University of Toronto
Faculty of Applied Science and Engineering
ASP112 & APS113
Conceptual Design Specification (CDS)

Team #	143	Date	March 29, 2023

Tutorial Section	TUT0127
Project Title	Modular Skate Assistant Device for City of Toronto Rinks
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Please check off which components you are submitting for your assignment.

✓ CDS submitted as a PDF to Quercus with the following components:
- ✓ Cover Page
- ✓ Executive Summary
- ✓ Introduction
- ✓ Problem Statement
- ✓ Service Environment
- ✓ Stakeholders
- ✓ Detailed Requirements (FOCs)
- ✓ Alternative Designs
- ✓ Proposed Conceptual Design
  - ✓ Measures of Success
- ✓ Conclusion
- ✓ Reference list
- ✓ Appendices

✓ Attribution table with ALL team members' signatures submitted as a PDF to Quercus. An incomplete or missing attribution table will result in zero on the assignment for the team.

Executive Summary

From October to March, over a hundred City of Toronto ice rinks are open to the general public for leisure skating. The City offers a range of accessible recreation equipment at its indoor rinks, including skate assistant devices. The SkateMate, a skate aid for new skaters, helps the user maintain balance and control while encouraging proper skating posture. These SkateMates are general-purpose and can provide support for both young children and adults, although the primary users are children.

The client of this project is Sophie Costantino, a rink guard for the Central Arena indoor rink. She is requesting a redesign of the current City of Toronto SkateMate due to the current product having a greater width than the rink gate that provides access to the ice, thus requiring users to lift the heavy device above the boards. The client needs a design that can be easily transferred onto the ice while still maintaining the support and safety of the skater.

The client's rink (Central Arena) will be the service environment for this project. City-run indoor ice rinks are controlled environments, with highly regulated temperature, humidity, and ice roughness conditions which constitute the physical environment. The living environment encompasses child and adult skaters and rink staff (such as rink guards, ice maintenance staff, and guest services supervisors). The virtual environment is outside of the scope of this project.

Several City of Toronto and non-affiliated stakeholders must also be considered when developing a new SkateMate. These groups include manufacturers, insurance organizations, inclusive services, the Skate Lending Library, and rink supervisors like the client herself.

The requirements for the project include functions, objectives, and constraints. The redesigned SkateMate must preserve the same functions as the current design. The primary functions will be to support the user while they skate, and the secondary functions include providing balance, steering and safety to the user in the event of a fall. The objectives for the redesign, many of which were provided by the client, define the aptness of the final conceptual designs. These objectives are durability, distinctiveness, lightweight, ease of storage, and advertisement space. The project also faces legal and client-imposed constraints. The redesign must abide by the Canada Consumer Product Safety Act, have a width of less than the width of the entrance, cost no more than 10% higher than the cost of the original device, and have a height within 5% of 29 in.

Using this information, the team proposed several design concepts which were used to create a morph chart based on the functions and objectives. Afterwards, the team proceeded to idea generation and selection, eventually boiling down the list to 16 ideas. Then, using both multi voting and a graphical decision chart, the team arrived at three designs that they believed would meet the client's needs the most.

Moving forward, the team looked into ways of measuring the success of the top three designs in the most important objective, durability. They came to the conclusion of creating 3D models and testing the fatigue life and fatigue safety factor of the designs. Using this data, the team arrived at the conclusion that the "Rotating Panels" design was the most suitable design for long term use.

1.0 Introduction

The client, Sophie Costantino, works at the City of Toronto rink, Central Arena, in Etobicoke, as a rink guard. Skating is a popular recreational activity in Toronto with 133 ice rinks belonging to the City of Toronto [1]. Sophie assists less experienced skaters by providing SkateMates, a skating assistant device (Figure 1) which helps new skaters (mostly children) learn how to skate.

Figure 1. Images of SkateMate provided by client.

However, the rink she works at features an older design and has a small entrance (Appendix A) which the SkateMate cannot pass through. This issue currently requires her to "lift the SkateMate over the gate" [2]. She believes there should be a new skate aid device that solves this issue. This document reviews the issues in the current SkateMate design and outlines project requirements which could aid the redesign.

2.0 Problem Statement

As she stated in [3], the client wants to be able to fit the SkateMate through the entrance onto the rink without lifting it overhead. She also wants children to be able to get the SkateMate onto the ice themselves without assistance. Currently, users who want to bring it onto the ice must ask for assistance if they are unable to lift it overhead. Ideally, the Skatemates that are used by the City of Toronto are designed to fit through all City of Toronto rink entrances as there is currently a lack of a device that provides the aforementioned benefits without posing transportation challenges when moving the device onto the rink.

There is a need for a skating aid device design that is easily transportable onto the ice at all City of Toronto rinks while providing a safe experience for skaters. The scope of the design includes the type of skating aid device that is used, its size, colour, and design. The client has stated in the client meeting that we can only change the device itself and changing the design so that it is no longer a skating aid device is strictly out of scope. The client has also stated that the virtual environment does not affect and should not be considered in this redesign. In addition, she stated that design considerations for users outside the current user base can be left out of scope.

3.0 Service Environment

Location: 50 Montgomery Rd, Etobicoke, ON M8X 1Z4 [3].

Figure 2. Image of rink at the location [4].

The tables below detail the service environment of the design.

Table 1: Physical environment

Physical Environment	
Entrance size	Width 28.7 inches Height 38.6 inches (measured) Shown in figure 3.
Range of Temperature Indoor	10 to 15 Celsius [5]
Range of Temperature on Ice	-4 to 4 Celsius [5]
Humidity	50%-55% [6]
Atmospheric Pressure	950 hPa to 1050 hPa. [7]
Ice Hardness	2 and 6 on Mohs Scale [8]
Ice Friction	Coefficient of friction between 0.005 to 0.02 [9]
Ice Roughness	50-100 micrometers (μm) [10]
Size of Ice Rinks	Max: 60.96m (200 ft.) long; 30.48m(100 ft.) wide Min: 60.96m (200 ft) long; 25.91m (85 ft) wide [11]

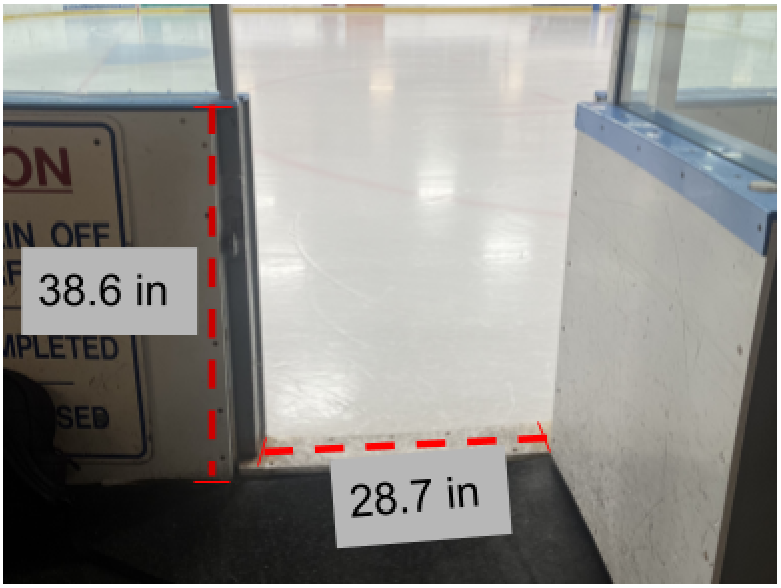


Figure 3: Entrance with measurements.

Table 2: Living environment

Living environment
• People: ○ Average Height Range: 115cm (6 yo girl) -175.1cm (adult male) [12] [13] ○ Age: 6-60 yo [2] ○ Language: English and French [2] ○ Skating Level: Beginner to Experienced [2] • Bacteria

4.0 Stakeholders
Following table lists and explains the significance of stakeholders (all potential stakeholders listed in Appendix B).

Table 3: Stakeholders with justification in ranked order (Appendix C)

Stakeholder	Justification
1. Inclusive Services	Inclusive skating services like those by the City of Toronto [16] need the skating assistant device for training lessons and drop in visits [17]. Final design would be in use by both experienced trainers and newcomers, so it should be easy to use for both.
2. Rink Supervisors	Rink guards responsible for monitoring recreational skating activities, ensuring a safe skating environment, and handling accidents/emergencies. [20] Safety and accessibility of the device could affect the number of accidents and injuries.

3. Manufacturers	Product manufacturers (ex. Skate Helper [14]) who supply the City of Toronto with skating assistant devices would require additional equipment depending on the new design. This could also impact factors including advertising on the SkateMate [14], storage/shipping and cost effectiveness, making it more difficult for suppliers to produce and distribute the final design.
4. Skate Lending Library	Skate lending libraries, such as the ones sponsored by Desjardins for the City of Toronto [19], have to make trips to different locations in order to distribute the skating assistant device so they are affected by how portable it is.
5. Insurance Organizations	Non-affiliated insurance groups may require insurance for City of Toronto ice bookings. [15] Fees will include a minimum $2 million liability insurance coverage, which can include equipment. Safety and usability of the redesigned SkateMate could potentially affect insurance charges.

5.0 Detailed Requirements

The following sections provide an overview of the functions, objectives and constraints of the project.

5.1 Functions

The following table, listing primary functions and corresponding secondary functions, was generated using functional basis and functional decomposition analysis in Appendix D along with the Black Box Method in Appendix E.

Table 4: Primary Functions and Corresponding Secondary Functions

Primary	Secondary
Support the movement of the user	● Provide user with balance ● Allow for user to steer ● Provide the user the ability engage and disengage independently ● Provide failsafe if user loses balance ● Slide smoothly across ice

5.2 Objectives

Table 5 contains objectives that were generated through idea brainstorming (Appendix F) based on information from the client and research. They were ranked by importance using pairwise comparison (Appendix G).

Table 5: Objectives Ranked from Most to Least Important

Objective	Justification	Metric	Goal	Reason
Durable	Products should be long lasting.	Number of years	≥ 5	Similarities in material and loading conditions, to plastic chairs, which tend to last 5 years [21].
Distinctive	Client stated that distinctive design prevents people from taking it home [2].	AI shape image comparison score between face and [18] using [22]	Dist ≥ 34	Client stated that the current SkateMate is distinctive [2]. Current Skatemate difference is 34 compared to [18] on [22].
Lightweight	Lower weight makes moving SkateMate in and out of the rink easier.	kg	≤ 7.11 kg	Weight of the current design is 7.11 kg [14]. Client prefers lighter products [2].
Easy to store	Product should be supported by current storage solution	in^3/12 products	≤48”x 40”x 60”	For the current SkateMate, a maximum of 12 products can fit on a standard pallet (48” x 40” x 60”). [14]
Advertisement space	Preference given by client during meeting [2].	in^2 space available	≥ 93.5in^2	Space available on current design is 93.5in^2 [14]

5.3 Constraints

Table 6 contains constraints imposed by the client or laws that the product must abide by.

Table 6: Constraints and Source

Type	Constraint	Justification
Legal	Must comply with Canada Consumer Product Safety Act [23].	Device falls under consumer products which this act applies to [24].
Client Imposed	Must have width less than 28.5 inches	Client requires that it fits through door [2]. 28.7 inches is measured width of door and some flexibility should be included
Client Imposed	Must be no more than 10% higher than the original device cost.	Client said City of Toronto will not be willing to replace current design if there is more than 10% increase in cost. [2].
Client Imposed	Must have a height that is within 15% of 29 inches.	Client Stated the height must be similar to current design so current user base can use it [2]. Current height is 29in [14]. 15% is variance in height for children aged 6 [25].
Client Imposed	Must not tamper with the ice rink.	Client stated the device cannot damage rink [2]

6.0 Alternative Design Generation, Selection and Description

The following section describes the idea generation, selection, and alternative design solutions.

6.1 Idea Generation Process

All team members engaged in unrestricted brainstorming to generate a diverse array of potential design elements. These ideas are presented in Appendix H. Any concepts that helped fulfill functions or constraints were incorporated into the morphological chart displayed in Appendix N.

Subsequently, the group utilized the morphological chart and other ideas to develop the 16 designs detailed in Appendix I. Each design had to include at least one morphological chart element corresponding to each function/constraint, and the chosen elements had to be compatible. Created 16 designs that incorporate innovative aspects while satisfying functions and constraints.

6.2 Alternative Design Selection Process
To reduce options, team members ranked each design (Appendix J). Designs with the highest aggregate rankings were retained. Appendix K features diagrams of some concept designs to ensure that all members had a clear understanding before voting.

The remaining seven designs were evaluated using the graphical decision chart in Appendix L. The team recognized that designs 3, 6, and 8 shared similarities and opted to combine them into a single design by integrating advantageous aspects of each. The chart indicates that the combined design, along with designs 15 and 16, best addresses the two critical objectives, leading the team to select these three as the alternative designs.

6.3 Alternative Design Descriptions
The following are the in-depth descriptions of the three alternative designs chosen in section 6.0 as well as how they meet the FOCs. Measurements are provided in Appendix M.

6.3.1 Design 1 – Light Ice
This design consists of two polystyrene bars attached to each side of a front pane. There are handles to support the user, whose weight is then distributed along two trapezoidal frames which allow it to support the applied force. It fits through the entrance since the largest width of the design is lower than the width of the entrance .

Table 7. How Design 1 Meets Objectives

Objective	Supporting Evidence
Durable	Thick and bulky design allows handling of consistently applied force
Distinctive	Unique Framing and handles
Lightweight	Plastic framing results in low weight
Easy to store	Slotted (Figure 5)
Advertisement space	Front panel

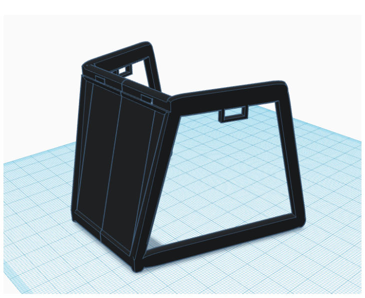
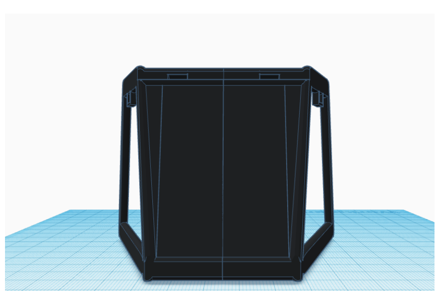
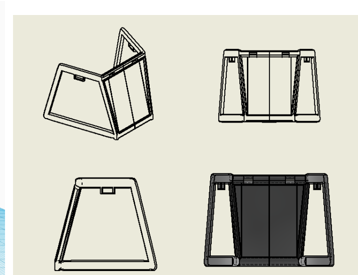




Figure 4. Side and front (left and middle image) views of design. Right is sketches of perspectives.

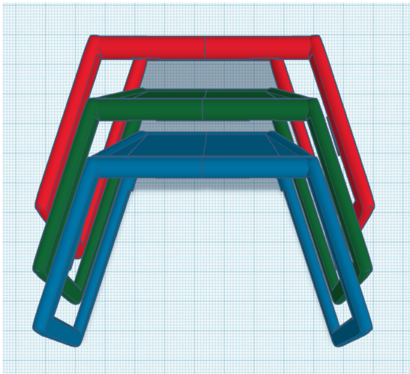


Figure 5. Top view of multiple slotted skating aids.

6.3.2 Design 2 – Family Skate Aid

This design is a multifunctional skating aid that has a balance support for users to hold while learning and a seat for breaks with parents or trainers. It includes several handles to facilitate balance and control under different scenarios for different users (Figure 6).

Table 8. How Design 2 Meets Objectives

Objective	Supporting Evidence
Durable	Rotomolding(pvc) ensure consistent wall thickness and robust exterior corners to enhancing the load-bearing capacity
Distinctive	Unique concept
Lightweight	Rotomolding–hollow(Figure 6)
Easy to store	Stacked(Figure 7)
Advertisement space	Front and Sides

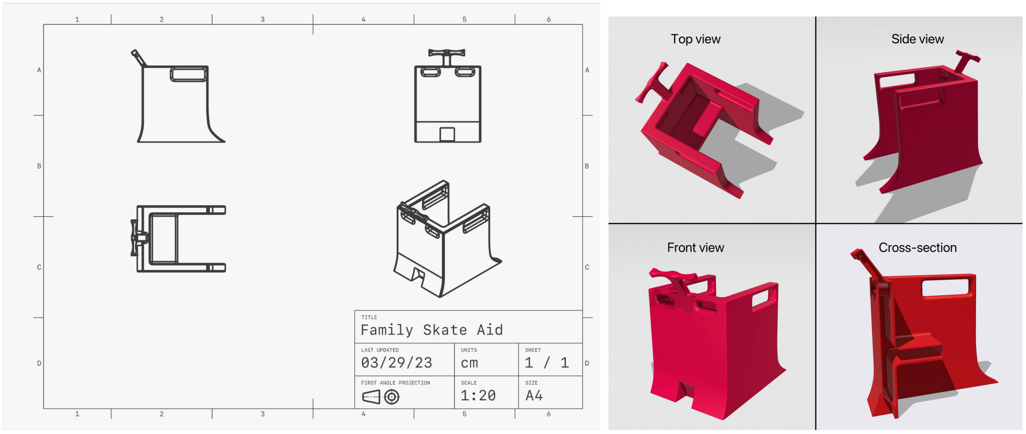


Figure 6. 2D projections (left) and 3D views (right) of the design.

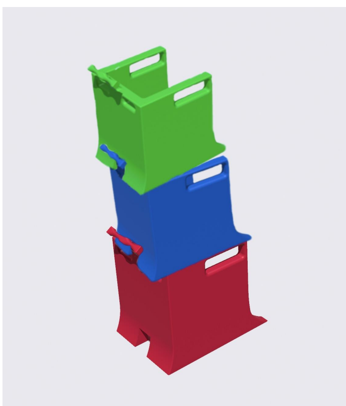


Figure 7. Storage demonstration.

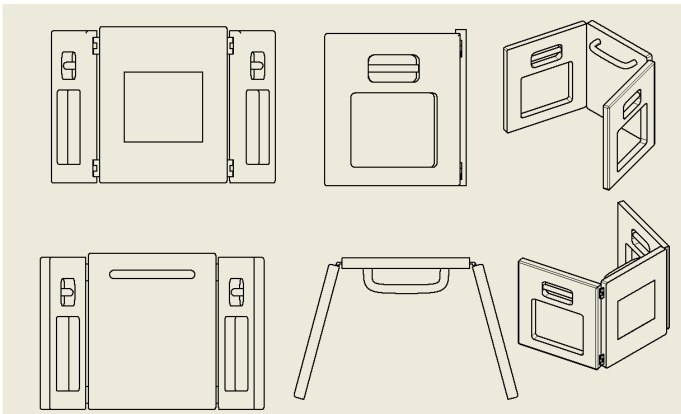
6.3.3 Design 3 – Rotating panel

This design has two side panels attached to the front panel using lockable hinges (Figure 8). The thick panels allow it to support the user’s weight and the hinges allow the panels to fold inward enough to fit through small doors when unlocked.

Table 9. How Rotating Panel Meets Objectives

Objective	Supporting Evidence
Durable	2 inch thick polyethylene panels and width of .23.87 inches supports weight
Distinctive	Similar visual features to current design which is distinct
Lightweight	Smaller than current design. Holes in panels reduce weight.

Easy to store	Can be bent and slotted together (Figure 9).
Advertisement space	Front panel (Bigger than original)



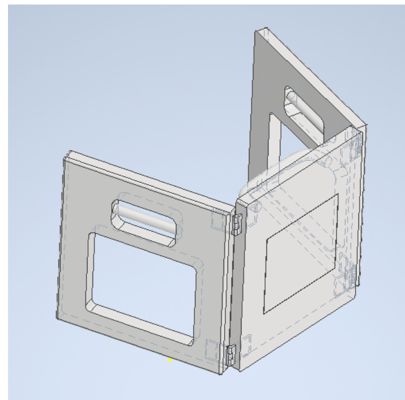


Figure 8. 2D projections (left) 3D view (right) of the design.

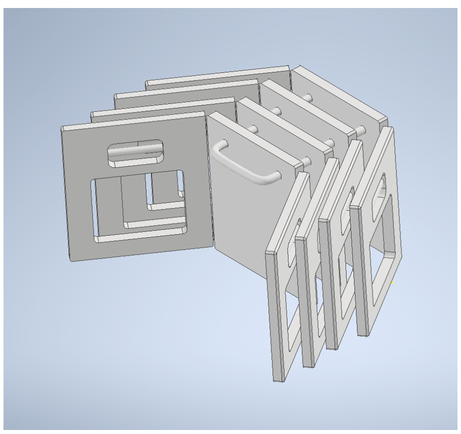


Figure 9. Design 3 Storage solution.

7.0 Proposed Conceptual Design Specification

From the three designs mentioned in section 6.0, Design 3, *Rotating Panels,* most effectively solves the client's problem. A comparison matrix(Appendix O) was used to compare the three designs and resulted in Design 3 scoring highest due to the design's simple approach of using the current design as a base and adding elements to make it meet needs. The addition of foldable panels allow the design to fit through small doors while still maintaining a high rear width. Similar to the current design, the wide width allows it to reliably provide ample support without failure. Dimensions were kept the same to support the same user base except for reductions in width for easier transportation through the door and weight reduction Appearances have also remained similar to maintain the uniqueness of the design. The design also adds additional functionality to the original design through more handles that provide a safer user experience along with a larger advertisement panel to benefit sponsors. This simple yet effective design maintains all the benefits of the current design used by the city of Toronto and addresses the flaws mentioned by the client, resulting in our team's recommendation.

8.0 Measures of Success

The measure of success for the new designs will deal with the most important objective: durability. To test for durability, we will be measuring fatigue life and fatigue safety factor using Ansys Workbench [26].

Before running simulations, we must calculate the forces that will be applied, gather fatigue data for selected materials, and model the designs using CAD software. Loading conditions that are representative of the expected service conditions will be assumed. To calculate the force on each handle, we will assume the average user is 10 year-old with a weight of 40 kg [27]. Using walkers as a benchmark, the maximum force that will be applied is half the user weight [28]. Since this is the total force, the force per handle will be half of that. The calculations are as follows:

$$\begin{aligned} Force &= mass \cdot acceleration \\ &= 40\,kg \cdot 9.81\frac{m}{s^2} \cdot 0.5 \cdot 0.5 \\ &= 98.1N \end{aligned}$$

Fatigue data (S-N curves) will be gathered through research papers and engineering handbooks.

The CAD models of the designs will be completed by Subat, Uaena, and Erfan in testing week 1. The simulations will be run by Kenya and any necessary design revisions will be completed in testing week 2. Testing will begin on Saturday, April 1st (tentative schedule below).

Table 10: Tentative testing schedule

Task	People	Time
Create 3D models	Erfan, Subat, Uaena	3 Days
Add materials and measurements to models	Erfan, Subat, Uaeana	2 Days
Run simulations	Kenya	2 Days
Report results of simulations	Kenya	1 Day
Plan to adjust 3D models	Erfan, Subat, Uaena, Kenya	2 Day
Make adjustments	Erfan, Uaena, Subat	2 Day
Re-run simulation (adjust models upon failure)	Kenya	2 Day

To run the simulations, we will be using the Static Structural Analysis module. The steps are as follows:

1. Input fatigue data to selected pre-existing materials (polystyrene, etc.) in Engineering Data.
2. Import the STP file of the model to Geometry.
3. Under Model, assign a material and generate a mesh.
4. Under Static Structural, apply a 98.1N downward force at a 75° angle to each SkateMate handle, simulating the user's grip during forward skating forward. The angle is a rough estimate based on images of user interactions with the current SkateMate. Apply a remote displacement to the base of the model to represent the support provided by the ice. This allows for translation of the object in only the horizontal directions.
5. Under Solution, insert the maximum principal stress contour map.
6. Add the Fatigue Tool to Solution. The loading type will be zero-based (meaning the force is applied in the direction set and then released in a cyclical pattern) to represent the on and off grip of the user. Choose one cycle of this force to be applied over one hour, simulating the length of a leisure skating session. The analysis type is stress life, the stress component is maximum principal, and the mean stress theory is Goodman.
7. Insert the Life and Safety Factor contour maps.
8. Click solve to evaluate the solutions.

These steps are subject to change should we need to deal with software errors or 3D model issues.

To analyze the results, observe the contour maps for each test. Fatigue life measures the number of cycles (hours) until a design fails from fatigue. To determine the number of years the design will last. Assume the SkateMate is used for 14 hours everyday (Central Arena is open from 9 am to 11 pm on weekdays [29]). Dividing the number of hours by 14 and then by 365 days results in the number of years that is compared to the objective goal of ≥ 5 years. A more successful design will have a higher minimum fatigue life. Fatigue safety factor predicts which parts of the design will likely fail before a given design life is reached. A safety factor of < 1 indicates failure before a set design life is reached [30]. Designs with a minimum safety factor of ≥ 1 will be considered successful. We can also use this information to determine which parts of the model may need revision or if materials should be changed. If unsuccessful, the model will be altered and re-tested.

See Appendix P for background information, justification for the technical decisions made, a detailed walkthrough of the process using an example model, and the limitations of the method.

9.0 Conclusion

After reviewing the requirements of the project, the team identified the key elements to incorporate in developing a redesign that best meets the client's needs. By considering factors such as the service environment, the needs of stakeholders, the primary/secondary functions of the design, and many more, the team moved on to writing out the CDS section of the project. By using ideation methods, we came up with and compared multiple designs, reducing our options to the three which we found to be best suited for the client needs. Subsequently, after further analysis, we finally arrived at our proposed conceptual design which we believe is the optimal choice for the client.

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10.0 Appendices

Appendix A: All images of provided by the client:

Figure 10. Images of SkateMate provided by client.

Figure 11. Image of skating rink entrance

Appendix B: Stakeholders brainstorming:

1. Skate assistant device companies/manufacturers
2. ~~Company that will be funding the redesign~~ (might just be city of toronto itself)
3. ~~Other city of Toronto rinks~~
    a. ~~Indoor rinks~~ ~~https://www.toronto.ca/data/parks/prd/facilities/indoor-rinks/index.html~~
    b. ~~Outdoor rinks~~ ~~https://www.toronto.ca/data/parks/prd/facilities/outdoor-rinks/index.html~~
    c. ~~Natural rinks~~ ~~https://www.toronto.ca/explore-enjoy/recreation/skating-winter-sports/public-leisure-skating/natural-ice-rinks/~~
4. ~~Other skating rink users~~
5. Non affiliated insurance organizations:
    a. https://www.toronto.ca/services-payments/venues-facilities-bookings/booking-park-recreation-facilities/last-minute-online-booking-system/?accordion=ice-rentals
    b. https://www.alignedinsurance.com/understanding-skating-rink-insurance-coverages/ types of insurance coverage
6. Inclusive services https://www.toronto.ca/city-government/accessibility-human-rights/accessibility-at-the-city-of-toronto/city-services-for-people-with-disabilities/accessible-recreation/
7. Sports stores selling ice skating equipment? (their sales could go away)
8. ~~City of Toronto Learn to Skate program~~ https://www.toronto.ca/data/parks/prd/skating/reg/learn/index.html
9. Skate lending library (in partnership with Desjardins Financial Group) https://www.toronto.ca/explore-enjoy/recreation/skating-winter-sports/public-leisure-skating/skate-lending-library/
10. Rink supervisors (in the event the thing damages the ice)
    a. https://www.toronto.ca/wp-content/uploads/2021/07/8f3a-natural-ice-rinks-guide.pdf
    b. https://city-of-toronto.talentify.io/job/rink-guard-etobicokeyork-district-toronto-on-city-of-toronto-28059

Appendix C: Pairwise Comparison table for stakeholders

Stakeholder	1	2	3	4	5	6	Total
1. Manufacturers		+1	0	+1	+1	0	3
2. Insurance Organizations	0		0	+1	0	0	1
3. Inclusive Services	+1	+1		+1	+1	+1	5
4. Equipment Retailers	0	0	0		0	0	0
5. Skate Lending Library	0	+1	0	+1		0	2

6. Rink Supervisors	+1	+1	0	+1	+1		4

Final ranking:
1. Inclusive Services
2. Rink Supervisors
3. Manufacturers
4. Skate Lending Library
5. Insurance Organizations
6. Equipment Retailers

Appendix D: Functional Basis
- Transport Mass
- Support Mass
- Stabilize Mass
- Convert Energy
- Convey Information

Appendix E: Black Box Method

Inputs	Black Box	Outputs
Mass: - User Secured - User Unsecured		Mass: - User Unsecured - User Secured
Energy: - Mechanical - Directional work energy from the user		Energy: - Resultant from input - Directional support energy
Information: - Where to grab - How to grab - How to position - How to carry		Information: - Whether the device is held correctly - Indication that the device is oriented - Indication that the device is carried properly

Appendix F: Objectives brainstorming
- Accessibility - accessible to children and adults (height/dimensions metric?)
- Durable - strength of material/structural strength (run static sim, measure minimum safety factor)
- Low cost - client gave a range (estimate material and manufacturing costs)
- Distinctive - looks different from other skatemates (color, shape, logo, etc metric)

- Easy to store - current ones are stackable (estimate how many would be able to fit in a given space)
- Easy to use - amount of force/torque needed to compact the skatemate to fit through the gate (estimate loads and do calculations)
- Advertising - can put advertisements on it (would need to have a flat surface to place ads, instead of just a frame)
- Size/weight?

Appendix G: Pairwise Comparison table for objectives

Objective	1	2	3	4	5	6	Total
1. Easy to store		0	0	0	0	1	1
2. Low cost	+1		0	+1	+1	+1	4
3. Durable	+1	+1		+1	+1	+1	5
4. Lightweight	+1	0	0		0	+1	2
5. Distinctive	+1	0	0	+1		+1	3
6. Advertisement space	0	0	0	0	0		0

Final ranking:

1. Durable
2. Low cost
3. Distinctive
4. Lightweight
5. Easy to store
6. Advertisement space

Appendix H: Potential Concepts from Each Member's Brainstorm

Uaena:

1. Foldable skateMate with security lock/safety lock
2. Changeable height and width like bike
3. More comfortable/convenience holder for kids to grab

4. In different shapes ?!
5. No shield on the sides to reduce air resistance

6. Hanger on the side for simple things
7. Try to structure by rigangle to increase load capacity
8. Allowing gradual reduction: the skateMate is something temporary for people to use, reduces in size or support over time, allowing the skater to gradually transition to skating without the trainer.
9. Storage box for personal belonging(phone) like something on rollercoaster
10. Cover by round soft material to prevent injury

Kenya:

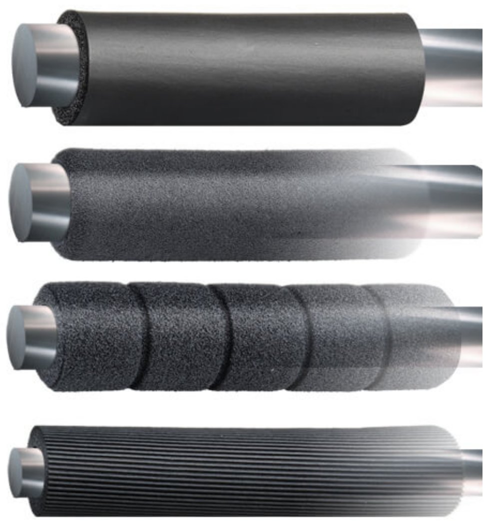
- Foldable along middle axis (second sketch) or at legs (first sketch), took inspo from folding tables and chairs
- Locking mechanisms
    - Spring button lock
    - Twisting a knob
- Removing the side pieces and just keeping the front and base might make it fit
- Decreasing width of sides
- Use 4 legs for support instead of a wide base - kind of like an upright walker for seniors
- Something like ski poles/crutches with triangular bases (I'll draw this out later), 2 handheld balances would be more flexible but idk if it would be easy to use for new skaters
- Skate trainers that stabilize the skates (creates larger surface area for balance) instead of users having to hold onto anything
- Material options MUST BE WATERPROOF
    - Current design uses molded plastic - don't know what kind though
    - PVC plastic
    - Rubber
- Objectives:
    - Distinctive - could make it striped, or have a different color band, logo could be printed or carved
    - Lightweight - cut out unnecessarily volume
    - Easy to store - foldable, height/width adjustable, curved (can fit one side in and then the other), use two items for support instead of one, small supports on skates rather than handheld
    - Advertisement space - large flat surface

Erfan::

- Foldable front piece [sketch to be added]
- Bolt length extenders (for metallic designs or general beam designs)

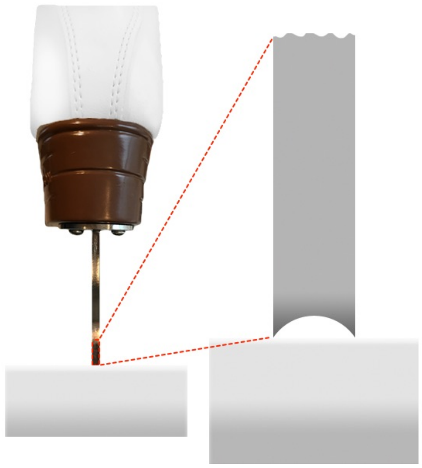
Reference image ^

- Padding for user grip



Reference image ^

- T & C shaped body [sketches TBA]
- Rounded edges on ice



Reference image ^

- Polycarbonate or HDPE body (1 is stronger but 2 is more resistant)
- Engraved city of toronto logo rather than added on
- Handles

- Bar structure similar to that of competitors in terms of supports

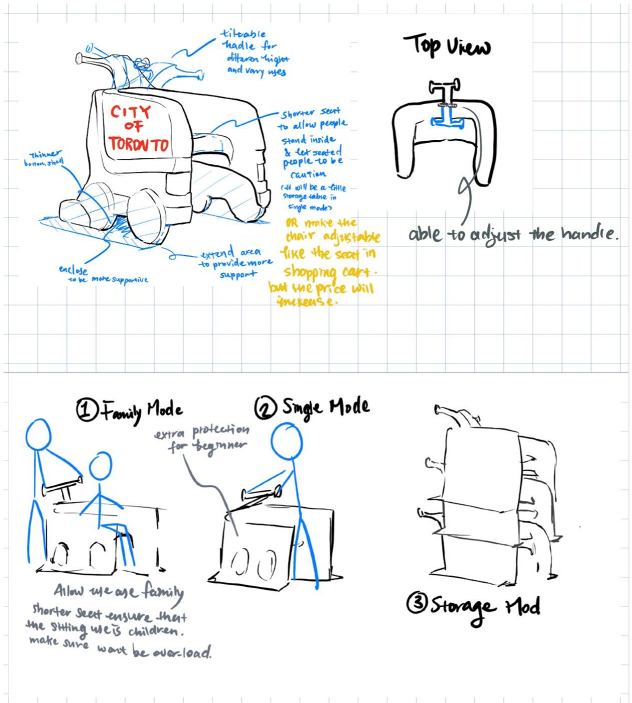
Reference image ^

- Circular or rectangular base design to support user all around
- Safety strap around the hip
- Flattened or or blunt edges
- Pointed sharp edges
- Integrated steering into handles
- Padded edges (in case user falls onto design)
- Rounded edges (same reason as padded)

Subat:
1. Extendable rods used for framing
2. Device held together by foldable hinge
3. Surface infront of device. Goes in front of user rather than around
4. Flexible horizontal material. Non-flexible vertical material
5. Putting separate parts together using methods such as screws. Saves on cost and easier to produce
6. Space for advertisement and logo on side of design
7. Lockable Rotating Sides that can fold in
8. Rotating Wheels on base
9. City of Toronto coloring (Blue white with red maple leafs)
10. Integrated holdable bars on the side

Appendix I: Full Design Ideas

1. Circular Base + Holdable bars on the side + Padding on grips + Support bars + Flattened/Blunt edges + Optimize shape, cut, volume
2. Safety strap around the hip + Integrated steering handles + Mountable/dismountable seat + wide sharp base to prevent tupping + Rounded edges on ice + surface in front of user rather than around
3. Rectangular base + Handles + Padding on grips + Support bars + rounded edges on ice + Device held together by foldable hinge.
4. Rectangular base+ Handles + Rubber padding grip + Rounded edges and padding around edges + Surface in front instead of around
5. Triangular base + handles + padding on grip + Rounded Edges + blunt edges + Extendable rods for framing
6. Trapezoidal base + Integrated holdable bars on side + metal bars with grip + support bars + blunt edges +Device held together by foldable hinge
7. Extendable rods used for framing + Flattened/ Blunt edges + Rounded edges + Metal bars to hold on to + Integrated holdable bars on the side + Trapezoidal base
8. Device held together by foldable hinge + Flattened/ Blunt edges + Padding around edges + Metal bars to hold on to + Integrated holdable bars on the side + Trapezoidal base
9. Device held together by foldable hinge + Flattened/ Blunt edges + Wide, sharp base to prevent tipping over + Metal bars to hold on to + Handles + Increase surface area of blade
10. Triangular base + 2 separate handheld + padding on grips + wide sharp base + flattened blunt edges + extendable rods
11. Rectangular base + holdable bars + padding on grips + rounded edges + flattened blunt edges + extendable
12. Increase surface area of skate blade + padding around edges + flattened blunt edges
13. Safety strap around the hip + Integrated steering handles + Metal bars to hold on to + sharp base to prevent tipping over + flattened bottom + foldable
14. Rectangular or circular hollow base + Using 2 separate handheld devices + Padding on grips + Support bars + Flattened/ Blunt edges + Device held together by foldable hinge
15. Trapezoidal base + Integrated holdable bars on the side + Metal bars to hold on to + Wide base to prevent tipping over + Flattened/ Blunt edges + Extendable rods used for framing
16.

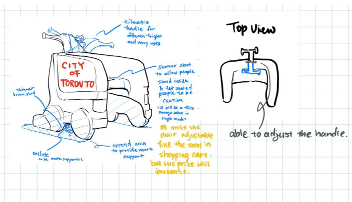


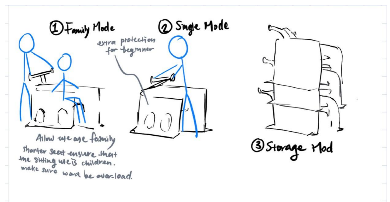
Appendix J: Design Ranking with Top 7 Highlighted

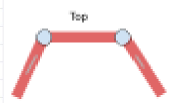
Idea #	Subat	Harry	Kenya	Uaena	Erfan	Sum
1	2	3	3	4	3	15
2	1	2	1	2	4	10
3	3	3	4	3	5	18
4	4	3	3	3	4	17
5	5	3	2	3	2	15
6	4	4	4	3	3	18
7	5	3	2	3	3	16
8	4	4	3	3	4	18
9	3	2	3	4	2	14
10	1	3	4	4	1	13
11	3	2	2	3	3	13
12	2	2	3	4	2	13

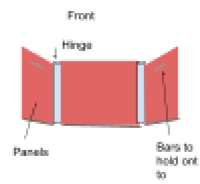
13	3	3	3	4	3	16
14	5	3	4	3	5	20
15	4	3	3	4	4	18
16	5	4	3	4	5	21

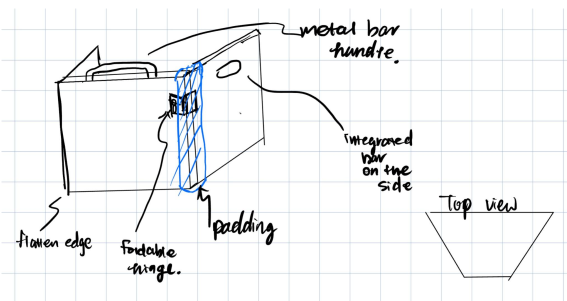
Appendix K: Diagrams of Ideas

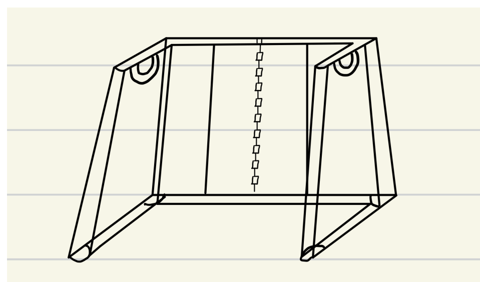




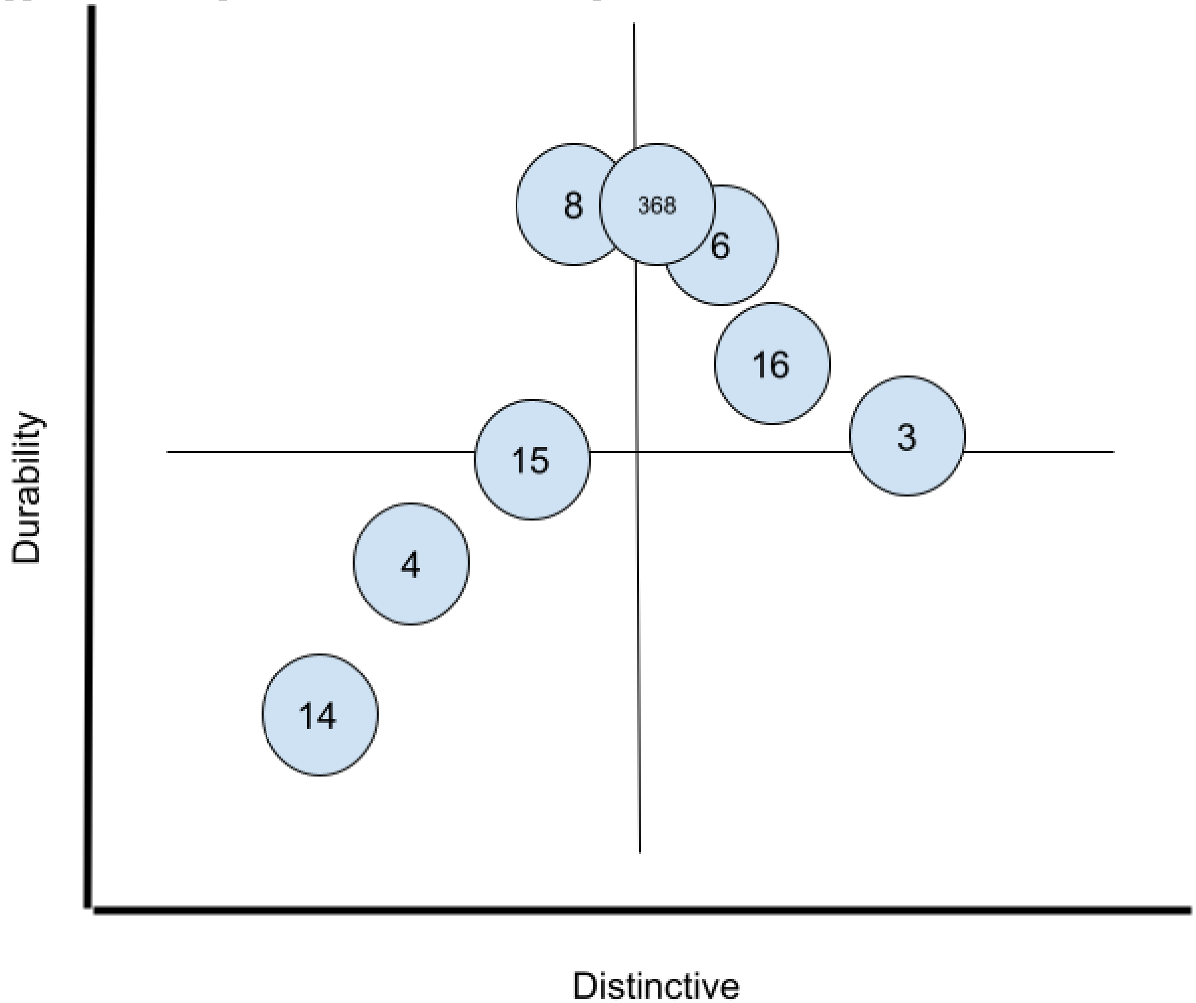








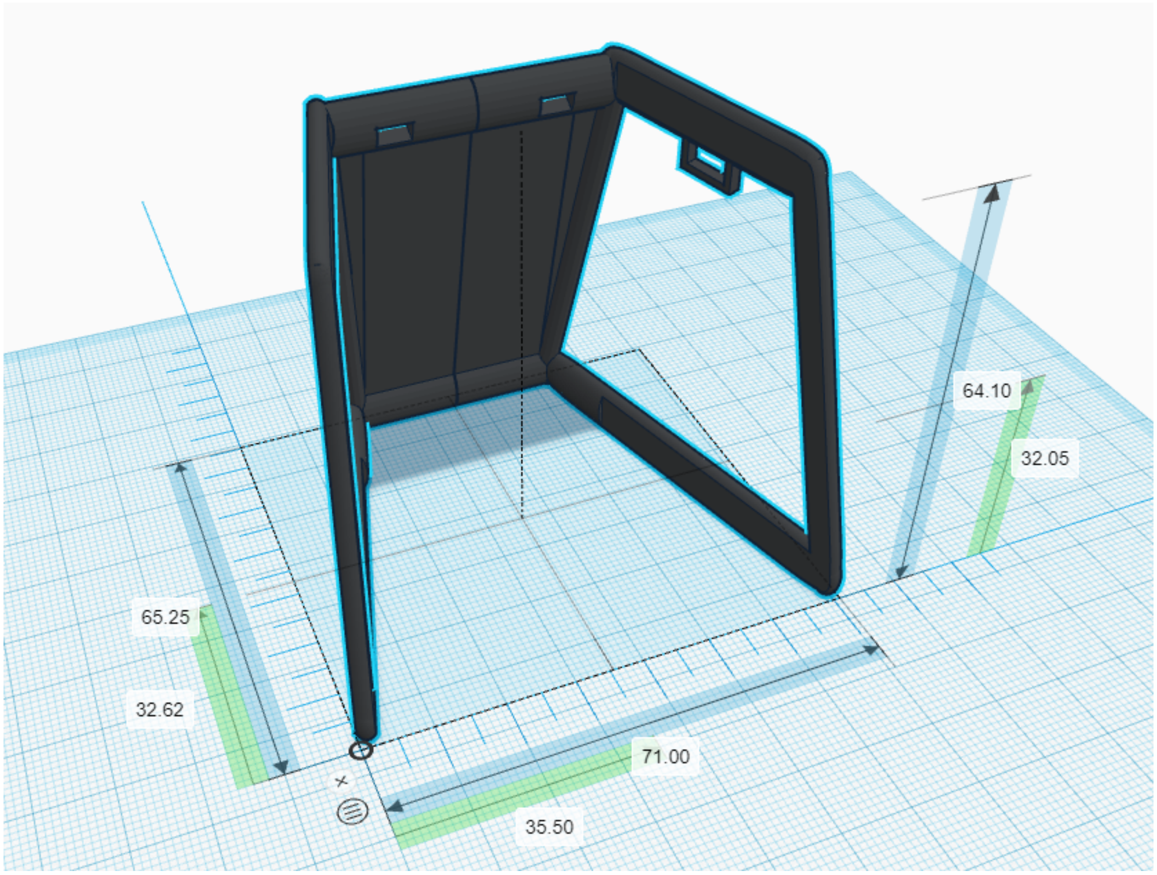
Appendix L: Graphical Decision Chart of Top Ideas



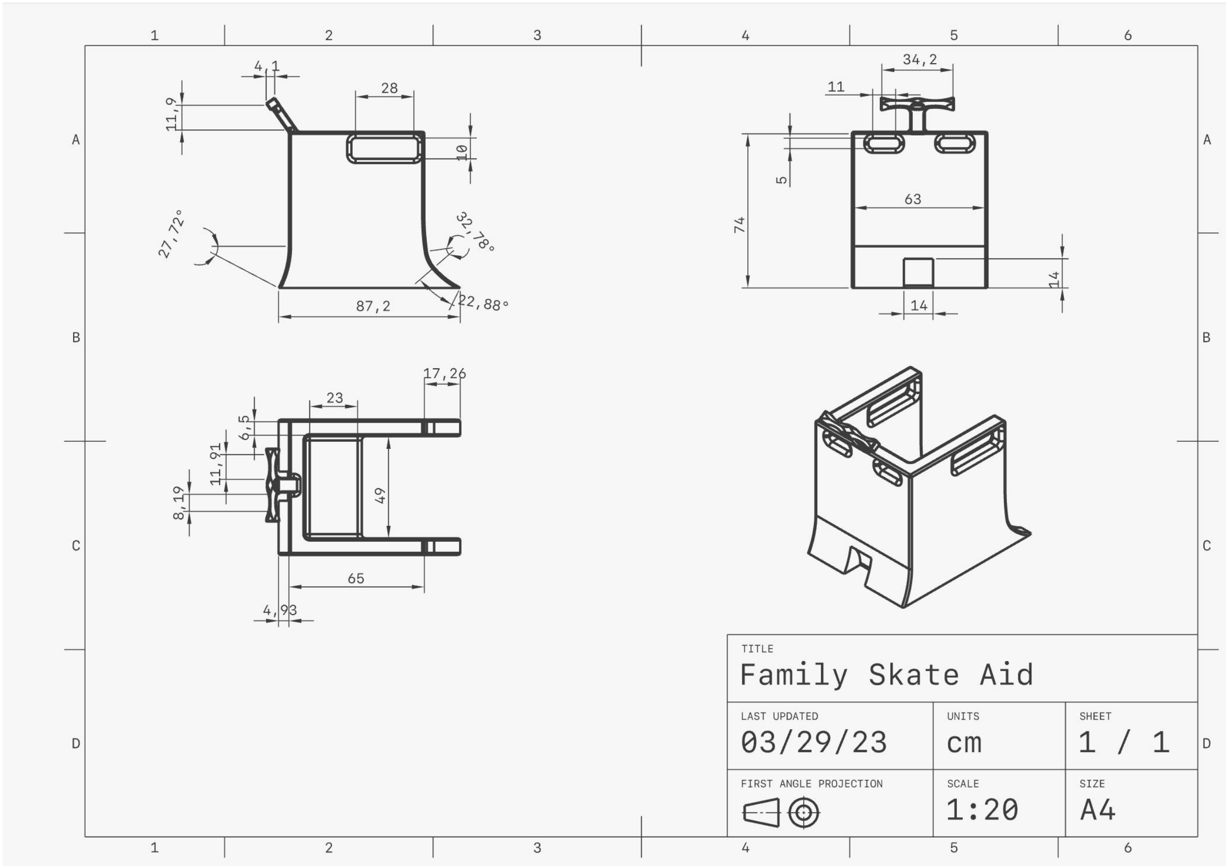
Appendix M: Measurement of Alternative Designs

The following section provides measurement of each alternative design

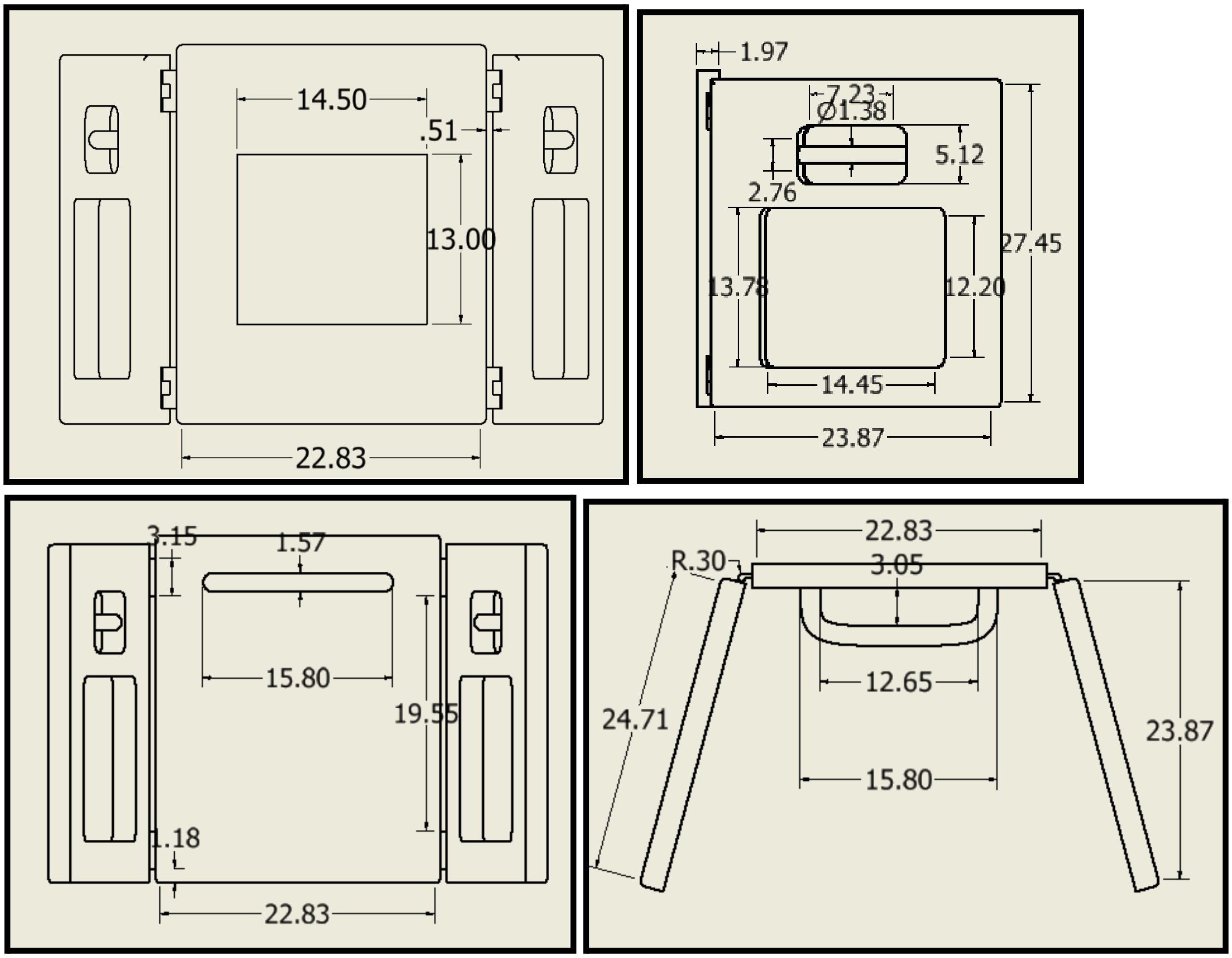
M-1 Measurements of design 1 in centimeters



M-2 Measurements of design 2 in centimeters



M-3 Measurements of design 3 in inches



Appendix N: Morph Chart

Subfunction / Constraint	Means	Means	Means	Means	Means
Provide User Balance	Rectangular or circular hollow base	Safety strap around the hip	Increase surface area of blade	Triangular base	Trapezoidal base
Allow User Steering	Handles	Integrated steering handles	Using 2 separate handheld devices	Integrated holdable bars on the side	Rotating Wheels on base
Allow user to engage and disengage without outside help	Padding on grips	Mountable dismountable seat	Metal bars to hold on to		

Provide failsafe for user imbalance	Support bars *similar to other products	Padding around edges	Rounded edges	Wide, sharp base to prevent tipping over	
Slide smoothly across ice	Rounded edges on ice	Flattened/ Blunt edges	Sharp triangular edges		
Meets width requirement	Extendable rods used for framing	Device held together by foldable hinge	Surface in front of user rather than around	Flexible horizontal material. Non-flexible vertical material	Optimize shape, cut out volume

Appendix O: Weighted Comparison Matrix

O-1: Objective Weighting

objective #	objective weight (%)
1	40
2	18.3
3	16
4	14
5	11.7

O-2: Design Ranking for Each Objective (0-100)

	Design #1	Design #2	Design #3
Objective #1	33.75	77.5	88.75
Objective #2	32.5	82.5	76.25
Objective #3	93.75	23.75	42.5
Objective #4	90	38.75	71.25
Objective #5	51.25	68.75	83.75

O-3: Score (Weight * Ranking)

	Design #1	Design #2	Design #3
Objective #1	13.50	31.00	35.50
Objective #2	5.95	15.10	13.95
Objective #3	15.00	3.80	6.80
Objective #4	12.60	5.43	9.98
Objective #5	6.00	8.04	9.80

Score	53.04	63.37	76.03

Appendix P: More information regarding the measures of success.
To test for durability, we must first identify the type of fatigue the designs will endure. During use, the designs will be subject to high cycle fatigue (HCF) [31]. This is characterized by low applied forces (forces that will be applied to the handles/sides of the SkateMate) that cause primarily elastic deformation.

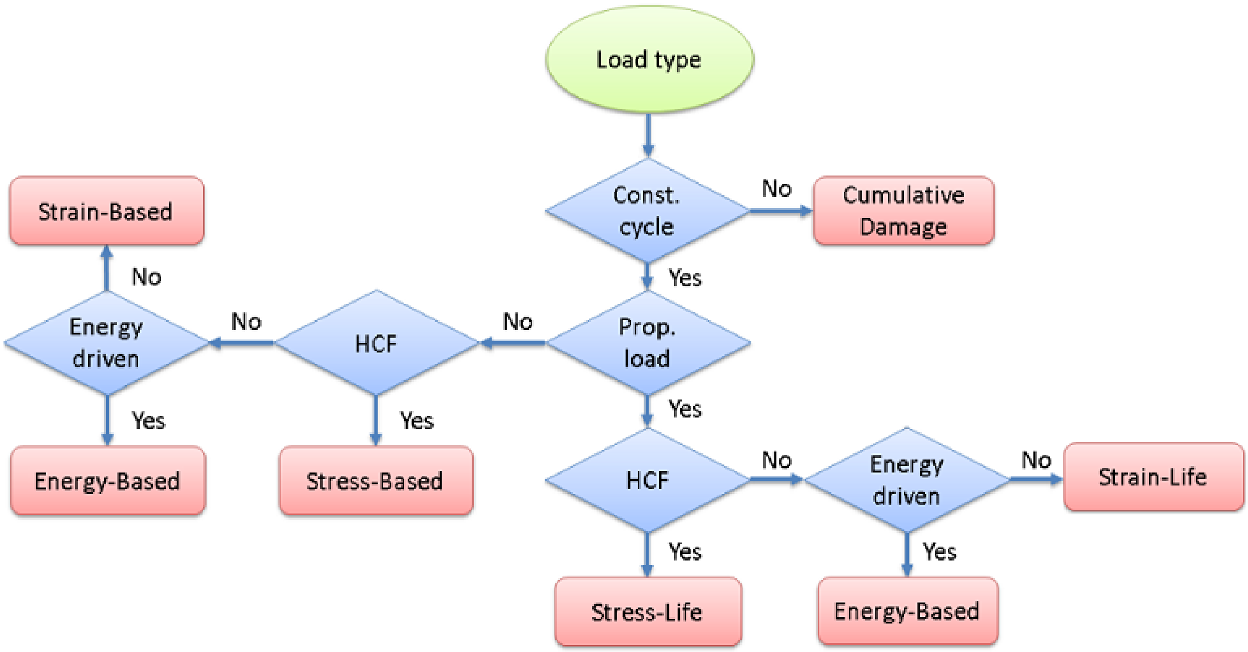


Figure 12. Selection of the fatigue model type [32].

In HCF situations, the stress-life approach to measuring fatigue is often used along with material performance data provided by S-N curves. These curves describe the number of cycles to failure (N) as a function of cyclic stress (S) for materials [33]. Since Ansys only provides this information for a limited number of preset materials, data points from graphs in research papers and engineering handbooks were inputted to create S-N curves for the materials we selected.

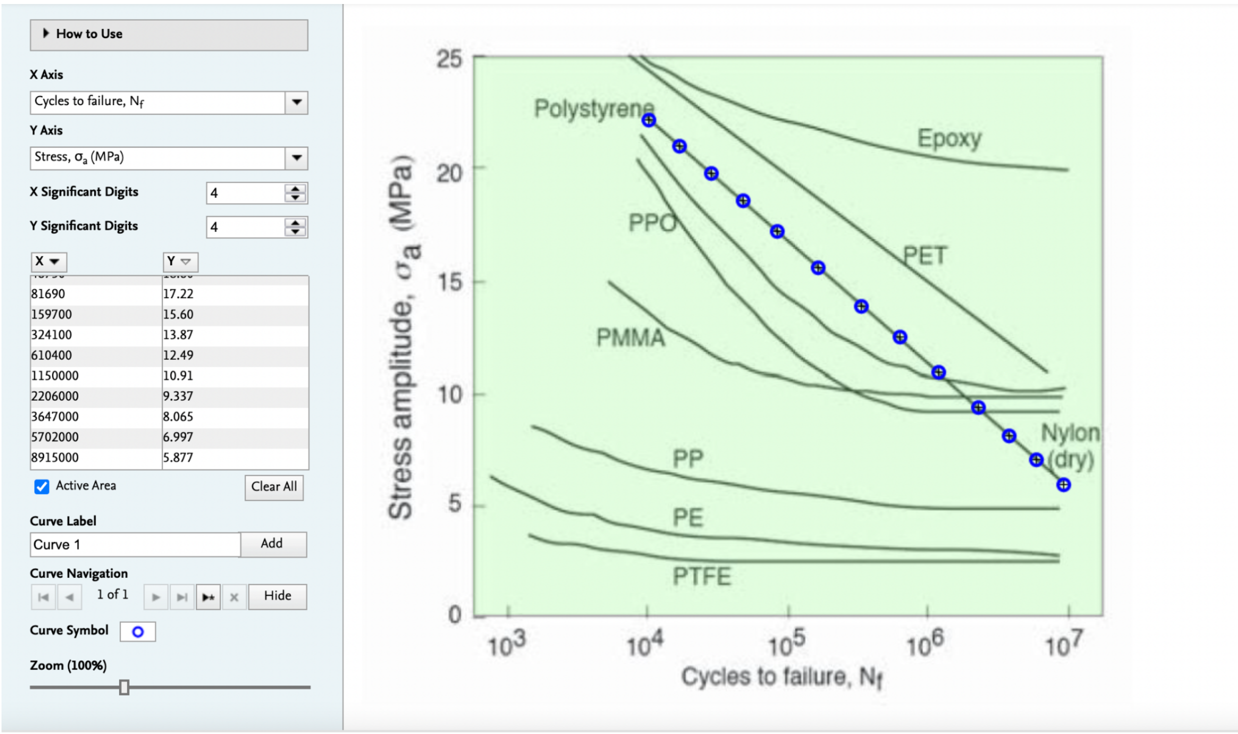
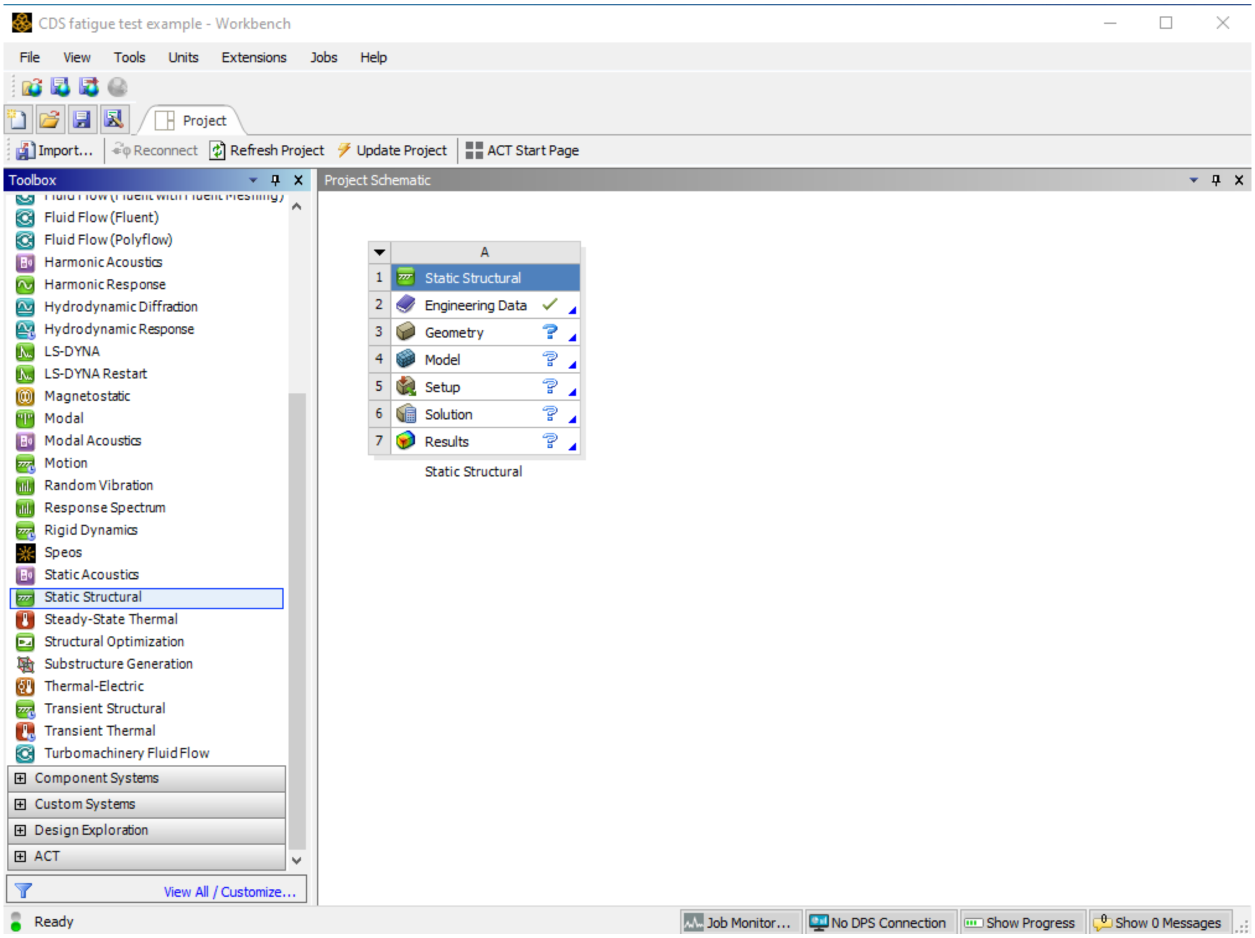


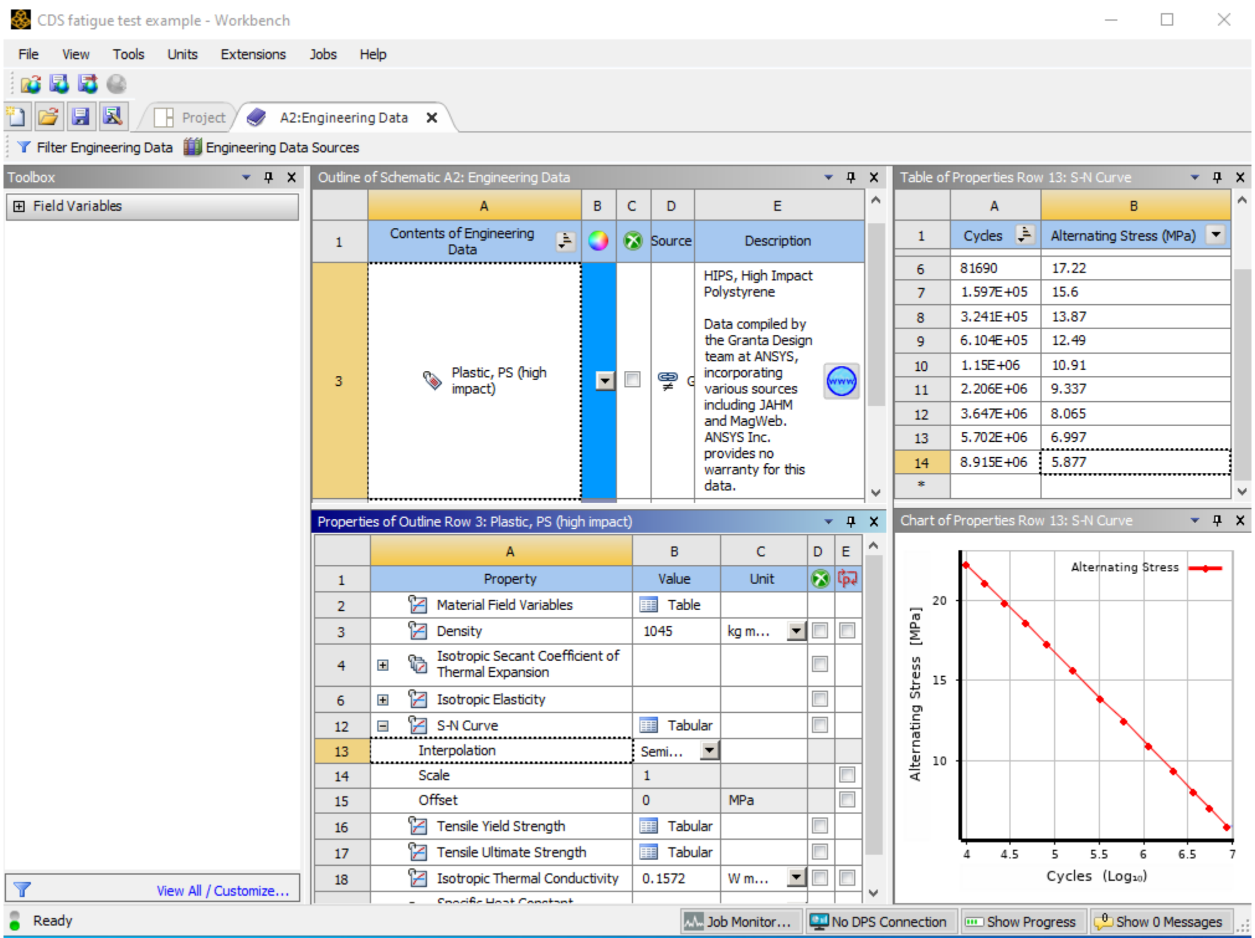
Figure 13. S-N curves for several thermoplastic and thermoset polymers [36].

In the Fatigue Tool setup, maximum principal is chosen for the stress component because it is often used to evaluate rigid materials (including plastics) that are more likely to undergo brittle fracture than ductile deformation [34]. Since the loading type is zero-based, the mean stress over the cycle is non-zero. Mean stresses can have a significant effect on fatigue performance and thus, a mean stress correction model should be used to account for this effect. The Goodman model was selected for this case because it accounts for tensile crack growth [35] and is often used for high strength and low ductility materials [37].

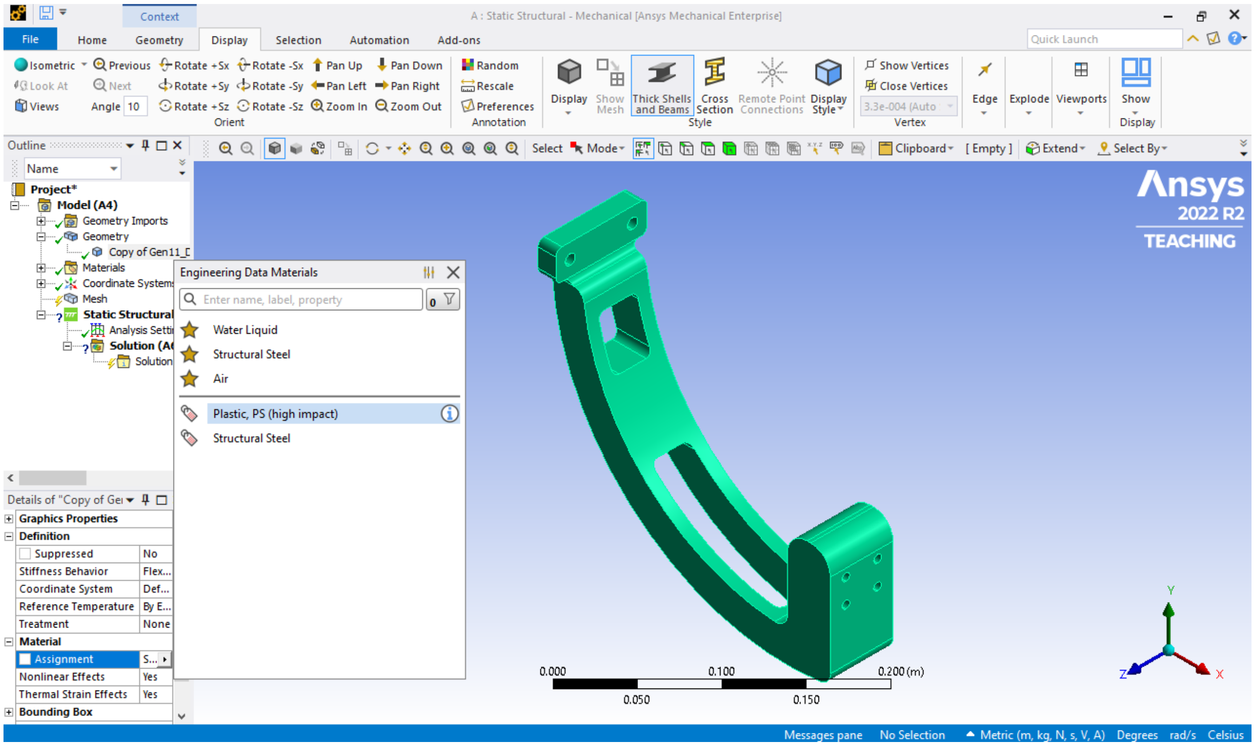
The following is a brief demonstration of the testing procedure described in section 9.0 Measures of Success. Since the example model and the SkateMate models are vastly different, different forces/supports will be applied, but the procedure remains the same. The model used was designed by Kenya in December of 2022.



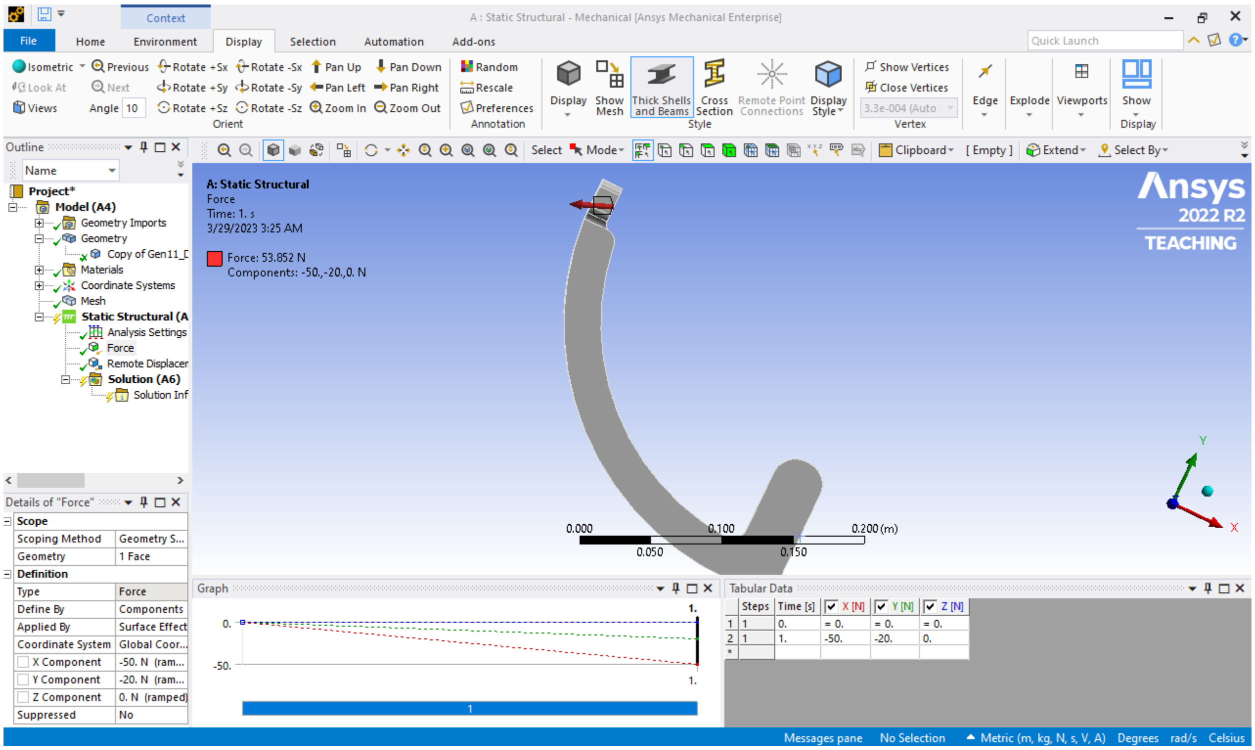
1. Input the fatigue data to selected pre-existing materials (polystyrene, etc.) in Engineering Data.



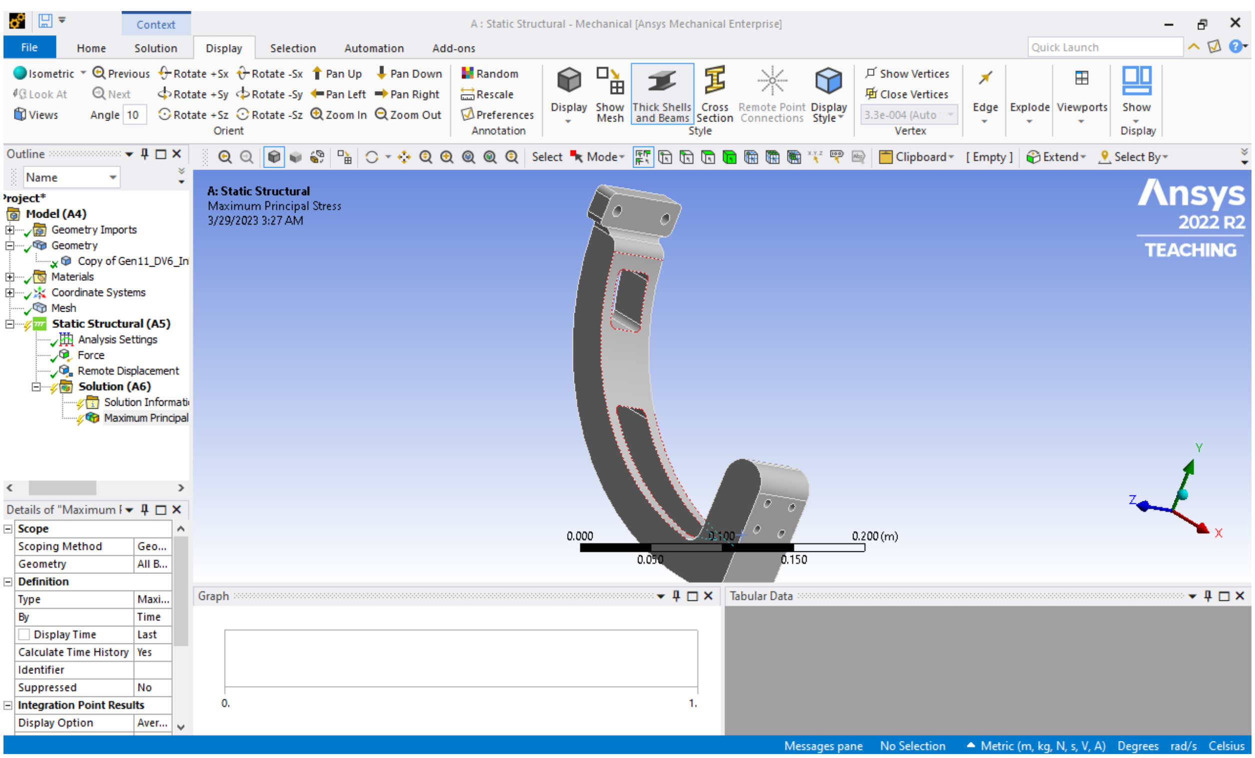
2. Import the STP file of the CAD model to Geometry.
3. In the Model, we can assign a preset material to the object and generate a mesh.



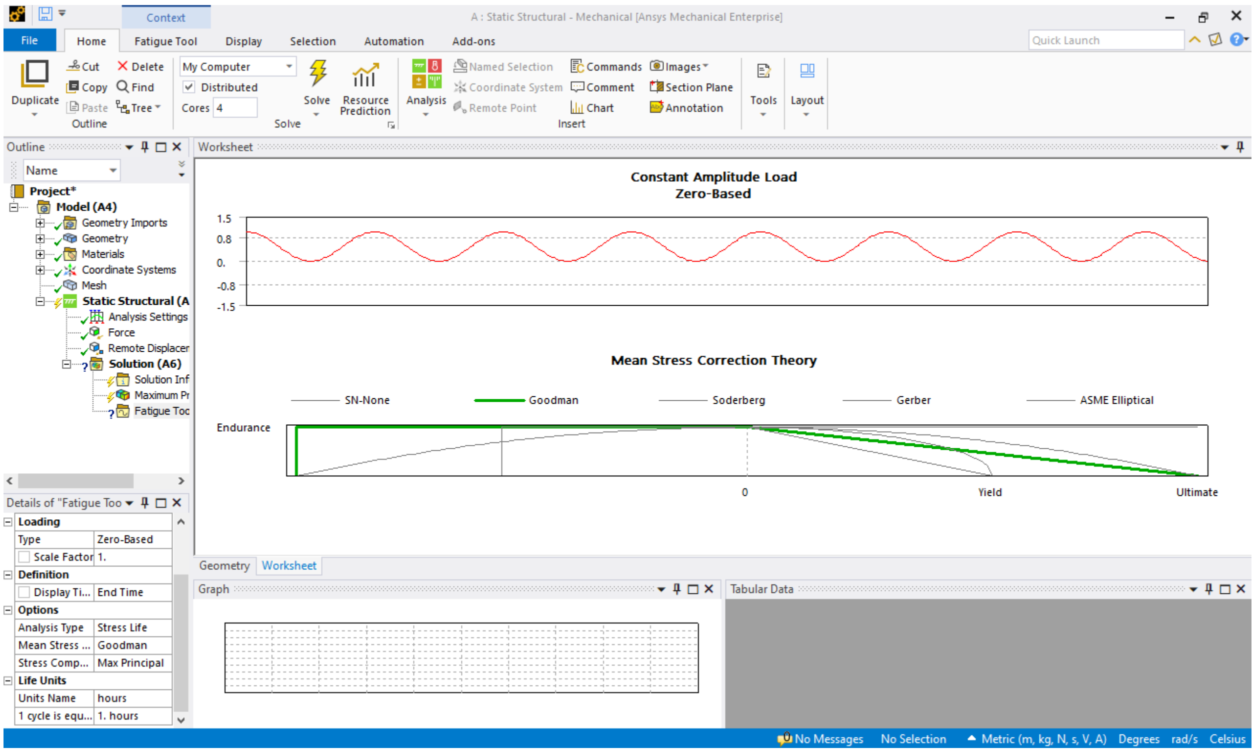
4. Under Static Structural, apply a downward force of 98.1N to each handle surface of the SkateMate. These forces will be applied at an angle of 75° to the handles to simulate a user's grip while skating forward. The angle is a rough estimate based on images of users interacting with the current SkateMate. Also apply a remote displacement to the base of the SkateMate to represent the support provided by the ice. This allows for translation of the object in the horizontal directions, but not the vertical direction.



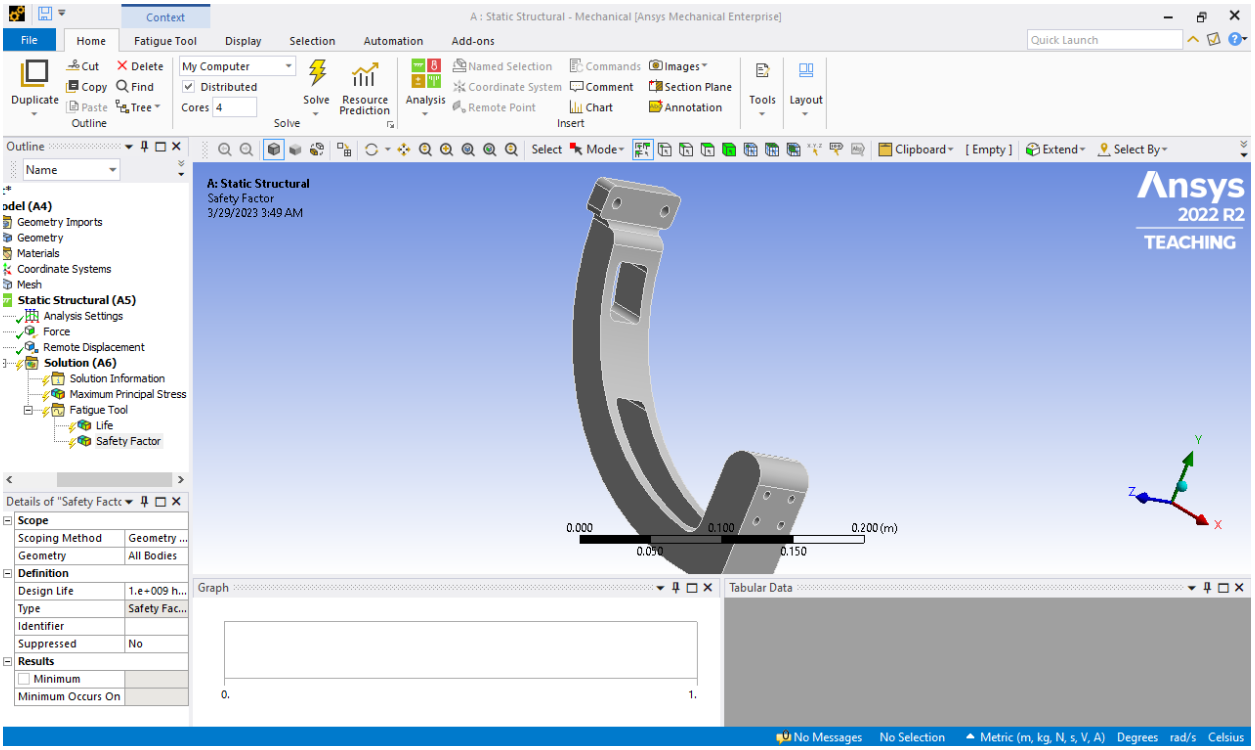
5. Under Solution, insert the maximum principal stress contour map, which shows the stress distribution under the applied load.



6. Add the Fatigue Tool to Solution. The loading type will be zero-based (meaning the force is applied in the direction set and then released in a cyclical pattern) to represent the on and off grip of the user. We can choose one cycle of this force to be applied over one hour, simulating the length of a leisure skating session. The analysis type will be stress life, the stress component will be maximum principal, and the mean stress theory will be Goodman.

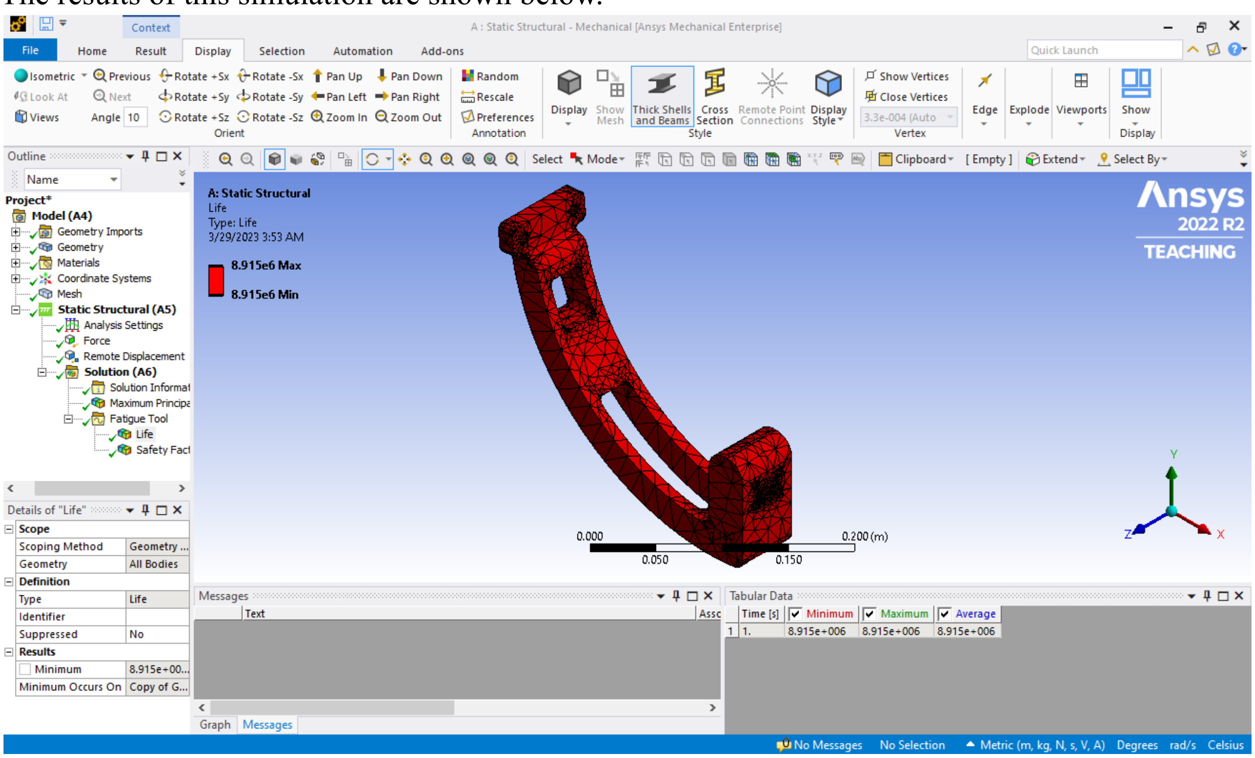


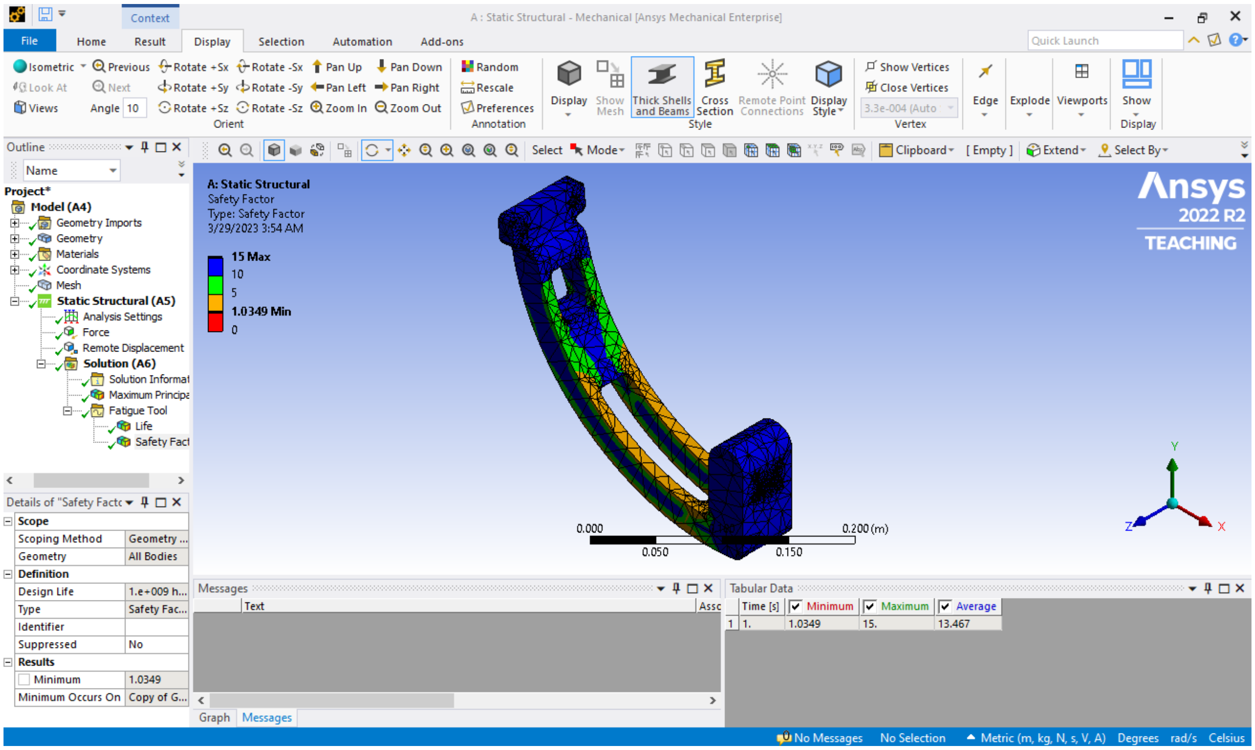
7. Insert the Life and Safety Factor contour maps.



8. Click solve to evaluate the solutions.

The results of this simulation are shown below.





The first contour map shows fatigue life. The minimum number of cycles (hours) that any part of this model will last is 8.915 x 10^6. This also happens to be the maximum number of cycles, but this will usually not be the case unless the material selected is much stronger relative to the force applied. The second contour map shows fatigue safety factor. The minimum safety factor is 1.0349 and the areas highlighted in orange are the most likely to fail relative to the rest of the design. However, it is still greater than 1, meaning that it should not fail before reaching the set design life of 10^9 cycles.

It is important to note that the results of the SkateMate simulation are only accurate for the specific magnitude and direction of the forces applied. The results may not hold for other scenarios with different forces, such as the user applying force on a different area, traveling in a different direction, or the user applying a force much larger than the estimate. Furthermore, the calculations are rough estimates based on assumed loading conditions. Inaccuracies in our interpretation of the scenario will affect the setup of the simulation and thus, the validity of the results. Regarding the data used to run the simulations, we will only be using material performance data we were able to find in research papers and engineering handbooks. This means that if we cannot find data for a specific material, we may need to substitute data for a similar material (for instance using data for uPVC instead of PVC). Also, the data used may not necessarily take into account the effect of temperature on the strength of a material, particularly polymers.