost of Goods Sold	$100,000	$250,000	$500,000

Gross Profit	$50,000	$150,000	$300,000
Operating Expenses	$30,000	$60,000	$100,000
Operating Income	$20,000	$90,000	$200,000
Net Income	**$20,000**	**$90,000**	**$200,000**

3. Using a NPV analysis, determine the break-even point (i.e. number of units that must be sold for your business to become profitable). Note: It is highly unlikely that your operating income will be positive in the first year because of fixed costs. Therefore, you must use a NPV analysis to compare costs and profits over multiple years based on present value. Draw two cash flow diagrams of the expenses and incomes for the next three years. Calculate the NPV value of each expense/income and determine the differences and then the break-event point.

Cash Flow Diagram for Incomes:

Year 1: $20,000

Year 2: $90,000

Year 3: $200,000

Cash Flow Diagram for Expenses:

Year 1: -$30,000

Year 2: -$60,000

Year 3: -$100,000

Year	Sales Revenue	Cost of Goods Sold	Operating Expenses	Net Cash Flow	Discount Rate	NPV
1	$150,000	$100,000	$30,000	$20,000	10%	$18,182
2	$400,000	$250,000	$60,000	$90,000	10%	$74,380
3	$800,000	$500,000	$100,000	$200,000	10%	$150,336

The NPV becomes positive in Year 1, indicating the break-even point.

4. Describe and justify all assumptions that you have made in developing your economics report. The assumptions must be factual based on a preliminary market research that you conduct in order to determine the amount of demand in your target market, the expected % of the market that you would own, and the unit price of your product based on a sound pricing strategy. Important

Note: we expect you to make many assumptions here. However, each assumption should be identified and justified using information you gathered from various sources. Provide references when using this information.

- **Assumption 1: There is a growing demand for the product/service in the target market.**

Justification: This assumption is based on market research indicating increasing consumer interest in similar products or services. Market trends, consumer surveys, and industry reports can support this assumption.

- **Assumption 2: The company aims to capture a conservative percentage of the target market, such as 5% within the first year.**

Justification: This assumption is based on the company's market analysis, understanding of competitors, and its own capabilities. Market share data from industry reports or competitor analysis can inform this assumption. Additionally, the company's marketing strategy, distribution channels, and unique selling propositions can influence its projected market share.

- **Assumption 3: The product will be priced competitively based on a cost-plus pricing strategy, with consideration given to the perceived value by consumers.**

Justification: This assumption is based on a sound pricing strategy that factors in production costs, competitor pricing, and consumer willingness to pay. Market research, including surveys and focus groups, can provide insights into consumers' price sensitivity and preferences.

- **Assumption 4: The company expects a certain cost structure, including fixed costs (e.g., rent, salaries) and variable costs (e.g., raw materials, marketing expenses).**

Justification: This assumption is based on the company's business plan and financial projections. Detailed cost estimates, including quotes from suppliers and vendors, can inform the company's cost structure assumptions.

References:

www.statista.com

www.marketresearch.com

3.2 Intellectual property report

1. Explore intellectual property databases (i.e. patents, industrial designs, integrated circuit topographies, trademarks, copyrights, creative commons, or open source software) to identify at least two intellectual properties related to your product or business:

a. http://cipo.gc.ca

b. http://www.freepatentsonline.com/

c. http://patft.uspto.gov/

a. https://patents.google.com/ or other

Patent: https://www.freepatentsonline.com/y2010/0314844.html

This is a patent for a dual blade skate design.

An ice skate having a low profile, dual blade assembly. The blade assembly is affixed to the sole of a boot, and each blade is positioned symmetrically about the center line of the boot, and separated by a lateral distance which is sufficient to avoid a build up of ice/snow between the blades. The blade assembly has a short vertical profile in order to provide a low center of gravity, for example, in the range of forty to sixty percent of the conventional vertical profile.

Copywrite: https://trademarks.justia.com/860/93/clifford-the-big-red-86093619.html

This is the Copywrite for Clifford the Big Red Dog, this is related because we wanted to put Clifford the Big Red Dog on the skates.

2. Explain the importance of these intellectual properties and the legal constraints they

place on developing your product or business.

As we are designing a skate which has two blades, it is important that we review patents of similar products to ensure we do not infringe on claims that have already been made. The following few items were found in the claim portion of the dual bladed skate design's patent:

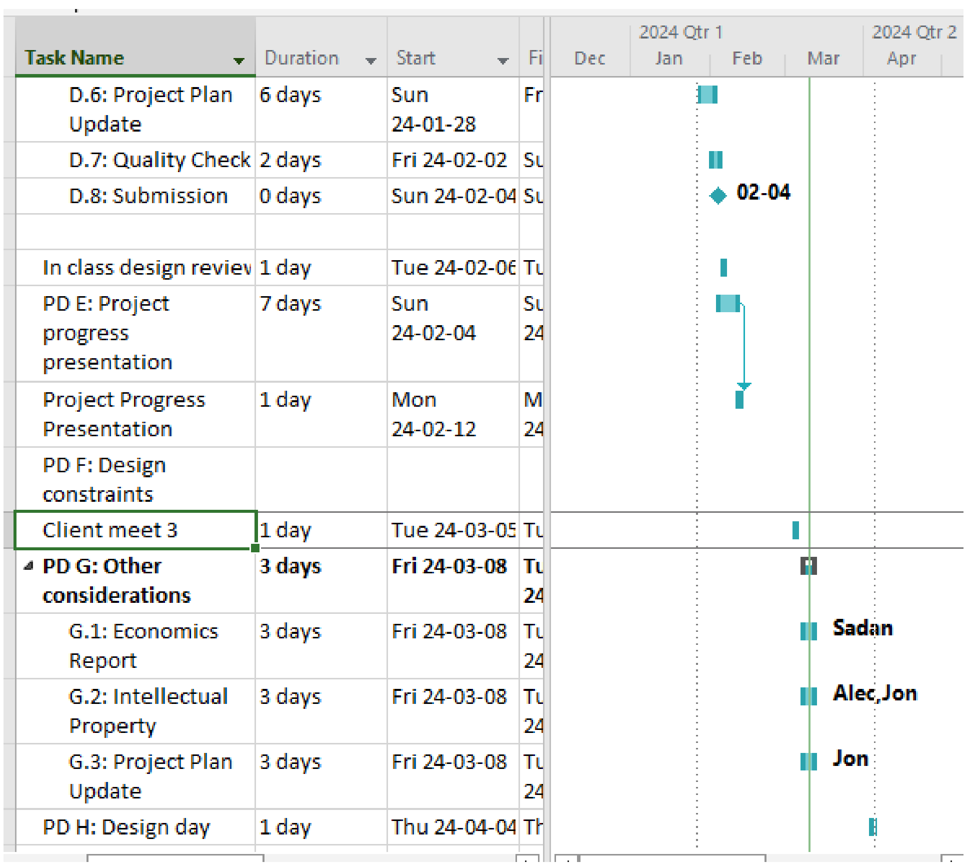
1. An ice skate, comprising: a boot having a sole; a blade assembly coupled to the sole of the boot, including a pair of blades each positioned symmetrically about a longitudinal center line of the boot, said blade assembly having a short vertical profile in order to provide a low center of gravity.

5. An ice skate as in claim 1, wherein the pair of blades is separated by a lateral distance which is sufficient to avoid a build-up of ice/snow between the blades.

7. An ice skate as in claim 5, wherein the lateral distance is approximately 3.6 cm.

Due to the specificity of items 5 and 7, the lateral distance of our own product should not be 3.6 cm for the purpose of avoiding a build-up of ice/snow between the blades.

3.3 Project plan update



Task Name	Duration	Start	Fi
D.6: Project Plan Update	6 days	Sun 24-01-28	Fr
D.7: Quality Check	2 days	Fri 24-02-02	Su
D.8: Submission	0 days	Sun 24-02-04	Su
In class design reviev	1 day	Tue 24-02-06	Tu
PD E: Project progress presentation	7 days	Sun 24-02-04	Su 24
Project Progress Presentation	1 day	Mon 24-02-12	M 24
PD F: Design constraints			
Client meet 3	1 day	Tue 24-03-05	Tu
PD G: Other considerations	**3 days**	**Fri 24-03-08**	**Tu 24**
G.1: Economics Report	3 days	Fri 24-03-08	Tu 24
G.2: Intellectual Property	3 days	Fri 24-03-08	Tu 24
G.3: Project Plan Update	3 days	Fri 24-03-08	Tu 24
PD H: Design day	1 day	Thu 24-04-04	Th

Add a screenshot of your ClickUp gantt chart.

4 Design Day Pitch and Final Prototype Evaluation

Write your design day pitch and plan your prototype demo.

5 Video and User Manual

5.1 Video pitch

Add link to video.

5.2 User manual

See separate template for the user manual. Do not write the content here.

6 Conclusions

Summarize your lessons learned and your work related to your project. Discuss any outstanding issues or implications for the project.

7 Bibliography

[1] M Rismalia et al. Infill pattern and density effects on the tensile properties of 3D printed PLA material. Journal of Physics: Conference Series, Volume 1402, Issue 4. 2019.

[2] Xometry et al. Fillet vs. Chamfer – What are the Differences and Uses?, 2016.

Insert your list of references here.