GNG 2101 – Introduction to Product Design and Development

Design Deliverable 9

Group F1.3

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Table 1. Acronyms

Acronym	Definition
UPM	User and Product Manual
BOM	Bill of Materials

1 Introduction

The User and Product Manual (UPM) provides the information necessary for individuals with mobility challenges and anyone interested in understanding the design and use of our on-handed foldable cane. This project, undertaken by a group of 5 engineering students in GNG2102, aims to create a practical and user-friendly mobility aid. This document is structured to guide the reader through an understanding of the product, its intended use, and the engineering behind its design. It begins with an overview of the problems that the cane addresses and its key features. It then provides detailed instructions on how to get started, use the cane, and address potential issues with the product. A significant portion of the manual is dedicated to the product documentation, highlighting the design considerations, the Bill of Materials (BOM), the manufacturing process, and the testing and validation procedures. Finally, the manual concluded with lessons learned and recommendations for future work.

2 Overview

Problem Definition & Project Importance

Mobility canes are essential tools for individuals with physical disabilities or temporary injuries, yet many standard canes are bulky, difficult to fold, or require two hands to operate making them impractical in fast-paced or crowded environments like public transportation. Our client needs a cane that is lightweight, foldable with one hand, and compact enough to store easily when not in use.

This problem is important because it directly impacts users' independence, comfort, and confidence. For users with limited mobility or dexterity, an accessible and user-friendly design can dramatically improve daily life by reducing physical effort and enabling quick transitions between walking and resting modes.

User Needs

The user needs a cane that:

- Can be folded and unfolded with one hand.
- Is lightweight (under 0.8 kg) and portable.
- Provides reliable support for up to 100 kg.
- Features an ergonomic handle and wrist strap for comfort and security.
- Can be stored in a compact pouch or carried easily.
- Includes visual cues to subtly indicate disability status when needed.

Key Differentiators

Our cane stands out from traditional mobility aids because:

- It features a spring-loaded telescopic mechanism for fast, one-handed deployment and retraction, even using the user's thigh as leverage.
- It has a custom ergonomic handle with an integrated ski-style wrist strap for ease of grip and reduced fatigue.

- The cane is designed using lightweight aluminum to balance strength and portability.
- The folded cane reduces to less than 30% of its full length, improving convenience for storage and transport.
- Aesthetics and personalization (colors, finishes) are considered for subtle disability indication.

Key Features & Functions

- Quick Folding/Unfolding: Push-button system for rapid transformation between cane and storage modes.
- Adjustable Height: Multiple locking positions to accommodate different user heights.
- Ergonomic Grip: Contoured handle for user comfort during prolonged use.
- Wrist Strap: Prevents accidental drops and allows hand-free moments.
- Non-slip Tip: Rubber foot designed for grip on a variety of surfaces.
- Compact Storage: Optional carrying pouch for folded cane.

System Architecture & Construction

Non-technical description: The cane is built with telescoping aluminum tubes connected via a spring-locking mechanism. The handle is made of 3D-printed material with an ergonomic design and attached wrist strap. The tip is also made of 3D-printed material to prevent slipping. No electronics are involved, making it lightweight and reliable.

User Access Mode:

The cane can be unfolded by pressing a twisting the handle and pushing the base down using a thigh or ground. To retract, twists back while applying upward pressure to collapse it.

Special Conditions:

- Best used on flat, dry surfaces.
- Not designed to support dynamic loads like running or jumping.

System Block Diagram

2.1 Conventions

No applicable conventions.

2.2 Cautions & Warnings

- Caution: Ensure all sections are locked before applying full body weight.
- Warning: Do not use on steep or icy surfaces where slipping is possible.
- Note:
    - If the product is modified in any way, warranty and safety cannot be guaranteed.

No software waivers or licensing are required for this product, as it is entirely mechanical.3 Getting started

This Cane has 2 states and 2 subsystems. The 2 states ate the extending position and the retracted position.

Figure 1: Extended Position of Cane

Figure 2: Retracted Position of Cane

The 2 subsystems include the locking mechanism and the retraction mechanism.

Figure 3: Diagram of Locking Mechanism

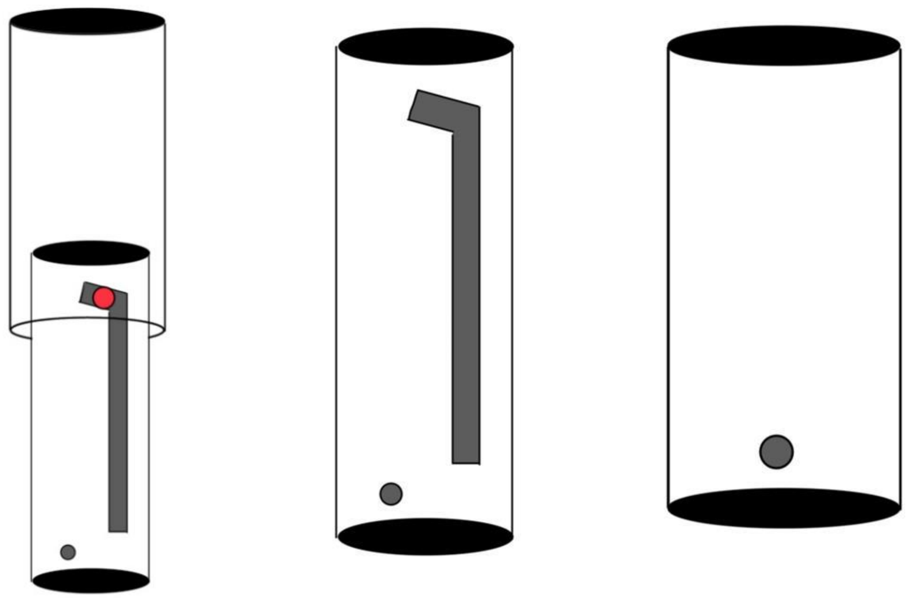
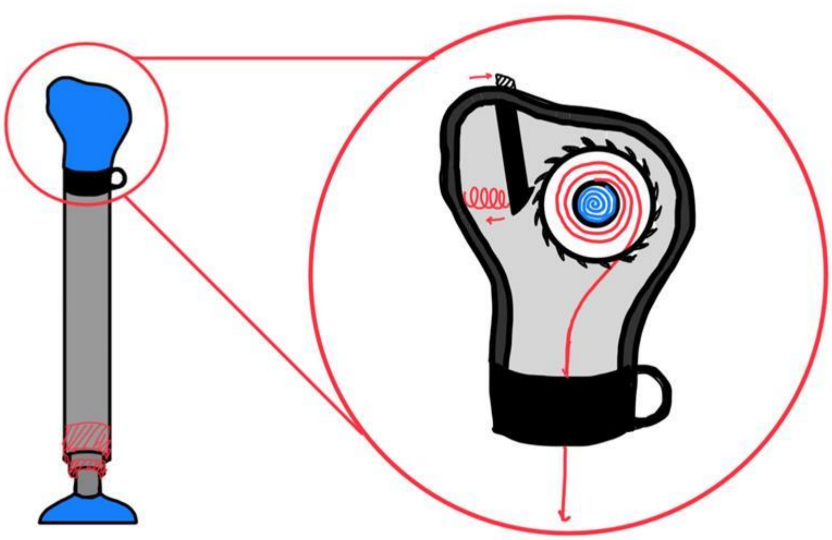


Figure 4: Diagram of Retraction Mechanism



The locking mechanism regards the aluminum poles and ensures that the cane stays in the extended position. The retraction mechanism is inside of the handle and assists the user in quickly retracting the cane.

The cane starts in the retracted position. To extend the cane, the user must step on the tip of the cane while holding onto the handle

Figure 5: Starting to extend the cane

Next, the user pulls the cane upwards to the extended position.

Figure 6: Extending the cane

Once the cane is fully extended, the user performs two 45º counter-clockwise turns to engage the locking mechanism. Now the can is safely locked in its extended position, allowing the user to use the cane. The user can slip the wrist-strap over their wrist for extra security.

Figure 7: Twisting the cane from the handle

Figure 8: Using the cane

When the user wishes to retract the cane, they must step on the tip and preform two 45^o clockwise turns to un-engage the locking mechanism. Then the retraction mechanism, will retract the cane into the minimized position.

Figure 9: Retracting the cane

Note: if the retraction mechanism fails, the user can press the cane against a surface (a wall, the ground, or their thigh),

3.1 Configuration Considerations

The one-handed foldable cane is a self-contained device that does not require connection to other systems or tools for its primary operations. The configuration is straightforward: the cane consists of the handle with the internal retraction mechanism, the telescoping aluminum poles with the external 3D-printed twist lick, and the 3D-printed non-slip tip. No assembly is required for regular use after the initial setup of the locking mechanism. The wrist strap is attached to the handle and is ready for use.

3.2 User Access Considerations

The primary intended user is an individual with a disability that limits their mobility, requiring a one-handed walking aid that can be easily folded and unfolded. The design of the handles aims to accommodate users with limited grip strength by allowing for hand extension rather than requiring a tight grasp. However, users with severe limitation in hand dexterity might find the operation of the twist lock mechanism challenging. The cane is designed to support a weight of up to 100 kg and is intended for user withing this weight range.

3.3 Accessing/setting up the System

The cane is pre-assembled, the primary setup involved understanding and practicing the locking and unlocking of the telescopic poles.

1. Familiarize yourself with the location and operation of the 3D-printed twist lock mechanism. Practice twisting to engage and disengage the lock.
2. Practice extending the cane by stepping on the tip while pulling the handle up until it is fully extended.
3. Practice locking the cane at the extended length by twisting the locking mechanism. Always ensure it is firmly locked before applying any weight.
4. Practice unlocking the cane by twisting the locking mechanism back.
5.

Practice retracting the cane by stepping on the tip, disengaging the lock, and stepping off the tip to let it retract. 3.4 System Organization & Navigation

The one-handed foldable cane consists of three main components:

1. Handle with retraction mechanism: This top section houses the internal spring-loaded coil system connected to a string that runs down to the tip. The handle also features an attached wrist strap.

   Figure #: Handle with retraction mechanism

2. Telescoping poles with locking mechanism: These three hallow aluminum tubes slide into each other to allow for extension and retraction. An external 3D-printed twist lock mechanism is secured to the outer pole and engages with slots on the inner pole to lock the cane while its extended.

   Figure #: Telescoping poles with locking mechanism

3. Tip: The bottom component is a 3D-printed cane tip with a non-slip design. It provides stability and a grip on the ground.

The handle connects directly to the top section of the telescoping poles. The subsequent poles sections slide within each other. The tip is the final component at the bottom of the assembly. The twist lock mechanism physically ca\lamps the outer pole to the inner pole when engaged.

3.5 Exiting the System

For physical prototypes: Describe the actions necessary to properly put away the system. To put the cane away when not in use:

1. Gently step on the tip of the cane.
2. Disengage the twist lock mechanism by twisting the handle in two 45^{o} clockwise turns.
3. Step off of the tip to allow the cane to fully retract. Guide the retraction is necessary.
4. The retracted cane can now be stored or carried using the wrist strap.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the <System Name and/or Acronym>.

4.1. Extending the Cane

To prepare the cane for use, the user must move it from its **retracted** state to its **extended** state.

Required Input:

- Step on the tip of the cane to stabilize it.
- Press the button on the handle to unlock the retraction system.
- Pull the handle upwards until the cane is fully extended.

System Output:

- The cane extends smoothly into its full length.
- The inner poles lock into alignment, ready for the locking twist.

Figure 10: *A user steps on the cane's base while pulling the handle to extend the cane.*

4.2. **Locking the Cane**

Once fully extended, the cane must be locked to ensure safe use.

Required Input:

- After extending, twist the handle counter-clockwise 90° (two 45° turns).
- This engages the external locking mechanism between telescoping tubes.

System Output:

- The cane becomes rigid and ready to support weight.
- Twist-lock prevents the inner poles from collapsing.

Figure 11: *Close-up of user twisting handle on extended cane.*

Notes:

- Always confirm the cane is securely locked before placing full weight on it.
- If the cane does not lock, verify that it is fully extended before twisting.

4.3. **Using the Wrist Strap**

The wrist strap adds safety by preventing the cane from falling if released.

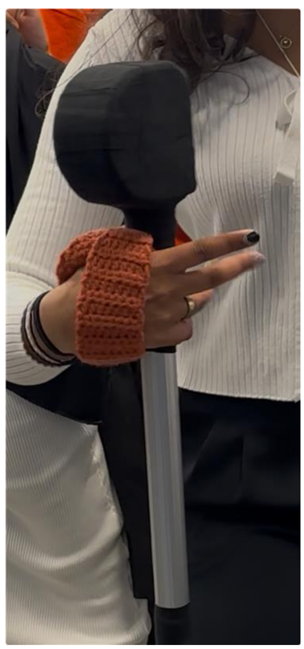
Required Input:

- Slide your wrist through the strap attached to the handle.

System Output:

- The cane remains securely tethered to your wrist, even if grip is loosened.

Figure 12: *Person holding cane with wrist strap looped around wrist*.



Tips:

- Adjust the strap for comfort and ease of use.
- Use during transit for additional stability.

4.4. **Retracting the Cane**

To store the cane, retract it back to its compact position.

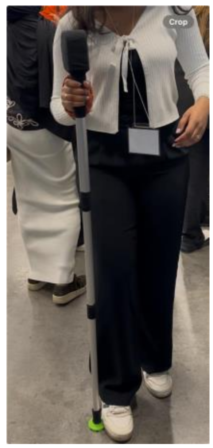
Required Input:

1. Step on the tip of the cane to keep it in place.
2. Twist the handle clockwise (two 45° turns) to unlock.
3. Press the button on the handle and hold.
4. Gently allow the handle to slide downward into its retracted state.

System Output:

- The cane compacts into its storage form.
- The telescopic tubes slide inward and the cane is ready to store or carry.

Figure 13: *Person stepping on tip and twisting out the locking mechanism.*



Caution:

- Do not force retraction. Let the mechanism work smoothly.
- Always ensure it is fully unlocked before trying to collapse it.

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

Error/Issue	Likely Cause(s)	Possible Corrective Actions
Cane does not extend smoothly	Obstruction in the telescopic tubes	Check for any debris or foreign objects in the tubes. Try gently twisting the handle while extending.
Cane collapses under weight	Twist lock mechanism not fully engaged	Ensure the rotating block of the locking mechanism is twisted fully

		into the horizontal slot until it feels secure.
Twist lock mechanism is difficult to turn	Jamming or misalignment	Try gently wiggling the poles while turning the lock. If it persists, inspect the locking mechanism for any damage or misalignment.
Retraction mechanism does not work	Internal or External obstruction	Check for any obstruction preventing the poles from sliding. If it continues, try manually compressing the cane against a surface while pressing the button
Non-slip tip appears worn or damaged	Normal wear and tear from use	Consider replacing the tip. Contact the design team for potential replacement options.

5.2 Special Considerations

- Do not use excessive force when extending or retracting the cane, or while operating the locking mechanism, as this could lead to damage.
- Regularly inspect all parts of the cane for any signs of wear, cracks, or lose components before use.

5.3 Maintenance

- Regular Inspection: Before each use, visually inspect the cane for any signs of damage, such as cracks in the handle or locking mechanism, dents in the aluminum tubes, or wear on the tip. Ensure all components are securely fastened.
- Cleaning: Wipe the cane down with a damp wash cloth to remove any dirt or debris. Avoid using harsh chemicals that could damage the materials.
- Locking mechanism check: Periodically check the twist lock mechanism to ensure it turns smoothly and engages securely. If it feels stiff or does not lock properly, inspect it for any obstructions or damage.
- Retraction Mechanism Check: Ensure the retraction operates smoothly and retracts without excessive resistance.

5.4 Support

For any questions, issues, or to report problems with the one-handed foldable cane, please contact the design team members:

- Emily Way (eway100@uottawa.ca)
- Jennifer Campbell (jcamp203@uottawa.ca)
- Anjali Chalayil Sreekumar (achal011@uottawa.ca)
- Alex Novac (anova038@uottawa.ca)
- Armand Guigma (aguig043@uottawa.ca)

Please provide a detailed description of the issue encountered, including when and how it occurred, and any relevant observations. This information will help us in understanding and addressing the problem.

6 Product Documentation

The final prototype of the one-handed foldable cane is a mechanical system. Its construction can be broken down into three main subsystems: the handle with the retraction mechanism, the telescoping pole with the locking mechanism, and the tip.

6.1 Handle and Retraction Mechanism

The handle was designed with ergonomics in mind, aiming for a comfortable grip that allows for hand extension as per the client's preference. It was 3D-printed using PLA/ABS filament. 3D printing was chosen for its ability to create complex shapes and allow for rapid prototyping and iteration based on client feedback. We considered using a silicon mold kit to create a softer, more comfortable grip, but this was not implemented in the final prototype due to time and budget constraints.

The retraction mechanism is inspired by a tape measure. It consists of disassembled measuring tape with a cord instead of the tape itself. The constant force spring was extracted and fully loaded to be reassembled into the casing that was 3d printed within our handle.

6.1.1 BOM (Bill of Materials)

Item	Description	Price ($)	Place of Purchase

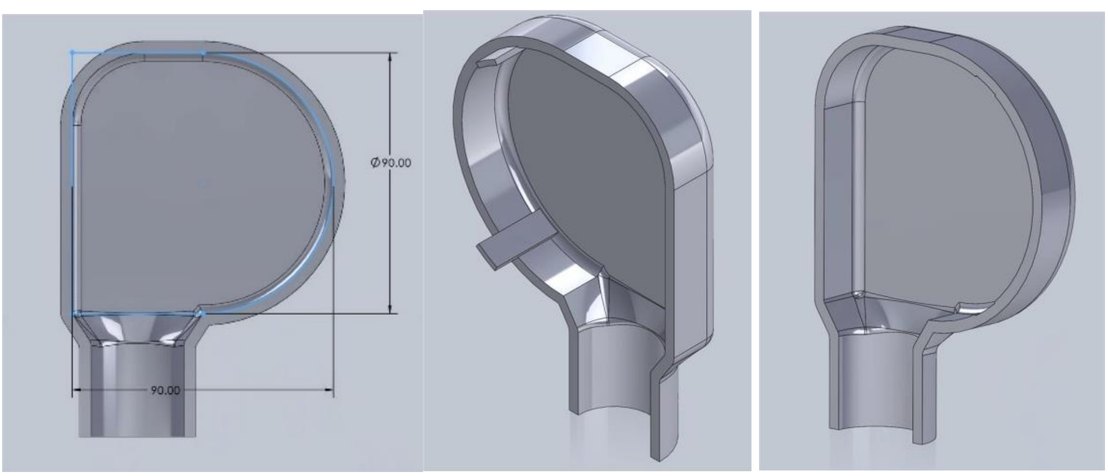
Craftsmen Tape Measure	Required the constant force spring from the inside of the tape measure	14.99 + 1.95	Rona
3D Printed Casing	Handle Casing	-NA-	Makerspace
Kinesiology Tape	Comfort Grip for Handle	8.77 + 1.14	Walmart
Gorilla Glue	Secure Parts	1.25 + 0.16	
Total ($)		28.26	

6.1.2 Equipment list

- SolidWorks
- Ultimaker Cura
- 3D printer
- Clamps
- Screwdriver

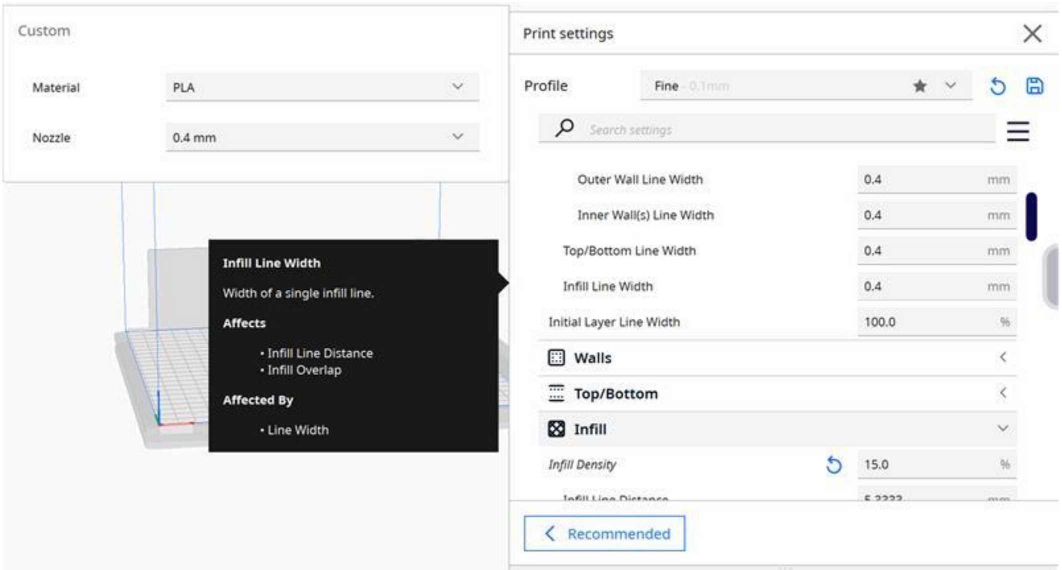
6.1.3 Instructions

1. Print the following handle design on a 3D printer.
   Figure 14: SolidWorks CAD of Handle



Use 0.4mm nozzle and 15% infill to set up the print using the Ultimaker Cura software

Figure 15: 3D printing set-up



2. Disassemble the measuring tape using a screwdriver. Remove the spring and replace the tape with the cord. Assemble everything back. Fixate the measuring tape casing inside the handle case, insert the top tube and glue both parts of casing together using gorilla glue. Wrap the plastic parts and 10 cm of the tube down starting from the handle. Focus on covering the entire surface first and follow with additional layers to improve comfort in areas with increased contact.
3. Optional: add a little personal touch to the cane by crocheting a strap. Attach it to the handle using more kinesiology tape.

6.2 Telescoping Pole and Locking Mechanism

Our design utilizes 3 aluminum poles from a pre-made telescopic painters pole. Aluminum was chosen for its strength-to-weight ratio, durability, and ease of machining. We considered using carbon fiber for weight reduction, but aluminum was more readily available within the project's resources. L-shaped sections were cut out of the poles using a mill to allow the for the sliding bolt mechanism. The dimensions and placement of these cutouts were determined based on the desired height.

6.2.1 BOM (Bill of Materials)

Item	Description	Price ($)	Place of Purchase
Aluminum Telescopic Painters Pole	3 telescoping poles that extend up to 8’	30.99 + 4.03	Rona
x4 M6 Bolt (10 mm)	Locking Mechanism stopper	-NA-	Brunsfield

x8 Washers	To ensure that the bolts are fixed in place and does not interfere with the next pole	-NA-	Brunsfield
Total ($)		35.02	

6.2.2 Equipment list

- Aluminum Poles
- Horizontal Bandsaw
- x4 M6 Bolt
- x8 washers
- Vertical Milling Machine
    - ¼" End Mill
    - #7 Drill Bit
    - ¼"-20 UNC Tap
    - Coolant
    - Collet
    - Edge finder

6.2.3 Instructions

Begin by separating the painter's pole into three separate tubes by breaking away all the plastic components for the existing locking mechanism.

Figure 16: Telescopic Pole

Once separate, mark a length of 1.5 ft on the pole. This will indicate where the cut will be made with the horizontal bandsaw.

Once marked, set up the horizontal bandsaw. Expand the vice, set up the pole so it's flat on the plate. Align the mark at 1.5 ft with the blade and tighten the vice enough so it's not deforming the tube but is fixed in place.

Turn the bandsaw on, adjust the coolant release, and set speed to 1.25 (recommended for aluminum), and make the cut. Repeat steps 2-3 for each tube.

Figure 17: Machining the poles

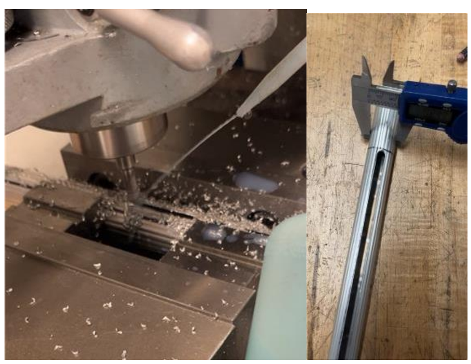
Once cut, make a mark on one side at ~0.5" from the end of the tube and the other side at the tube ~0 .25" from the end. Connect the two marks with a straight line along the tube. This will be the length of the slot.

Now begin to set up the Vertical Milling Machine. Set up parallels inside the vice and place the pole so that the slot line is centered. ~45% of the pole should be extruding out the top of the vice.

Center the pole to ensure that the slot is parallel to the length of the pole. Set up the collet and edge finder and set a fixed 0 value for z where the edge finder will be in contact against the side of the pole. Start the machine, set the Z=0, and use the edge finder against the length of the pole and set Y=0. Now, use the edge finder against the other side of the pole, where Z=0, and once the edge finder aligns perfectly, halve the Y distance to find the center of the pole.

Next, cut the slot. Remove the edge finder and insert the ¼” end face mill. Align the end face so that it is hovering above the end of the line marked earlier. Change the Z axis height so that the end mill lightly brushes against the part, set that value to Z=0. Go in 10 thou (0.01 inches) at a time until the slot is fully cut through.

Figure 18: Milling the Poles



Repeat the above steps for each tube.

Next, set the vice position on the mill to 15 degrees.

Similar to the steps above, cut a 1-inch slot perpendicular to the initial slot on the side where the slot is ½” away from the edge. This will be the locking area, repeat this for all the tubes.

Now using the opposite side from the perpendicular slot, drill a hole using the #7 drill bit. Do this to sections 1 and 2.

Tap these holes with ¼”-20 UNC tap.

Align the hole with the slot and place 4 washers between the head of the bolt and the pole. Screw this into the hole.

6.3 Tip

The tip was 3D-printed and designed to be non-slip for stability.

6.3.1 BOM (Bill of Materials)

Item	Description	Price ($)	Place of Purchase
PLA/ABS filament	The material to 3D print the cane	0	MakerSpace
SolidWorks2024	The software used to design the cane	0	Provided through University
Total		0	

6.3.2 Equipment list

- SolidWorks 2024
- 3D-Printer
- PLA/ABS filament

6.3.3 Instructions

1. Design a non-slip tip using SolidWorks or another CAD software. Consider a shape and texture that will provide a good grip on various surfaces. Ensure the tip is wide enough to step on the tip for assisting the retraction and extension.
2. 3D print the tip using PLA/ABS filament.
3. Securely attach the 3D-printed tip the bottom of the innermost telescopic pole.

6.4 Testing & Validation

- **Load-Bearing Test:** The prototype of the pole and locking mechanism was tested by gradually adding weight. The prototype could easily support the target of 100 kg with a 1.5 safety factor.
- **Locking Mechanism Test:** The locking mechanism was tested by applying force to the extended cane to ensure the sliding bolt securely prevented retraction. The mechanism successfully held the weight applied during the prototype testing.
- **Usability Test for Locking Mechanism:** Users practiced extending, locking, unlocking, and allowing the automatic retraction of the cane to assess ease of use and speed. The feedback on the concept was positive regarding the automatic retraction.
- **Durability of Opening/Closing Mechanism:** The smooth operation of the sliding bolt and the intended function of the spring-loaded retraction were observed. Long-term testing with the final prototype, including repeated cycles of extension and retraction (target of 10,000 cycles), is necessary to assess the durability and reliability of these mechanisms.

7 Conclusions and Recommendations for Future Work

The design and prototyping of the one-handed foldable cane have demonstrated the feasibility oof a lightweight and portable mobility aid with one-handed operation and automatic retraction. The internal sliding bolt locking mechanism addresses the client's need for a secure and efficient locking method. Future work should focus on:

- Developing a compact carrying pouch for enhanced portability
- Exploring different materials for the handle and tip to improve comfort, grip, and durability.
- Extensive long-term durability testing of all components, including the locking and retracting systems under various environmental conditions.
- Minimizing the size of the retraction mechanism. Currently, the handle is bulky. With a smaller retraction system, there would be more options for the handle shape and size.
- Adding a button to the retraction mechanism so the cane wouldn't accidentally retract itself during use.
- Formal safety testing and certification to ensure the product meets relavent standards for mobility aids.
- Investigation design elements that serve as a visual cue to indicate the user's disability.

APPENDICES

9 APPENDIX I: Design Files

Project Deliverables:

Deliverable B:

Introduction

The goal of this project is to design a one-handed, foldable cane that is lightweight, easy to use, and capable of being quickly folded and unfolded with one hand. This report works to identify the problem and plan the design process. After identifying the core user needs and requirements, the problem definition is states. The report outlines the design specifications, including metrics and benchmarking, and provides a functional analysis of various design concepts. Overall, the document will provide a comprehensive overview of the design process, from the problem definition to concept evaluation, eventually leading to a design solution that balances functionality, ease of use, and portability

2. Sustainability Report and DFX

2.1 Sustainability report

Table 3: Sustainability Constraints

Triple Bottom Line	Positive Impact	Negative Impact
Economic	Jobs creation	High initial investments
	Affordable manufacturing cost	Competitive market limits profitability
	Revenue from recycling used product into raw material	Marketing expenses.

Environmental	Use of recyclable materials	carbon emissions during manufacturing
	Lightweight and compactable design minimizes the fuel usage for transportation	e-waste is produced if an electric design is used
	Long-lasting design reduces the frequency of replacements	Raw material extraction
Social	Enhances accessibility	Limited global availability
	Community awareness	Unique designs are harder to repair
	Increased user safety	Obsolescence

Economic:

The project promotes job creation in manufacturing, assembly, and distribution, while affordable production costs make it accessible to a broader market. Innovative features can drive increased sales and position the product competitively. However, the project requires a high initial investment in production facilities and equipment, and profitability may be constrained by intense market competition. Additionally, marketing expenses to build brand awareness could further impact the financial outlook, requiring strategic resource allocation to ensure economic sustainability.

Environmental:

Using recyclable materials can significantly reduce the waste output of a product. For a large manufacturing company, using recyclable materials would help the product reach the necessary environmental regulations and reduce long-term material costs if they can be reused. On a smaller scale, sourcing leftover materials from the MakerSpace reduces waste and cost for this project.

Additionally, a compact and lightweight cane design allows for more units to be shipped per container, which reduces fuel consumption. This allows major companies to ship their products while lowering their carbon footprint.

A durable cane reduces waste and materials by minimizing the need for frequent replacements, decreasing the environmental impact over time. However, manufacturing processes like 3D printing, injection molding, or metal machining contribute to carbon emissions. Using carbon offset programs and renewable energy can lower carbon emissions. Additionally, the made-to-order aspect of this project supports a smaller-scale, precise manufacturing process, making it easier to optimize emissions at every stage. Incorporating electrical components like motors or batteries will lead to the contribution of e-waste, especially if recycling programs for electronics are not well-established in production regions. Proper disposal methods, using recyclable electrical components, and sticking to industry standards is needed to lower e-waste. Finally, extracting materials like materials or polymers can harm ecosystems and contribute to pollution. Large companies must ensure materials are ethically and sustainably sourced. For example, a woodworking company may commit to planting a certain number of trees per year to account for their materials extraction. To design the cane, this team should use the recycled materials from the MakerSpace to reduce the negative environmental impact and showcase sustainable practices on a smaller scale.

Social

The cane is designed to improve mobility and independence for individuals with disabilities or mobility challenges, helping them to navigate their environments safely and confidently. This allows users to participate in social, professional, and recreational activities that may otherwise be inaccessible. Additionally, the cane can raise community awareness about hidden disabilities. Many individuals with mobility challenges, like the client, face issues where others fail to recognize their need for accommodations, such as priority seating on public transportation. By incorporating subtle visual cues into the cane's design-such as distinct colours, patterns, or symbols it can serve as an indicator of a user's disability. This could promote greater empathy and cooperation for the public to provide accommodation. The cane's design focuses on enhancing user safety by providing physical support. This will lower the risk of injury and provide peace of mind for users and their surroundings. This positive impact extends beyond physical safety, contributing to greater confidence and improved quality of life. While the cane addresses accessibility challenges, its global availability may be restricted by factors such as production costs, availability of materials, or distribution networks. These limitations may make the product inaccessible to those in lower-income or remote areas. Ensuring affordability and widespread availability is crucial to maximizing its societal impact. Furthermore, the personalized and unconventional design will complicate repairs, leading to higher costs for repairs, particularly if specialized tools, materials, or expertise are required. Lastly, as technology evolves, the cane may face obsolescence, leaving older designs less desirable. This could lead to dissatisfaction among users who cannot access frequence upgrades. Additionally, if the cane is not designed with replaceable components, the users are forced to replace the entire product instead of upgrading specific parts.

2.2 LCA report

Product Evaluated: Single-hand folding cane

Objective and Scope

The objective of this LCA report is to evaluate the environmental performance of the single-handed folding cane designed with sustainability and efficiency in mind. The goal is to produce a cane using recyclable and lightweight materials, ensuring an environmentally friendly design while maintaining functionality and durability. This report will assess the cradle-to-cradle life cycle stages of the cane, including raw material sourcing, production, transportation, use, and end-of-life management, to identify opportunities for improvement and promote sustainable practices.

Define the steps of the cycle which will be covered: Determine the stage(s) of the product life cycle you are analyzing. Write a brief description here:

The stages of the product life cycle that will be analyzed in the report follow a cradle-to-cradle scope, offering an examination of the product's journey through the chosen lifecycle. First, the processing and production of the product will be evaluated, which includes the transformation of raw materials into usable parts and their assembly. Next, the transportation will be examined, focusing on the logistics and environmental impacts of moving the materials and product across the supply chain. The retail and use are the next phase that will be explored, examining the distribution and sale of the cane, including the packaging and accessibility in retail/other platforms. Finally, there is the end-of-life stage which encompasses recycling, waste management, and the product's potential reintegration into the production cycle.

Define the aspect of sustainability that will be studied: Circle the area that will be studied

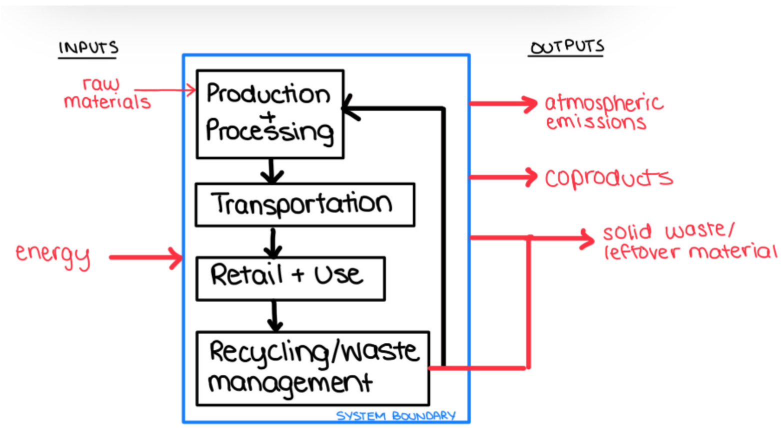
Environmental Economic Social

Define the duration of the study: Determine the length of time you will consider for doing your study:

The length of time considered for this product will be a timeframe of 5 years.

Conceptual limit of the system: Draw a diagram with your specific product and its system boundaries. Includes system inputs and outputs.

Figure 1: Product Life



Inventory analysis

Step 1 Acquiring materials:

Type of raw material	Points
Bauxite	1
Silica	1
Total points	2

Step 2 Material processing:

Plastics or metals in the product	Points
Aluminum	1
Silicon	1
Total points	2

Step 3 Manufacturing:

Different parts and pieces of the product	Points
Body of the cane	1

Handle	1
Base	1
Total points	3

Step 4 Packaging:

Packaging	Points
None	0
Paper or cardboard packaging only	5
Plastic packaging only	15
Plastic and cardboard packaging	10
Styrofoam or rubber packaging	15
Instruction sheets included separately in packaging	5
Total points	0

Step 5 Transport:

Transport	Points
Yes, by plane, truck or boat	15
None	1
Total points	1

Step 6 Using the product:

Product Usage	Points
The product can be used once	15

The product can be used for 6-12 months	12
The product can be used for 2 years	11.25
The product can be used for 5 years	10
The product can be used for more than 10 years	5
Total points	11.25

Step 7 Disposal:

Parts of the product made from plastics or metals	Points
The product must be discarded	15
Some materials in the product can be recycled	5
All products and materials in the product can be recycled	0
Total points	5

Impact assessment

Total points	34.25

Interpretation and improvement

What could you change about your product to improve its environmental impact? Describe your improvements here.

The greatest contributors to the product’s environmental impact are the materials used to manufacture it. The process of turning bauxite into aluminum is one that relies on hydroelectric dams that have been known to negatively harm the surrounding environment. Using only recycled aluminum, or a more environmentally friendly material to make the body of the cane would mitigate this impact. The use of silicone presents a similar issue. The processing of silica to silicone emits a significant amount of carbon dioxide, presenting a negative environmental impact. This could also be mitigated by finding an alternative material that can be recycled, and that has a more environmentally friendly manufacturing process. Another top contributor to the environmental impact is the product’s lifespan. The cane can last approximately two years with regular use, then can only be partially recycled. Focusing on more sustainable materials that will last longer than 2 years can mitigate the negative environmental impacts once the product has reached the end of its lifespan.

Look at your inventory analysis above. Recalculate your score if you were to use the improvements you just described. Has your score changed? By how much?

Using the above improvements, the total points decrease by 6.25. Assuming an increase in the product lifespan from 2 years to 5 years, the total points will decrease by 1.25, then by only using recyclable materials the points will decrease by 5 points.

What should you do to further reduce the environmental impact of your product?

After making changes to the material and the product lifespan, the manufacturing process could be examined to further reduce the environmental impact of the product. Using machinery of any sort, from the transportation used to obtain the materials, to manufacturing them into a working cane contributes negatively to the environment in some form or another. Using more sustainable travel methods, as well as ensuring that canes are made to order, only using machinery when necessary, will reduce such an impact.

2.3 Design for X

Following the client meeting and their statements multiple factors were identified that could potentially impact the focus of the cane design.

Design for Safety

Objective: Minimize potential dangers related to the use of the cane (particularly reducing risks of injury)

Metrics: Maximum acceptable load (N), Safety factor (dimensionless)

Constraints: Cane supports a minimum load of 100kg with a safety factor of 1.5. Material choice for the tip ensures a non-slip surface.

Design criteria:

Elastic (non plastic) deformation under expected loads

Non-slip (ex. Rubber) material for the handle and tip

Edges rounded to prevent injuries

Design for Manufacturing

Objective: Design an easy to produce cane with minimal cost and complexity

Metrics: Manufacturing cost($/unit). Production time (h/unit)

Constraints:

Assuming the tools are provided by the Makerspace, materials selection allows production within a budget of 75$

Assembly requires no more than 3 steps

Design criteria:

Use of off-the-shelf components where possible

Design for automated fabrication process (ex.: 3D printing, laser-cutting). This might be difficult in the context of this project but works as an example

Design for Usability (and portability as a sub aspect)

Objective: Enhance user experience by ensuring the cane is easy to use, carry, and store

Metrics: weight (kg), foldability and compact storage dimension (cm)

Constraints: weight is below 0.8kg, folded length is les than 30% of initial length

Design criteria:

Ergonomic handle is designed for prolongated use

Lightweight but durable materials such as aluminum or carbon fiber

Foldable cane with a secure locking mechanism

Design for Speed

Objective: Minimize the time required to bring the product to the market

Metrics: Time to finish the ideation process. Time to complete the final prototype.

Constraints: Choice of concept will be made in the next 2 weeks. Final prototype created and tested by the design day

Design Criteria:

Rapid prototyping using 3D printing to receive feedback fast.

Design multiple pieces at the same time in order to shorten the design process

Design for Reliability

Objective: Ensure consistency and durability of the product throughout its life

Metrics: Product lifespan in years, number of successful uses before failiure (cycles)

Constraints: The cane maintains functionality for a minimum of 5 years and withstands 10000 successful uses without failure

Design criteria: Use of materials resistant to wear and tear. Test the product in real-world conditions (loading and environmental tests).

3. Problem Definition, Concept Development, and Project Plan

3.1 Client Needs

Table 4: Client Needs

	NEED	**mp.**
	The cane is lightweight	
	The cane is useable with only one hand	
	The cane assembles and disassembles quickly	
	The cane assembles and disassembles using one hand	
	The cane comes with carrying pouch to store it	
	The cane resembles a walking stick	
	The grip of the cane allows for hand extension	
	The cane supports the user's weight	
	The cane is compatible with client's active lifestyle	
0	The cane indicates that the user is disabled	

*1 being the least important, 5 being the most important

Table 5: Client Knowns and Unknowns

Knowns	Unknowns
Client has a very active lifestyle (competitive cyclist, goes to the gym frequently, is a student, etc.) Client uses public transit and requires a free hand to board safely Client uses the dominant side of their body to walk Client requires use of their hand while using the cane Client prefers a walking stick as opposed to a cane Client has health issues that limit mobility Client's hand is better at extending than grasping Client has difficulties carrying a backpack, requires somewhere to put the cane when not in use Client does not place a lot of weight on the cane	Client's level of mobility and dexterity in dominant hand Client's grip and hand strength in dominant hand Client's level of balance and how much support they require Client's weight (to establish how much weight the cane should be able to withstand) Client's dominant hand Client's colour preferences for the cane

Client has an invisible disability, would like some form of identification that will inform people so they can sit in the accessible seating on the bus	

3.2 Problem definition

The client needs a one-handed foldable walking cane that prioritizes ease of use, potability, and a lightweight design. The device must open and close quickly with one hand, provide support without compromising strength, and include a convenient storage solution for when the cane is not in use. The cane should feature an ergonomic grip that minimizes the need for excessive grasping, ensuring comfort during use.

3.3 Market study

Table 6: List of Metrics

Metric #	Need #	Metric	Imp	Units
1	1	Weight	3	kg
2	8	Supported weight	2	kg
3	3	Time to extension / contraction	4	s
4	4	Stability with one hand	5	1 to 10 scale
5	5	Stored size	3	cm3
6	6	Aesthetics	3	1 to 10 scale
7	6	Cane length	3	m
8	4	Number of segments	2	
9	9	Price	4	$

Deliverable C:

1. Introduction

The goal of this project is to design a one-handed, foldable cane that is lightweight, easy to use, and capable of being quickly folded and unfolded with one hand. This report works to identify the problem and plan the design process. After identifying the core user needs and requirements, the problem definition is states. The report outlines the design specifications, including metrics and benchmarking, and provides a functional analysis of various design concepts. Overall, the document will provide a comprehensive overview of the design process, from the problem definition to concept evaluation, eventually leading to a design solution that balances functionality, ease of use, and portability

2. Sustainability Report and DFX

2.1 Sustainability report

Table 3: Sustainability Constraints

Triple Bottom Line	Positive Impact	Negative Impact
Economic	Jobs creation	High initial investments
	Affordable manufacturing cost	Competitive market limits profitability
	Revenue from recycling used product into raw material	Marketing expenses.
Environmental	Use of recyclable materials	carbon emissions during manufacturing
	Lightweight and compactable design minimizes the fuel usage for transportation	e-waste is produced if an electric design is used
	Long-lasting design reduces the frequency of replacements	Raw material extraction
Social	Enhances accessibility	Limited global availability
	Community awareness	Unique designs are harder to repair
	Increased user safety	Obsolescence

Economic:

The project promotes job creation in manufacturing, assembly, and distribution, while affordable production costs make it accessible to a broader market. Innovative features can drive increased sales and position the product competitively. However, the project requires a high initial investment in production facilities and equipment, and profitability may be constrained by intense market competition. Additionally, marketing expenses to build brand awareness could further impact the financial outlook, requiring strategic resource allocation to ensure economic sustainability.

Environmental:

Using recyclable materials can significantly reduce the waste output of a product. For a large manufacturing company, using recyclable materials would help the product reach the necessary environmental regulations and reduce long-term material costs if they can be reused. On a smaller scale, sourcing leftover materials from the MakerSpace reduces waste and cost for this project. Additionally, a compact and lightweight cane design allows for more units to be shipped per container, which reduces fuel consumption. This allows major companies to ship their products while lowering their carbon footprint. A durable cane reduces waste and materials by minimizing the need for frequent replacements, decreasing the environmental impact over time. However, manufacturing processes like 3D printing, injection molding, or metal machining contribute to carbon emissions. Using carbon offset programs and renewable energy can lower carbon emissions. Additionally, the made-to-order aspect of this project supports a smaller-scale, precise manufacturing process, making it easier to optimize emissions at every stage. Incorporating electrical components like motors or batteries will lead to the contribution of e-waste, especially if recycling programs for electronics are not well-established in production regions. Proper disposal methods, using recyclable electrical components, and sticking to industry standards is needed to lower e-waste. Finally, extracting materials like materials or polymers can harm ecosystems and contribute to pollution. Large companies must ensure materials are ethically and sustainably sourced. For example, a woodworking company may commit to planting a certain number of trees per year to account for their materials extraction. To design the cane, this team should use the recycled materials from the MakerSpace to reduce the negative environmental impact and showcase sustainable practices on a smaller scale.

Social

The cane is designed to improve mobility and independence for individuals with disabilities or mobility challenges, helping them to navigate their environments safely and confidently. This allows users to participate in social, professional, and recreational activities that may otherwise be inaccessible. Additionally, the cane can raise community awareness about hidden disabilities. Many individuals with mobility challenges, like the client, face issues where others fail to recognize their need for accommodations, such as priority seating on public transportation. By incorporating subtle visual cues into the cane's design-such as distinct colours, patterns, or symbols it can serve as an indicator of a user's disability. This could promote greater empathy and cooperation for the public to provide accommodation. The cane's design focuses on enhancing user safety by providing physical support. This will lower the risk of injury and provide peace of mind for users and their surroundings. This positive impact extends beyond physical safety, contributing to greater confidence and improved quality of life. While the cane addresses accessibility challenges, its global availability may be restricted by factors such as production costs, availability of materials, or distribution networks. These limitations may make the product inaccessible to those in lower-income or remote areas. Ensuring affordability and widespread availability is crucial to maximizing its societal impact. Furthermore, the personalized and unconventional design will complicate repairs, leading to higher costs for repairs, particularly if specialized tools, materials, or expertise are required. Lastly, as technology evolves, the cane may face obsolescence, leaving older designs less desirable. This could lead to dissatisfaction among users who cannot access frequence upgrades. Additionally, if the cane is not designed with replaceable components, the users are forced to replace the entire product instead of upgrading specific parts.

2.2 LCA report

Product Evaluated: Single-hand folding cane

Objective and Scope

The objective of this LCA report is to evaluate the environmental performance of the single-handed folding cane designed with sustainability and efficiency in mind. The goal is to produce a cane using recyclable and lightweight materials, ensuring an environmentally friendly design while maintaining functionality and durability. This report will assess the cradle-to-cradle life cycle stages of the cane, including raw material sourcing, production, transportation, use, and end-of-life management, to identify opportunities for improvement and promote sustainable practices.

Define the steps of the cycle which will be covered: Determine the stage(s) of the product life cycle you are analyzing. Write a brief description here:

The stages of the product life cycle that will be analyzed in the report follow a cradle-to-cradle scope, offering an examination of the product's journey through the chosen lifecycle. First, the processing and production of the product will be evaluated, which includes the transformation of raw materials into usable parts and their assembly. Next, the transportation will be examined, focusing on the logistics and environmental impacts of moving the materials and product across the supply chain. The retail and use are the next phase that will be explored, examining the distribution and sale of the cane, including the packaging and accessibility in retail/other platforms. Finally, there is the end-of-life stage which encompasses recycling, waste management, and the product's potential reintegration into the production cycle.

Define the aspect of sustainability that will be studied: Circle the area that will be studied

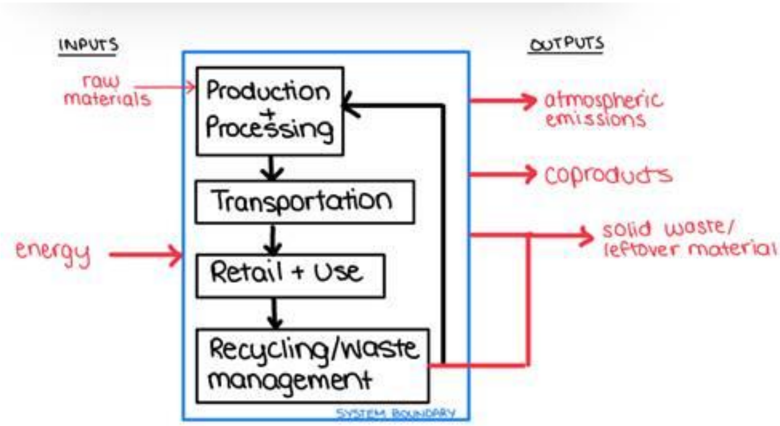
Environmental　　　　Economic　　　　Social

Define the duration of the study: Determine the length of time you will consider for doing your study:

The length of time considered for this product will be a timeframe of 5 years.

Conceptual limit of the system: Draw a diagram with your specific product and its system boundaries. Includes system inputs and outputs.

Figure 1: Product Life



Inventory analysis

Step 1 Acquiring materials:

Type of raw material	Points
Bauxite	1
Silica	1
Total points	2

Step 2 Material processing:

Plastics or metals in the product	Points
Aluminum	1
Silicon	1
Total points	2

Step 3 Manufacturing:

Different parts and pieces of the product	Points
Body of the cane	1

Handle	1
Base	1
Total points	3

Step 4 Packaging:

Packaging	Points
None	0
Paper or cardboard packaging only	5
Plastic packaging only	15
Plastic and cardboard packaging	10
Styrofoam or rubber packaging	15
Instruction sheets included separately in packaging	5
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Step 5 Transport:

Transport	Points
Yes, by plane, truck or boat	15
None	1
Total points	1

Step 6 Using the product:

Product Usage	Points
The product can be used once	15

The product can be used for 6-12 months	12
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Step 7 Disposal:

Parts of the product made from plastics or metals	Points
The product must be discarded	15
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Total points	5

Impact assessment

Total points	34.25

Interpretation and improvement

What could you change about your product to improve its environmental impact? Describe your improvements here.

The greatest contributors to the product's environmental impact are the materials used to manufacture it. The process of turning bauxite into aluminum is one that relies on hydroelectric dams that have been known to negatively harm the surrounding environment. Using only recycled aluminum, or a more environmentally friendly material to make the body of the cane would mitigate this impact. The use of silicone presents a similar issue. The processing of silica to silicone emits a significant amount of carbon dioxide, presenting a negative environmental impact. This could also be mitigated by finding an alternative material that can be recycled, and that has a more environmentally friendly manufacturing process. Another top contributor to the environmental impact is the product's lifespan. The cane can last approximately two years with regular use, then can only be partially recycled. Focusing on more sustainable materials that will last longer than 2 years can mitigate the negative environmental impacts once the product has reached the end of its lifespan.

Look at your inventory analysis above. Recalculate your score if you were to use the improvements you just described. Has your score changed? By how much?

Using the above improvements, the total points decrease by 6.25. Assuming an increase in the product lifespan from 2 years to 5 years, the total points will decrease by 1.25, then by only using recyclable materials the points will decrease by 5 points.

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After making changes to the material and the product lifespan, the manufacturing process could be examined to further reduce the environmental impact of the product. Using machinery of any sort, from the transportation used to obtain the materials, to manufacturing them into a working cane contributes negatively to the environment in some form or another. Using more sustainable travel methods, as well as ensuring that canes are made to order, only using machinery when necessary, will reduce such an impact.

2.3 Design for X

Following the client meeting and their statements multiple factors were identified that could potentially impact the focus of the cane design.

Design for Safety

Objective: Minimize potential dangers related to the use of the cane (particularly reducing risks of injury)

Metrics: Maximum acceptable load (N), Safety factor (dimensionless)

Constraints: Cane supports a minimum load of 100kg with a safety factor of 1.5. Material choice for the tip ensures a non-slip surface.

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Lightweight but durable materials such as aluminum or carbon fiber

Foldable cane with a secure locking mechanism

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Objective: Minimize the time required to bring the product to the market

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Objective: Ensure consistency and durability of the product throughout its life

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Constraints: The cane maintains functionality for a minimum of 5 years and withstands 10000 successful uses without failure

Design criteria: Use of materials resistant to wear and tear. Test the product in real-world conditions (loading and environmental tests).

3. Problem Definition, Concept Development, and Project Plan

3.1 Client Needs

Table 4: Client Needs

	NEED	**mp.**
	The cane is lightweight	
	The cane is useable with only one hand	
	The cane assembles and disassembles quickly	
	The cane assembles and disassembles using one hand	
	The cane comes with carrying pouch to store it	
	The cane resembles a walking stick	
	The grip of the cane allows for hand extension	
	The cane supports the user's weight	
	The cane is compatible with client's active lifestyle	
0	The cane indicates that the user is disabled	

*1 being the least important, 5 being the most important

Table 5: Client Knowns and Unknowns

Knowns	Unknowns
Client has a very active lifestyle (competitive cyclist, goes to the gym frequently, is a student, etc.) Client uses public transit and requires a free hand to board safely Client uses the dominant side of their body to walk Client requires use of their hand while using the cane Client prefers a walking stick as opposed to a cane Client has health issues that limit mobility Client's hand is better at extending than grasping Client has difficulties carrying a backpack, requires somewhere to put the cane when not in use Client does not place a lot of weight on the cane	Client's level of mobility and dexterity in dominant hand Client's grip and hand strength in dominant hand Client's level of balance and how much support they require Client's weight (to establish how much weight the cane should be able to withstand) Client's dominant hand Client's colour preferences for the cane

Client has an invisible disability, would like some form of identification that will inform people so they can sit in the accessible seating on the bus	

3.2 Problem definition

The client needs a one-handed foldable walking cane that prioritizes ease of use, potability, and a lightweight design. The device must open and close quickly with one hand, provide support without compromising strength, and include a convenient storage solution for when the cane is not in use. The cane should feature an ergonomic grip that minimizes the need for excessive grasping, ensuring comfort during use.

3.3 Market study

Table 6: List of Metrics

Metric #	Need #	Metric	Imp	Units
1	1	Weight	3	kg
2	8	Supported weight	2	kg
3	3	Time to extension / contraction	4	s
4	4	Stability with one hand	5	1 to 10 scale
5	5	Stored size	3	cm3
6	6	Aesthetics	3	1 to 10 scale
7	6	Cane length	3	m
8	4	Number of segments	2	
9	9	Price	4	$

Similar solutions:

Option: Comfkey cane (13.69$):

Figure 2: Comfkey Cane

Table 7: Comfkey details

Product Dimensions	18.01 x 32.99 x 7.01 cm; 250 g
Colour	Black
Packed Size	27 centimeters
Height	18 Centimetres
Length	33 Centimetres
Weight	0.3 Kilograms
Width	7 Centimetres
Material	Aluminum
Maximum Height Recommendation	37 Inches
Number of Items	1
Batteries Included?	No
Brand	COMFKEY
Item Weight	250 g

REHAND Walking Cane (44.68$) :

Figure 3: REHAND Walking Cane

Table 8: REHAND details

Brand	rehand
Material	Aluminum, Rubber
Colour	Original Black
Shaft material	Aluminum
Item Weight	520 g

The adjusting range of walking stick itself is from 2'7" (78cm) to 3'2" (96cm), constructed with durable & lightweight aluminum frame, can be fitted into a briefcase, wheelchair bag, or even purse, all terrain pivoting & slip-resistant base

Kuiper foldable crutches (30.45$)

Figure 4: Kuiper foldable crutches

Table 9: Kuiper details

Material	Aluminum alloy
Weight	0.47 kg

Table 10: Benchmarking

Selection Criteria	Weight	Comfkey	REHAND	Kuiper
Weight	0.1	5	2	3
Supported weight	0.05	2	4	5
Time to extension / contraction	0.15	3	3	4
Stability with one hand	0.2	3	4	5
Stored size	0.1	5	2	1
Aesthetics	0.1	3	4	2
Cane length	0.1	4	5	5
Number of segments	0.05	4	2	2
Price	0.15	5	4	5
Total Score	1	34	30	32

According to the benchmark score, the Comfkey cane is the best amongst its competitors. However, its alternatives tend to obtain similar scores. Additional benchmarking would be ideal with other concepts.

3.4 Target Specifications

Table 11: Marginal and ideal target values

Selection Criteria	Units	Margin Value	Ideal Value
Weight	kg	<0.750	<0.300
Supported weight	kg	>60	100
Time to extension / contraction	s	<15	5
Stability with one hand	1 to 10 scale	>6	10
Stored size	cm3		
Aesthetics	1 to 10 scale	>6	10
Cane length	m	60-115	85
Number of segments		2 to 4	3 to 5
Price	$	30-80	70

Weight (<0.300 kg): Lightweight ensures portability

Supported weight (100 kg): Meets safety standards for a wide range of users.

Time to extension/contraction (5 s): Quick operation reflects user expectations for convenience.

Stored size (cm^3): Necessary for ease of transport.

Cane length (60-115 cm, 85 cm): Versatile length accommodates a variety of user heights.

Number of segments (2-4, 3-5): Balances portability with structural integrity observed in competing products.

Price ($30-80, 70): Affordable but competitive among mid-to-high-end market options. Fits into the project budget

4. Concept development

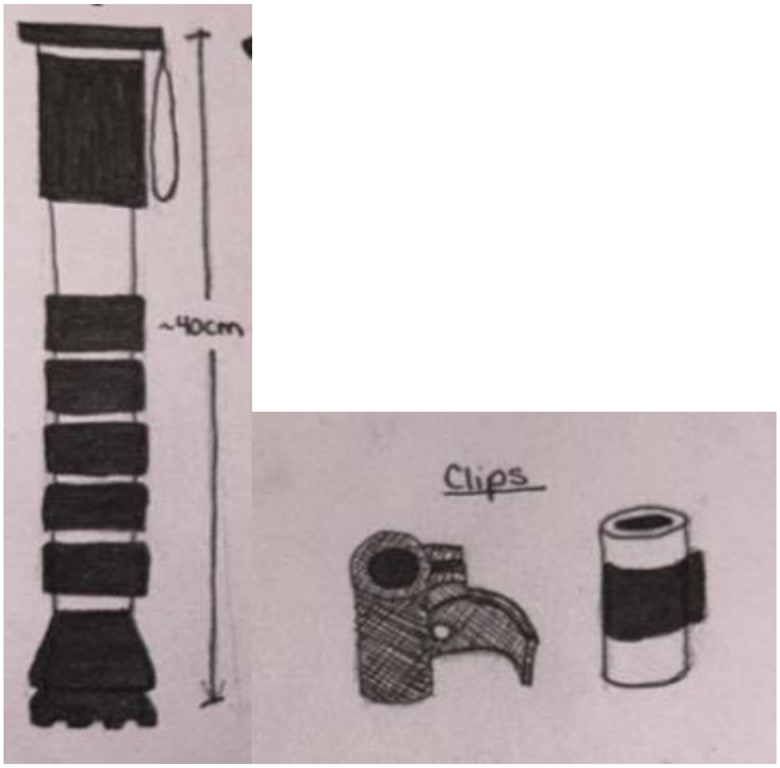
4.2: Comparing Prototypes

The group members sketched various ideas for each subsystem; the pole, handle, and tip. Each concept was evaluated against the target criteria and ranked on a scale from 1-3 based on how well it met each specification. The rankings were then multiplied by the corresponding weights of importance, and the total scores were used to determine the most promising concepts.

Pole

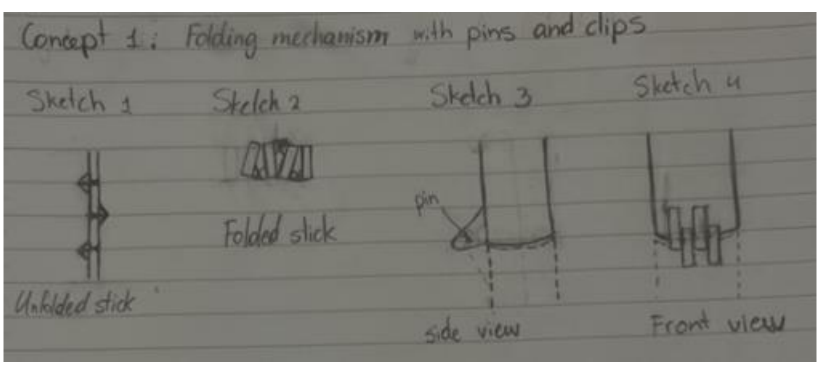
Design 1: Telescopic with clips

Figure 5-6: Telescopic pole with clips



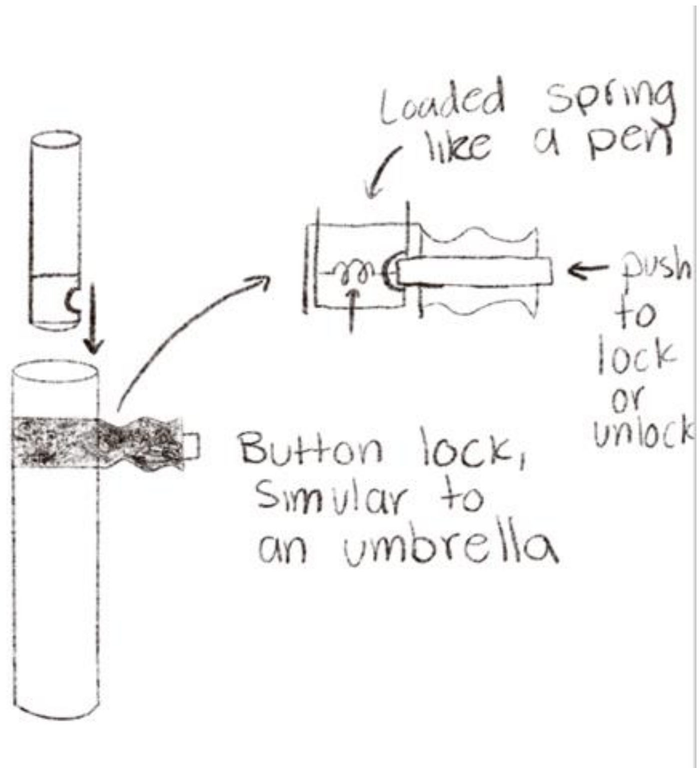
Design 2: Folding

Figure 7: Folding pole



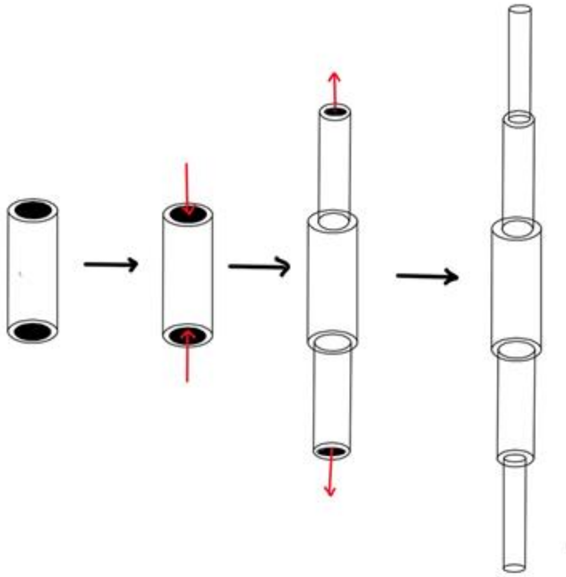
Design 3: Telescopic with button

Figure 8: Telescopic Pole with Buttons



Design 4: Push-Push Mechanism

Figure 9-10: Push-Push Pole



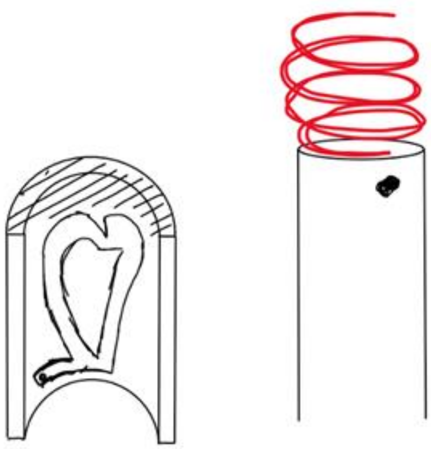


Table 12: Comparison of Pole designs

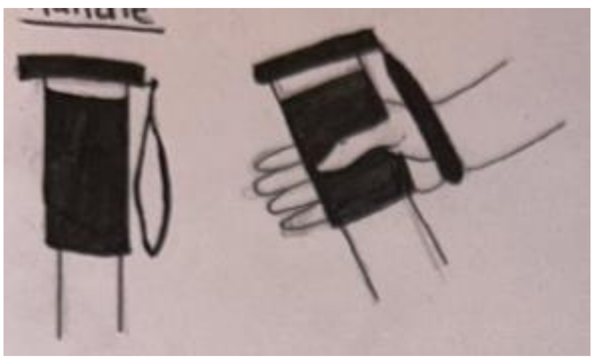
Selection Criteria	Weight	Design 1	Design 2	Design 3	Design 4
Weight	.1	3	2	3	2
Supported weight	.05	3	1	2	3
Time to extension / contraction	.15	2	1	3	3
Stability with one hand	.2	3	3	3	2

Stored size	.1	3	2	1	1
Asthetics	.1	3	1	3	2
Cane length	.1	3	3	3	2
Number of segments	.05	1	2	3	1
Price	.15	3	2	2	3
Total Score		2.75	2.0	2.6	2.65

Handle

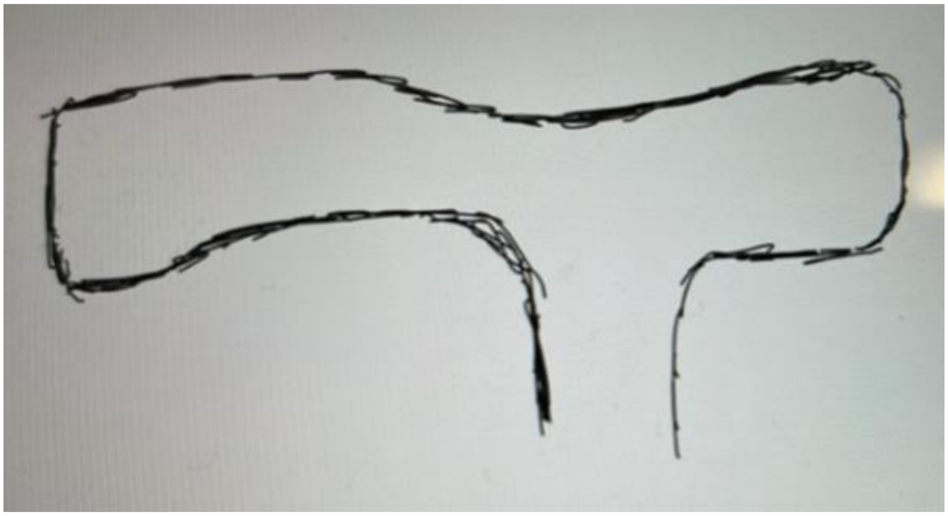
Design 1: Ergonomic Grip

Figure 11: Ergonomic Grip



Design 2: opera/crutch grip

Figure 12: Opera/crutch Grip



Design 3: Forearm Walker Grip

Figure 13: Forearm Walker Grip

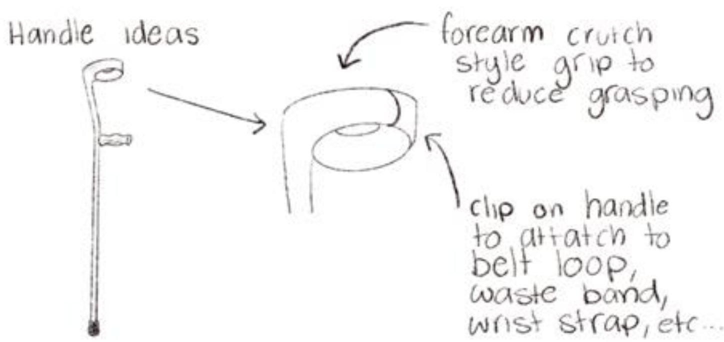


Table 13: Comparison of Handle Designs

Selection Criteria	Weight	Design 1	Design 2	Design 3
Weight	.1	3	2	1
Supported weight	.05	2	3	
Time to extension / contraction	.15	3	3	3
Stability with one hand	.2	3	2	2
Stored size	.1	3	2	1
Asthetics	.1	3	2	1
Cane length	.1	3	3	3
Number of segments	.05	3	3	3
Price	.15	3	2	1

Total Score		2.95	2.35	1.85

Tip

Design 1: Tip with Grip

Figure 14: Tip with Grip

Design 2:

Figure 15: Round Tip

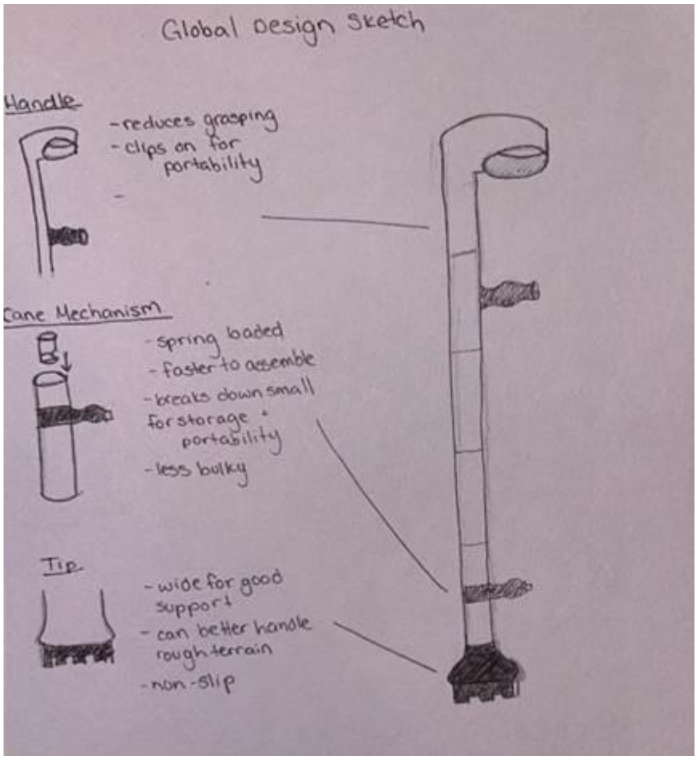
Table 14: Comparison of Tip Designs

Selection Criteria	Weight	Design 1	Design 2
Weight	.1	3	3
Supported weight	.05	3	3
Time to extension / contraction	.15	3	3
Stability with one hand	.2	3	3
Stored size	.1	3	3
Esthetics	.1	3	3
Cane length	.1	3	3
Number of segments	.05	3	3
Price	.15	3	3
Total Score		=	=

Note: The tip doesn't affect the functionality of the cane based on the specifications. It is up to the client's preference and the terrain of where the cane is in use.

3.5: Global Design Sketch

Figure 16: Global Design Sketch



3.6 How the concepts relate to target specifications

The chosen design is a telescopic mechanism with clip locks, ensuring that the cane is lightweight, compact, and easy to use. The telescopic design allows for quick and secure length adjustments, meeting the target specification of 60–115 cm. The clip locks ensure stability by securely locking the segments in place, enabling the cane to support weights between 60 and 100 kg. The time to extension or contraction is optimized to be under 5 seconds, offering efficiency for users.

The design also meets the target weight specification by using lightweight materials and keeping the cane's weight under 0.750 kg. The telescopic mechanism also ensures a compact stored size, enhancing portability.

Benefits:

The clip-lock mechanism provides an intuitive and reliable way to adjust the cane's length with one hand.

Lightweight materials ensure the cane is easy to carry without compromising strength.

The cane's compact size when folded makes it highly portable.

The quick adjustment system ensures user convenience.

Clips are robust and prevent unintended retraction.

Drawbacks:

The clip locks may wear out with prolonged use, requiring occasional maintenance.

Some users with limited hand strength may find the locking mechanism challenging.

More moving parts can slightly increase manufacturing complexity.

3.7 How the concepts relate to the DFX

The telescopic cane with clip locks meets the DFX factors identified in Deliverable B in the foll wing ways:

Design for Safety:
The cane can hold up to 100 kg with a safety factor of 1.5, which makes it reliable for users. The tip is made of non-slip rubber to prevent slipping, and all edges are rounded to avoid any chance of injury.

Design for Manufacturing:
To make the cane easy and affordable to produce, off-the-shelf components and lightweight materials like aluminum will be used. The design is simple enough to keep the manufacturing cost under $75 and only needs three steps to assemble.

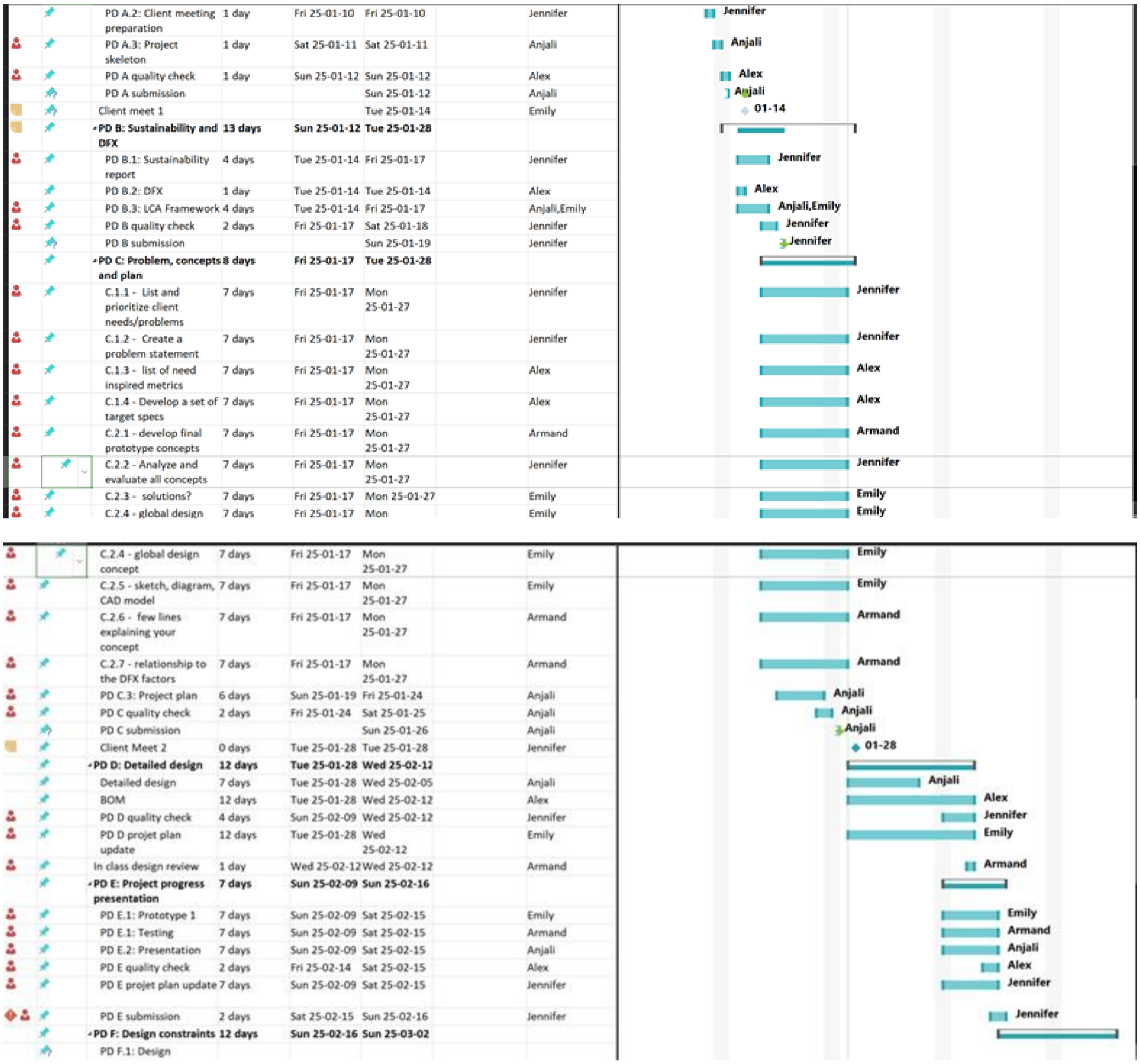
Design for Usability and Portability:
The cane is super lightweight (less than 0.8 kg) and folds down to about 30% of its full size, making it easy to carry around or store. The ergonomic handle makes it comfortable for long-term use, and the clip-lock system makes adjusting and folding quick and simple.

Design for Speed:
To stick to the project deadline, the focus will be on on rapid prototyping with 3D printing. Multiple parts will be worked on at the same time to speed up the design process and get everything ready for the design day.

Design for Reliability:
Durable materials like aluminum will be used to make sure the cane lasts at least 5 years and can handle over 1,0000 uses without breaking. It will also be testedunder real-world conditions to make sure it’s reliable

Project Plan

Figure 17: Project Plan



Task Name	Duration	Start	Finish	Resource Names
PD A.2: Client meeting preparation	1 day	Fri 25-01-10	Fri 25-01-10	Jennifer
PD A.3: Project skeleton	1 day	Sat 25-01-11	Sat 25-01-11	Anjali
PD A quality check	1 day	Sun 25-01-12	Sun 25-01-12	Alex
PD A submission			Sun 25-01-12	Anjali
Client meet 1			Tue 25-01-14	Emily
PD B: Sustainability and DFX	**13 days**	**Sun 25-01-12**	**Tue 25-01-28**	
PD B.1: Sustainability report	4 days	Tue 25-01-14	Fri 25-01-17	Jennifer
PD B.2: DFX	1 day	Tue 25-01-14	Tue 25-01-14	Alex
PD B.3: LCA Framework	4 days	Tue 25-01-14	Fri 25-01-17	Anjali,Emily
PD B quality check	2 days	Fri 25-01-17	Sat 25-01-18	Jennifer
PD B submission			Sun 25-01-19	Jennifer
PD C: Problem, concepts and plan	**8 days**	**Fri 25-01-17**	**Tue 25-01-28**	
C.1.1 - List and prioritize client needs/problems	7 days	Fri 25-01-17	Mon 25-01-27	Jennifer
C.1.2 - Create a problem statement	7 days	Fri 25-01-17	Mon 25-01-27	Jennifer
C.1.3 - list of need inspired metrics	7 days	Fri 25-01-17	Mon 25-01-27	Alex
C.1.4 - Develop a set of target specs	7 days	Fri 25-01-17	Mon 25-01-27	Alex
C.2.1 - develop final prototype concepts	7 days	Fri 25-01-17	Mon 25-01-27	Armand
C.2.2 - Analyze and evaluate all concepts	7 days	Fri 25-01-17	Mon 25-01-27	Jennifer
C.2.3 - solutions?	7 days	Fri 25-01-17	Mon 25-01-27	Emily
C.2.4 - global design concept	7 days	Fri 25-01-17	Mon 25-01-27	Emily
C.2.5 - sketch, diagram, CAD model	7 days	Fri 25-01-17	Mon 25-01-27	Emily
C.2.6 - few lines explaining your concept	7 days	Fri 25-01-17	Mon 25-01-27	Armand
C.2.7 - relationship to the DFX factors	7 days	Fri 25-01-17	Mon 25-01-27	Armand
PD C.3: Project plan	6 days	Sun 25-01-19	Fri 25-01-24	Anjali
PD C quality check	2 days	Fri 25-01-24	Sat 25-01-25	Anjali
PD C submission			Sun 25-01-26	Anjali
Client Meet 2	0 days	Tue 25-01-28	Tue 25-01-28	Jennifer
PD D: Detailed design	**12 days**	**Tue 25-01-28**	**Wed 25-02-12**	
Detailed design	7 days	Tue 25-01-28	Wed 25-02-05	Anjali
BOM	12 days	Tue 25-01-28	Wed 25-02-12	Alex
PD D quality check	4 days	Sun 25-02-09	Wed 25-02-12	Jennifer
PD D projet plan update	12 days	Tue 25-01-28	Wed 25-02-12	Emily
In class design review	1 day	Wed 25-02-12	Wed 25-02-12	Armand
PD E: Project progress presentation	**7 days**	**Sun 25-02-09**	**Sun 25-02-16**	
PD E.1: Prototype 1	7 days	Sun 25-02-09	Sat 25-02-15	Emily
PD E.1: Testing	7 days	Sun 25-02-09	Sat 25-02-15	Armand
PD E.2: Presentation	7 days	Sun 25-02-09	Sat 25-02-15	Anjali
PD E quality check	2 days	Fri 25-02-14	Sat 25-02-15	Alex
PD E projet plan update	7 days	Sun 25-02-09	Sat 25-02-15	Jennifer
PD E submission	2 days	Sat 25-02-15	Sun 25-02-16	Jennifer
PD F: Design constraints	**12 days**	**Sun 25-02-16**	**Sun 25-03-02**	
PD F.1: Design				

Conclusions

The design process for the one-handed, foldable cane has highlighted several key challenges in creating a practical mobility aid. Through analysis of the client meeting notes, it has become clear that the most important needs are usability and portability. While significant progress has been made in developing design specifications and analyzing possible solutions, there is a lot more brainstorming and client input needed. It will be essential to continue testing the design based on client feedback to address any concerns regarding real-world use. The implication of this project extends beyond the design solution, as the process offers valuable insights into user-centered design processes and the importance of incorporating accessibility features into everyday products.

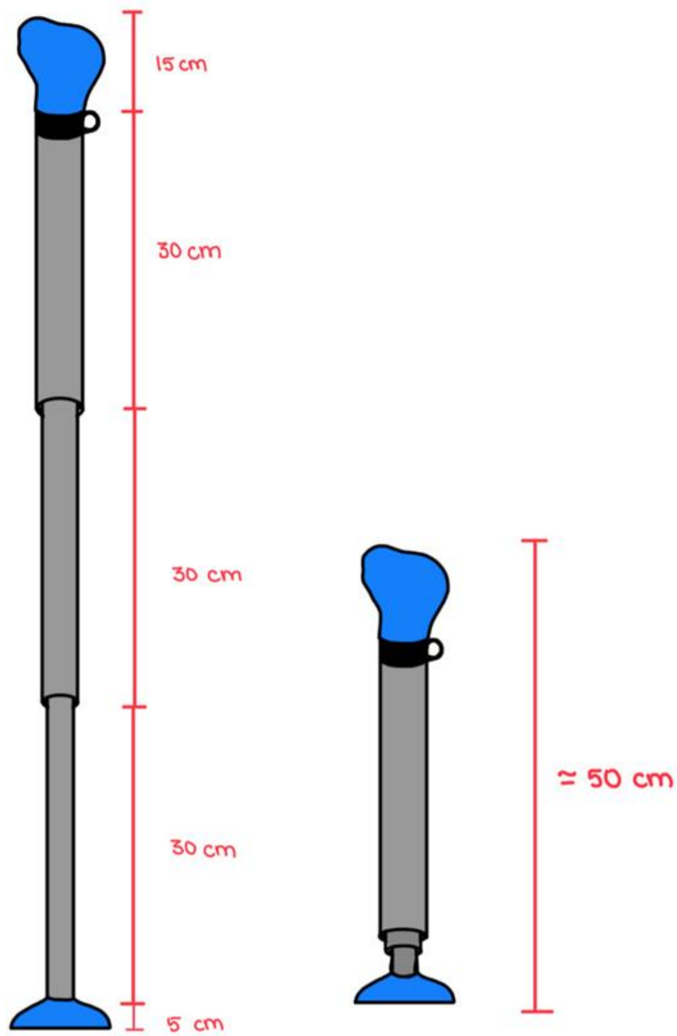
Deliverable D:

1. Introduction
2. Client Feedback

Upon presenting the gathered needs and problem definition to the client, she expressed that the information gathered accurately reflected what she needed and desired from the product. She also expressed that her dominant side was the left, and she wanted to avoid putting excessive weight on this dominant side, so the cane must be adjusted to reflect these needs. The preliminary concept sketches were presented as well, and the client expressed concern with a folding mechanism. She stated that it might not be adequately efficient, since she needs to be able to disassemble the cane in the few moments it takes for the bus to pull over at a stop. Upon reviewing a telescopic cane with clips, the client expressed contentment with the possible design, and shared that she uses her thigh to shorten an umbrella, so a similar strategy could be used for the cane. One drawback of telescopic canes, however, is the possibility of it being too heavy when compact, and since the size of the sections must increase to hold the one above it, the weight would also increase. Another concern noted with the telescopic approach was that the clips or buttons needed to keep the cane open might be challenging to work with. The client would need to let go of the cane to unfasten the clips, or push the buttons, which can lead to instability and awkwardness. Overall, the client liked the idea of a telescopic mechanism that would allow her to use her thigh to close it, but with a fast-compacting mechanism that did not require her to let go of the cane.

Using these design constraints, the preliminary sketches can be modified and combined to form a first prototype that could meet all the client's needs. For the handle, one that resembles the handle of a walking stick or ski pole would best suit the client's needs, and an adjustable strap can be added for additional security and comfort. As for the body of the cane, a telescopic approach to assembly and disassembly would be best, as per the client's feedback, but a method to keep the pole extended without the use of clips or buttons must be found. One option is cutting out grooves on the inside of the cane, then using spring-loaded clips to keep it in place. This way, when the button is pushed to activate the spring mechanism, the inner portion slides out of the grooves, allowing for the cane to be opened or shut. Once the button is released, the mechanism slides back into place, locking the cane as-is.

3\.
Detailed Design


15 cm
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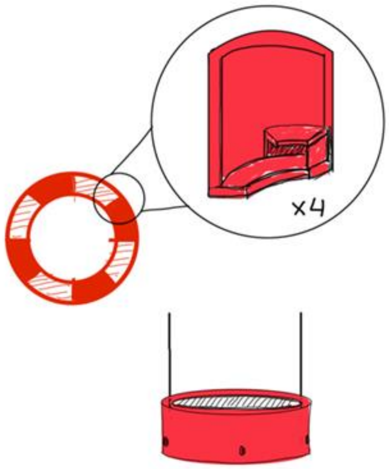
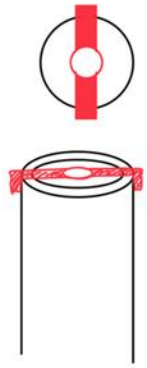
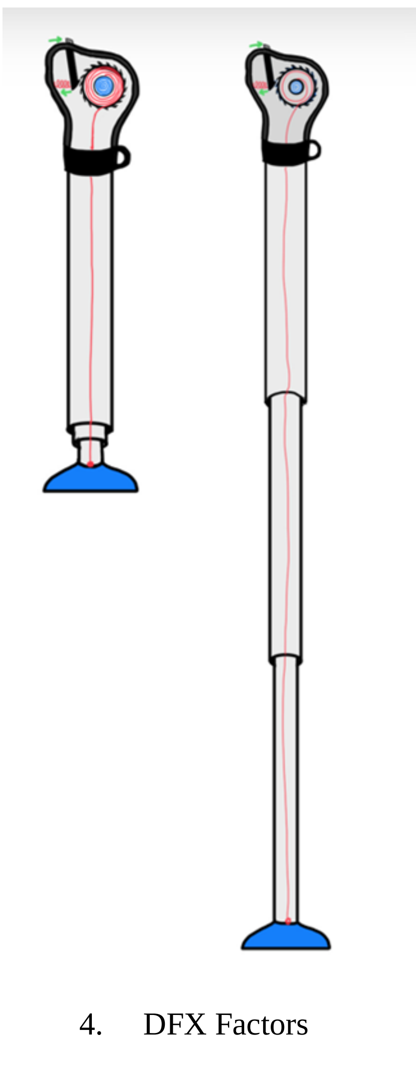
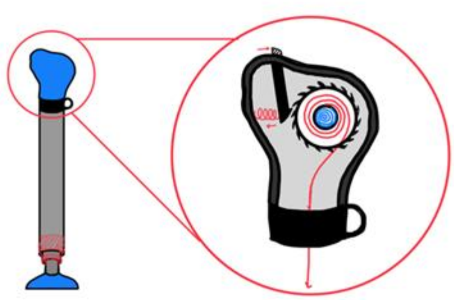
5 cm
≃ 50 cm









4. DFX Factors

To ensure the success of the foldable cane, the design must address several kay DFX factors to ensure safety, usability, manufacturability, speed, and reliability.

Design for Safety

Safety is crucial for any mobility aid, and the cane must provide reliable support under various conditions. It must support dynamic loading forces and be structurally stable to prevent collapses that would result in injury. The cane must support a minimum load of 100kg with a safety factor of 1.5. To achieve this, the locking mechanism for the telescopic extensions must be engineered to lock firmly in place to prevent retraction during use. Materials must be selected for their strength and durability. The primary material choice for the pole is aluminum because it's strong, lightweight, and easy to machine. Additionally, the cane tip will be designed with a non-slip shape and material such as rubber.

Design Usability (and Portability as a sub aspect)

Usability and portability are the core focuses of this design. As the cane must be easy to use, carry and stored for people with mobility impairments. It must be lightweight, with a target wight of less than 0.8kg. Additionally, the cane should be easy to fold and store, reducing its length to less than 30% of its extended size when collapsed. The design will incorporate a telescopic pole with a secure locking mechanism that uses a single button to open and close the cane quickly. Ideally, gravity will do most of the work to extend and collapse the cane once the button is pushed by the user. The handle will be ergonomically designed for comfortable use over long periods, with a wide knob-like shape and a wrist strap for added security. The compactness of the cane when folded will also be a priority as portability is a key factor. A likely solution to the portability is a fanny-pack type storage bag to store the cane when not in use.

Design for Manufacturability

The design must be manufacturable within the constraints of the university's makerspace, which includes access to manufacturing resources. This requires a careful selection of materials and designs that can be produced using the available tools such as woodworking tools, 3D printers, CAD software (SolidWorks), laser cutters, mills, and lathes. The manufacturing cost for one cane must be under 100$ CAD. The design will incorporate off-the-shelf materials for parts like the locking mechanism and handle to reduce complexity and cost. Where custom parts are needed, they will be designed using automated processes like 3D printing for manufacturing simplicity. Using the recycled, free, materials provided by MakerSpace will also reduce costs. This approach helps to minimize production time and cost.

Design for Speed

To meet project deadlines, the design process must prioritize rapid prototyping and iteration. The ideation process will be completed by week 5, to move onto prototyping using 3D printing. Multiple components will be designed and prototypes simultaneously to minimize the time needed for refining the design. This plan will make sure that any design flaws can be revised early, guaranteeing enough time to manufacture the final product. The final prototype must be ready by the design day in week 11.

Design for Reliability

Reliability is needed to ensure that the cane performs consistently over its intended lifespan. The cane should withstand at least 10,000 cycles of extension and retraction, as well as daily use for a minimum of five years. To achieve this, durable materials like aluminum will be used for the pole as it is resistant agans wear and tear. The locking mechanism and handle will be tested rigorously, ensuring they remain functional with frequent use. Environmental rests will be conducted to simulate real-work conditions, such as exposure to moisture, temperature fluctuations, and physics stress. In addition, real-world loading tests will be performed to guarantee the cane can support the maximum weight capacity.

5. Resources and Skills

The development and manufacturing of the telescopic foldable cane will require a combination of technical and hands-on skills, as well as access to resources within the university MakerSpace.

Skills available within the Team

Computer-Aided Design (CAD): Proficiency in a CAD software such as SolidWorks is very helpful in the prototyping phase. The ability to take brainstorming sketches to a 3D model is necessary to create a concrete design.

Mechanical Design and Analysis: Knowledge of mechanical principles, including load distribution, stress analysis, and material selection, ensures that the cane is structurally strong and meets the safety requirements.

Following an Engineering Design Process: All team members have completed GNG1103 which provided insightful experience of working with a design team. Since everyone is familiar with following an engineering design process, the project should run smoother.

Machining use: The CEED certifications and training gained from hands-on experience with milling, lathes, and manual machining are essential for manufacturing this product.

Materials processing and assembly: Understanding the properties of metals and polymers will ensure that all the components are properly manufactured and assembled.

Testing: The team has experience in conducting mechanical and environmental tests, such as load testing, to verify that the final product meets the required standards.

Resources available

3D Printers: 3D printers are helpful when designing small and unique shaped components which could be helpful in manufacturing components of the cane locking mechanism or a custom ergonomic handle grip.

Laser Cutters: Laster cutters provide high precision cutting and engraving components of various materials.

Welding and Metalworking Tools: Metalworking tools are needed for joining or reinforcing metal parts, improviing the structural integrity of the cane.

Hand Tools: Hand tools such as drills, saws, files, and clamps are helpful for assembly and fine adjustments.

Lathes and Mills: Lathes and Mills provide precise machining, especially for cylindrical components. This will be necessary when manufacturing the pole sections and locking mechanism of the cane.

Skills missing from the Team

Missing CEED training: The Manufacturing Training Center (MTC) allows the team members to develop skills with helpful manufacturing resources such as welding, fabrication, and hand tools. As the team moves into the manufacturing stages of the design, any missing CEED training will be required.

6. Time Required

To complete our one-hand folding cane project efficiently, we have estimated the time required for each key task based on workload, team availability, and potential risks. The breakdown is as follows:

Estimated Time for Key Tasks

Detailed Design and CAD Modeling: 10–20 hours

Material Sourcing and Purchasing: 7–15 hours

Prototype Manufacturing (3D Printing, Machining, Assembly): 40–70 hours

Testing and Iteration (Load Testing, Usability, Environmental Conditions): 20–30 hours

Final Adjustments and Optimization: 10–25 hours

Final Presentation and Design Day Preparation: 10–20 hours

Total Estimated Workload: 97–180 hours

Available Team Hours Per Week

Each team member has approximately 3–6 hours per week available.

Minimum total hours per week (5 members × 3 hours) = 15 hours/week

Maximum total hours per week (5 members × 6 hours) = 30 hours/week

Total Available Team Hours Over 6 Weeks

Minimum: 15 hours/week × 6 weeks = 90 total hours

Maximum: 30 hours/week × 6 weeks = 180 total hours

Feasibility Assessment

Our total estimated workload ranges from 97 to 180 hours, meaning that if every team member contributes only 3 hours per week (90 hours total), we may not have enough time to complete everything efficiently.

If every team member contributes closer to 6 hours per week, we can reach 180 hours, which aligns with our upper workload estimate.

Some tasks can be completed in parallel to maximize efficiency (sourcing materials while finalizing CAD, testing while refining the design).

Potential risks include:

Delays in material availability or tool access at the MakerSpace.

Extended testing iterations if the first prototype has issues.

Time-consuming assembly or troubleshooting unexpected design flaws.

By maintaining efficient task management and time tracking, we believe the project can be completed within the given timeframe while meeting all required deliverables.

7. Product Assumptions

Several key assumptions influence our ability to successfully design, manufacture, and test the cane. If any of these assumptions are incorrect, we may need to adjust our approach.

1. Material and Component Availability

Aluminum tubing, rubber grips, and fasteners will be readily available within our budget.

The MakerSpace will provide access to necessary 3D printing, machining, and assembly tools.

2. Functionality and User Experience

The telescopic locking mechanism will function smoothly with one hand and remain secure over time.

The cane must support at least 100 kg while remaining lightweight (<0.8 kg).

The folding mechanism must work reliably over 10,000 cycles of use.

3. Manufacturing Constraints

The total manufacturing cost must not exceed $100, requiring us to optimize material selection.

3D-printed components must be durable enough for functional testing without breaking under stress.

4. Testing and Validation

We assume we will have enough time to conduct load testing, usability tests, and environmental exposure assessments (temperature).

User feedback will be reliable in determining the final design adjustments.

5. Project Timeline Feasibility

Weekly progress meetings will ensure the team stays on schedule and prevent major delays.

The final product must be completed before Design Day, so all major modifications should be finalized in advance.

By monitoring these assumptions and remaining adaptable, we can ensure the smooth execution of our project while staying within our time and resource limits

Deliverable F:

Design Constraints

3.1 Identify your two most important non-functional design constraints (DFX factors) that play an important role in the development of your prototypes. Justify your reasoning

One of the most important non-functional design constraints is usability/portability. The cane is intended for a user with mobility impairments that requires a lightweight, one-handed, and easy-to-use device. The user needs a cane that can be quickly deployed and stored, especially when using public transit, requiring a one-handing compacting mechanism. It's essential that the cane is portable and stores into a small and easy to carry from. If the design does not meet usability criteria, it won't be effective for its target users.

Another important design constraint is safety. Since the cane is a mobility aid, it must provide secure and reliable support. Ensuring a non-slip tip, sturdy structure, and stable locking mechanism is essential for preventing falls and injuries. The cane must be structurally sound and support at least 100kg with a safety factor of 1.5 to ensure no risk of failure. If the safety aspects are not properly addressed, the cane may fail under normal use conditions, putting the user at risk.

3.2 For each design constraint, explain in detail what changes would need to be made to your design to satisfy the constraint (if any) or what already exists in the design to respect the constraint.

To ensure usability and portability, several design elements have already been implemented, and additional modifications can further improve performance. The current design features a telescopic pole with a twist-to-lock. The twist locking mechanism enables quick and one-handed folding/unfolding. Additionally, a wide handle with wrist strap ensures a comfortable grip and secure handling over extended use. The wrist strap also provides a way to easily carry the cane whether it's extended or retracted. The 6063 Aluminum and ABS plastic is used to make the cane lightweight for ease of carrying, while its ability to fold down to 30% of its full length makes it convenient to store. Lastly, using a spring-loaded system enhances the ease of use when retracting the cane. However, some improvements can be made such as introducing a quick0access storage pouch would improve portability, ensuring that users can easily carry the cane when not in use.

For safety, the current design supports a maximum load of 100kg with a 1.5 safety factor, ensuring structural integrity. The non-slip rubber tip prevents slipping on various surfaces. The materials of the cane have been chosen to make the cane durable overtime and will be tested for extended use. Testing different rubber compounds and adding micro-textures to the tip can also enhance grip and longevity. Incorporating a shock-absorbing insert in the cane would minimize the vibrations from ground contact, making the cane more comfortable for extended use. Absorbing the impact forces would reduce the strain on the user making it safer for people with joint pain or reduced grip strength. Lastly, adding visibility features like a reflective strip, or small LED lights can increase user safety in low-light conditions. These improvements will ensure the cane remains safe and user friendly in all intended use cases.

3.3 Provide proof (e.g. analysis, simple calculations and/or simulations, research) to demonstrate the effectiveness of your design in satisfying the constraints. Justify the process and methods you used

To validate that the design meets these constraints, several tests should be performed. The following tables outline the testing that will be done on a prototype of the pole mechanism.

Table 1: Type of Testing

Test Number , Reason for Prototype , Evaluation , Level of Prototype

, Communication, Performance
Measurement, Risk
Management,
Learning/Understanding , What are you testing with
your concept (target
measurable attributes)? , HiFi/LoFi Focused, HiFi/LoFi
Comprehensive

1 , Risk Managment , Load bearing capabilities of Cane Pole , HiFi Focused

2 , Performance , Durability of opening/closing mechanism , HiFi Focused

Table 2: Testing Metrics

Kind of Prototype , Metrics , Test Description

Visual, Analytical,
Physical , What metrics will you test?
, What specifically will you test

Physical , The maximum weight the cane can hold , That the joints can sustain weight and repeated use to ensure the cane doesn't collapse.

Physical , The durability and performance of the opening/closing mechanism , Making sure the product doesn't break/deterirorate over repeated use and continues to work smoothly

Table 3: testing Analysis

Analysis Method , Results , Interpretation , Notes

Specifically how will you test,
include things like duration,
sequence of test, equipment, etc , Observe and record
results , Pass or fail (include
reason) , 1. Include location of
sketch, software
libraries, reference
materials, etc.
2. Take notes on how
you can improve
your next prototype
3. Other important
things to remember

Stress test the prototype by adding more and more weight to the cane, until it breaks or surpasses the maximum load of 100kg + a 1.5 safety factor. , Record the weight that breaks the cane , Pass: it doesn't break before it reaches the needed weight capacity + safety factor Fail: It breaks before reaching the required load , Sketch location: Solid Works Test Location: MakerSpace Adding the handle to more closely mimic the final product for more thorough testing.

Stress test the prototype by rapidly opening/closing the cane. Repeat 500 times or until the mechanism deteriorates (gets harder to open/close, gets stuck/jammed, gets weaker) , Record how the experience of opening/closing the cane changes overtime. , Pass: The opening/closing remains smooth after 500 consecutive trails. Fail: The structural integrity of the cane weakens during the stress tests. , Sketch location: Solid Works Test Location: MakerSpace Adding the handle and tip to more closely mimic the opening/closing motions for more thorough testing.

The first test ensures that the cane is safe while the second test validates the usability. To further prove that the design is safe, detailed calculations have been performed to ensure that the selected materials can safely withstand the applied load. Additionally, an analysis was conducted to determine the minimum required lip width for the telescopic sections, to make sure the locking mechanism securely holds the cane in place during use. These calculations provide essential proof that the design meets the safety constraints.

Figure 1-2: Safety Calculations

Prototype 2

4.1 Summarize any new client feedback that you have received or any new testing results and clearly state what needs to be changed or improved in your design. Update your detailed design accordingly.

Key Client Feedback & Required Changes

✓ Folding Efficiency: Concerned about the time required to collapse each section. Prefers an internal locking mechanism over visible clips.

✓ Thigh-Activated Folding: Likes using her thigh to shorten the cane. Prefers a fast, one-button compacting system.

✓ Locking System Customization: Wants adjustable locking points for custom height settings.

✓ Weight Concern: Telescopic sections may become too heavy. Prefers lightweight materials like carbon fiber over aluminum.

✓Handle & Strap Preferences: Prefers a thicker ergonomic grip and a ski-style wrist strap for better control.

Required Design Improvements:

Modify the locking mechanism to ensure it can be released without fully letting go of the cane. Consider a spring-loaded push-button or groove-based system instead of manual clips.

Optimize material choices to reduce weight while maintaining strength (aluminum or carbon fiber for segments).

Redesign the handle to improve ergonomics and add a wrist strap for better grip security.

Adjust segment proportions to balance weight distribution, preventing the cane from becoming too top-heavy.

4.2 Define the most critical product assumptions that you have not yet tested. Explain which of your DFX factors from Project Deliverable B this assumption(s) relates to.

As we move forward with refining our one-hand folding cane, we have identified three critical assumptions that require validation through testing. These assumptions directly impact the usability, safety, and overall performance of the product. Each assumption is linked to key Design for X (DFX) principles outlined in Project Deliverable B to ensure our design meets the intended functional, structural, and ergonomic requirements.

Assumption 1: The Modified Locking Mechanism Will Function Efficiently with One Hand

One of the most important aspects of the cane's design is ensuring that the user can collapse and extend the cane using only one hand. The locking mechanism should be fast, secure, and easy to engage/disengage without requiring excessive force or complex actions. The client has expressed a preference for using their thigh as leverage while collapsing the cane, which means the mechanism must function reliably in this context.

Challenges & Uncertainties:

Force Required – Will the user be able to unlock the cane with minimal effort?

Locking Speed – Can the mechanism be operated within a few seconds?

Stability – Will the cane remain stable while being collapsed without causing imbalance?

Reliability Over Time – Will the locking system hold up after repeated use without becoming loose or ineffective?

Impact on Design:

The locking mechanism's placement and actuation method must be optimized to allow quick and intuitive operation.

If the current design is too stiff or requires two hands, we may need to redesign the mechanism

Related DFX Factor: Design for Usability – The mechanism should be intuitive and effortless to use, allowing individuals with limited dexterity to operate the cane smoothly.

Assumption 2: The Cane Will Maintain Structural Stability While Remaining Lightweight

Description:
The cane must be strong enough to support at least 100 kg of user weight while also being lightweight enough for easy carrying and handling. A balance must be struck between structural integrity and weight reduction to meet both safety and portability requirements.

Challenges & Uncertainties:

Material Selection – Will aluminum or carbon fiber tubing provide sufficient strength while keeping the total weight under 0.8 kg?

Joint and Connection Strength – Will the telescopic joints and locking system withstand repeated stress without becoming weak?

Impact of Tube Thickness – How thin can we make the tubes while maintaining load-bearing capacity?

Effect of Repeated Use – Will the cane remain structurally sound after prolonged use (e.g., after 10,000 extension/contraction cycles)?

Impact on Design:

If aluminum tubing is too heavy, we may consider switching to carbon fiber or a hybrid design to reduce weight.

Finite Element Analysis will be required to simulate stress distribution in different parts of the cane.

Load testing will help determine whether telescopic joints or connectors need reinforcement to prevent failure under weight.

Related DFX Factor: Design for Safety – Ensuring that the cane remains structurally stableunder load and does not bend, break, or fail unexpectedly.

Assumption 3: The Adjusted Handle Design Will Improve Comfort and Security

Description:
The handle and wrist strap play a crucial role in ensuring that the cane is comfortable and secure to use for extended periods. Since the client relies on a single hand to operate the cane, the grip should be ergonomic, reducing strain on the hand and wrist. Additionally, the wrist strap should prevent accidental drops and allow for easy retrieval.

Challenges & Uncertainties:

Grip Comfort – Will the handle shape minimize hand fatigue during prolonged use?

Wrist Strap Effectiveness – Will the wrist strap provide sufficient security without limiting mobility?

Handle Material – Does the handle material offer a non-slip surface while remaining comfortable to hold?

Size and Weight Distribution – Is the handle proportional to the overall cane design, or does it make the cane feel unbalanced?

Impact on Design:

The handle should be shaped to reduce pressure points and improve grip stability.

A rubberized or foam-coated grip may be needed for better comfort and non-slip performance.

The wrist strap length and attachment should be tested to ensure that it does not interfere with normal use.

Related DFX Factor: Design for Usability – Ensuring that users experience comfort and security while using the cane for extended periods.

4.3 Define the tests that you must perform to assess the assumption(s).

Test 1: Usability Test for Locking Mechanism

Objective: Ensure that the locking system can be operated with one hand and collapsed quickly.
Procedure:

Have users extend and collapse the cane five times using only one hand.

Measure the time required and force needed to operate the mechanism.

Gather feedback on ease of use and comfort.

Success Criteria: The mechanism should allow full operation within 5 seconds, with an ease-of-use rating of at least 8/10.

Test 2: Load-Bearing and Weight Test

Objective: Ensure that the cane supports 100 kg while staying under 0.8 kg.
Procedure:

Weigh the fully assembled cane.

Apply a gradual vertical load up to 100 kg and observe any bending or deformation.

Success Criteria: No structural failure or noticeable bending should occur under 100 kg of force.

Test 3: Ergonomics and Comfort Assessment

Objective: Validate the handle design and wrist strap comfort over prolonged use.
Procedure:

Have users hold and walk with the cane for at least 30 minutes.

Ask for feedback on grip comfort, wrist strap security, and overall feel.

Success Criteria: At least 80% of users should report comfort with the handle and strap after extended use.

The mechanism works by using the slots as guides to prevent the rods from twisting upon retraction and extension. The locking mechanism works by twisting the block piece into the horizontal slot, which prevents the rod from retracting and allows the user to place force on the rod without fear.

4.6 Carry out prototype testing, analyze and evaluate performance compared to the updated target specifications first developed in Project Deliverable C and document all your testing results and prototype specifications. Present your testing in an organized, tabular format that shows expected versus actual results (i.e. compare your measured prototype specifications to your target specifications by including both in a similar table to the one your developed for Project Deliverable C).

Since we are using 3D-printed PLA pieces tpo replicate aluminum, the equivalent force that it is able to withstand is much lower, therefore using the aluminum cross-sectional area of 223.7 mm^2 and a maximum force of 100N, it can be calculated with yield strength and force that the PLA equivalent force is 36.5 N.

Gym weights equivalent of 1kg (10N) were placed on the extended locked mechanism. The table below shows the pass/fail chart.

Equivalent Force on Aluminum , Force on PLA , Pass/Fail

26.9N , 10N , Passed

54.8N , 20N , Passed

82.2N , 30N , Passed

109.6 , 40N , -NA-

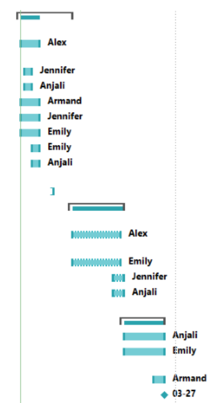
4.7 Outline what your team intends to present to your client(s) and what information you would like to gather at your next client meeting

At the next client meeting, the team will be presenting a second prototype of the product, along with plans for future prototyping and building a finalized product, The client will be able to see part of the design process that led to the prototype being designed and manufactured the way it has, and the specifications that the product adheres to (ex. maximum weight, height, etc.). A CAD model of the design will be shown to demonstrate how the cane can be operated, along with any physical prototypes made at that point. It is important at this stage to present the information in a way that conveys the engineering of the product, while still ensuring that the information is digestible for the client.

Upon presenting the prototypes, it would be ideal to gather the client's likes and dislikes about the design. It would also be beneficial to address any concerns she may have, and learn how we can make the cane more optimal for her before the final prototype is designed. Other necessary information includes her height, the terrain in which she intends to use the cane, how tall she would like the cane to be, and whether she wanted a cane that clearly indicates she is disabled (as mentioned in the first client meeting).

Project Plan Update

PD F: Design constraints	**12 days**	**Sun 25-02-16**	**Sun 25-03-02**	
PD F.1: Design constraints	5 days	Mon 25-02-17	Fri 25-02-21	Alex
PD F.2: Prototype 2	2 days	Tue 25-02-18	Wed 25-02-1	Jennifer
PD F.2: Testing	2 days	Tue 25-02-18	Wed 25-02-1	Anjali
F.2.1-2.3	5 days	Mon 25-02-1	Fri 25-02-21	Armand
F2.4-2.6	5 days	Mon 25-02-1	Fri 25-02-21	Jennifer
F.2.7	5 days	Mon 25-02-1	Fri 25-02-21	Emily
PD F quality check	2 days	Thu 25-02-20	Fri 25-02-21	Emily
PD F projet plan update	2 days	Thu 25-02-20	Fri 25-02-21	Anjali
Client meet 3			Tue 25-02-25	
PD G: Economic and IP considerations	**12 days**	**Sun 25-03-02**	**Sun 25-03-16**	
PD G.1: Economics report	11 days	Mon 25-03-03	Sat 25-03-15	Alex
PD G.2: IP report	11 days	Mon 25-03-0	Sat 25-03-15	Emily
PD G quality check	2 days	Fri 25-03-14	Sun 25-03-16	Jennifer
PD G projet plan update	2 days	Fri 25-03-14	Sun 25-03-16	Anjali
PD H: Design day	**10 days**	**Sun 25-03-16**	**Thu 25-03-27**	
Final prototype	9 days	Mon 25-03-1	Thu 25-03-27	Anjali
Design day presentation	9 days	Mon 25-03-17	Thu 25-03-27	Emily
PD H quality check	3 days	Tue 25-03-25	Thu 25-03-27	Armand
Design Day	0 days	Thu 25-03-27	Thu 25-03-27	Jennifer



Deliverable G:

Introduction

This report provides an economic analysis and intellectual property report on the product and design. Based on the assumption that the proposed cane design is in production/on the market, cost breakdowns such as the fixed/variable/direct table are used to analyze overall expenses. A mock income statement for a 3-year term is created to analyze cash flow and an NPV analysis is conducted to determine the breakeven point over the same term.

1.0 Economics Report

1.1 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.

Table 1: Variable and Fixed Costs

Variable , Direct Costs , Material Costs , $2600/tonne , link

3D Printing Expenses , $3000/100kg , link

Packaging Materials , $550 – $950 , link

Shipping Costs , $5000 , link

Labor Costs , $208,000/year , $20/h for 5 employee

Variable Indirect Costs , Marketing Costs , $5,000–$10,000 , link

Utilities , $700-$1000 , link

Maintenance & Repairs , $2000 , Rough estimate

Fixed Costs , Fixed Direct Costs , Initial Tools & Equipment , $50000-$80000 , link

Fixed Indirect Costs , Rent , $7,880–$15,760 , link

Business Registration & Legal Fees , $500 , link

Insurance , $500-$1500 , link

, , , ,

1.2 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)

Assumptions:

Selling Price per Cane = $150

Growth: 5% each year

Sales Projections:

Year 1: 6000

Year 2: 6300

Year 3: 6615

Materials (per cane): $63

Raw Materials (aluminum): $26

3D Printing Expenses: $30

Packaging: $7

Fixed costs: $259,000

Labour (40 hours a week) = $20 / hour

$41,800 / year / employee

$209,000 / year

Facility lease = $50, 000 / year

Table 2: Three Year Income Statement:

, Year 1 ($) , Year 2 ($) , Year 3 ($)

Revenue , , ,

Sales (Units) , 6000 , 6300 , 6615

Price Per Unit , 150 , 150 , 150

Total Revenue , 900,000 , 945,000 , 992,250

Cost of Goods Sold , , ,

Direct Materials , 378,000 , 396,900 , 416,745

Gross profit , 522,000 , 548,100 , 575,505

Operating Expenses , , ,

Fixed Costs , 259,000 , 259,000 , 259,000

Net income , 263,000 , 289,000 , 316,000

Calculation Summary:

Revenue = Sales(units) * Price per Unit

Direct Materials = Sales (units) * Material Cost per Cane

Gross Profit = Revenue – Direct Materials

Net Income = Gross Profit – Fixed Costs

The numbers are based off the average profits and costs of an accessibility aid product company with 5 employees.

1.3 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.

Assumptions;

10% discount rate

PV = C(1+r)t�� = �1+��

Table 3: Present Values of Yearly Income

Year	Operating income	Present value
1	$263,000	$239,090.91
2	$289,100	$238,925.62
3	$316,505	$237,739.06
total		$715,755.59

$$\text{Break Even Units} = \frac{\text{Fixed Costs}}{\text{Selling Price} - \text{Variable Cost}}$$

$$\text{Break Even Units} = \frac{259{,}000}{150 - 63}$$

$$\text{Break Even Units} = 2{,}977$$

Therefore, 2977 Canes must be sold to break even. This is expected to be reached in the first year.

Cash Flow Diagrams:

Figure 1. Cash Flow Diagram for Year 1

Figure 2. Cash Flow Diagram for Year 2

Figure 3. Cash Flow Diagram for Year 3

1.4 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.

These assumptions are based on market research for the Ottawa region.

Target Market Size

Ottawa has 172,150 seniors (17% of the population) and 90,000+ mobility-impaired individuals.

About 5,000 canes are estimated to be sold annually in the Ottawa region.

Our business aims to capture 5% of local market share (250–500 units in Year 1).

Sales Assumptions

Initial Production Volume: 6,000 units

Annual Growth Rate: 5%

Break-Even Target: 2,977 units (achieved in Year 1)

Pricing Assumptions

Standard folding canes retail between $40-$70 in Canada. Premium canes (carbon fiber, ergonomic) sell for $100–$150.

The product’s $150 price point is competitive for a high-quality aluminum folding cane.

Cost Assumptions

Materials: Aluminum price of $2,600/tonne and 3D printing filament at $3,000/100kg reflect real supplier pricing.

Labour: Based on Ontario's industrial manufacturing wages ($20/hour).

Rent: Small industrial space in Ottawa costs between $7,880–$15,760 per year.

Marketing: Initial marketing budget of $5,000–$10,000, focusing on e-commerce and local pharmacy partnerships.

Conclusion

At a $150 price point, the business is profitable in Year 1.

Break-even at 2,977 units, which is achievable in Year 1.

Expected Net Income:

Year 1: $263,000

Year 2: $289,000

Year 3: $316,000

Growth Strategy:

Increase sales volume by expanding distribution channels.

Target national sales via online platforms.

Introduce premium variants ($180+ models).

2.0

Intellectual Property Report

2.1 Intellectually Property Databases

2.1.1 Compact Folding Cane (United States Patent Application 20200008545)

This cane made in the United States features foldable technology to reduce the size, and also has a base that the user can step on to assist with compacting and using the cane. This design is similar to the product this team is building in the sense that they can both be compacted, and they both feature a base that the user will step on during use.

Link to patent: https://www.freepatentsonline.com/y2020/0008545.html

2.1.2 Compact Folding Cane (United States Patent 10863803)

This cane features a folding mechanism that utilizes two cane segments, a handle, and a tip. It is similar to our product in structure, but differs in folding technology. It is also incredibly similar to the previous compact folding cane patent.

Link to patent: https://www.freepatentsonline.com/10863803.html

2.1.3 Telescopic Walking Cane

This patent features a cane that utilizes a telescopic collapsing technology, similar to our own. It also features spring-loaded technology, an extension mechanism considered by our team when designing our cane. It also features a thermometer and a light to assist the user.

Link to patent: https://www.freepatentsonline.com/3987807.pdf

2.2 Explain the importance of these intellectual properties and the legal constraints they place on developing your product or business.

Project Plan Update

Conclusion

By assuming the product and design were in production/on the market, a fixed/variable/direct table was created by outlining possible cost associated with large-scale production. An income statement created for the given 3-year period shows that the net income for Year 1 at $263 000, Year 2 at $289 000, and Year 3 at $316 000, as well as an NPV analysis conducted for the same period as well. All assumptions used within the report are justified and described within section 1.4. An intellectual property study was also conducted where 3 similar products were referenced in the creation of our product with their patents listed as well.

Deliverable H:

3 Minute Elevator Pitch Script

Welcome judges/everyone! Thank you so much for taking the time to come see our project. Before we officially start our presentation, we would like to call up one volunteer. Anyone?

Awesome, okay so what you're going to do is put one hand behind your back and extend this mini makeshift cane. Remember, you're only allowed to use one hand, but you can utilize any other part of your body to help out.

Awesome! Now you're going to fold it up again. This time, you only have 15 seconds and I'm going to give you this bag of materials to hold as well.

Pretty difficult right? Well, these are the issues our client was facing.

Our client has limited mobility in one hand, and no mobility in the other. She is an incredibly independent individual and regularly uses public transport to get around.

However, due to the limited range of canes on the market, she finds it hard to navigate her day-to-day life with a cane that is designed to be opened/closed with both hands and doesn't serve her need of an aid in balance.

To summarize, our client needed a cane that could easily collapse, aid in balance, and be stored away efficiently, however, all of these features must be incorporated in a way that can be navigated with a single hand.

That's here we come in! Meet our team, the Cane-iacs!

Our job was to design a lightweight collapsable cane that can be used with a single hand.

DEMO (START CLOSED) – done by another person while someone else talks

Our design uses telescopic tubes with a twist-lock mechanism to lock the cane once fully extended. We also have an automatic retraction system, similar to the one we see in a tape measure, built into the handle, which aids in quickly storing the cane away when not in use.

Our design uses 3 lightweight aluminum tubes, 1 power spring, and 2 3D-printed pieces for the tip and handle.

As you can see from our posterboard, we have gone through various prototyping stages where we've tried many different variations of the same idea.

From a clamp lock to a geared spring casing, our design has been repeatedly tested to ensure that we have an efficient, yet simple system to use.

Our design is a low budget, completely mechanical system, ensuring longevity with easily replaceable parts.

Our poster board also incorporates other features we would like to add into our future design.

With a higher budget, access to proper suppliers, and an extended time frame, we believe we have a product that could genuinely help a lot of people in a similar situation to our client.

Would anyone like to test out the cane?

Thank you so much for listening to our presentation today! Once again, we're the cane-iacs, we're crazyyy about canes!

Does anyone have any questions?

-

2 Line Summary

This project presents a one-handed foldable cane with a rapid retraction mechanism and secure twist-lock. This device prioritizes portability and usability for individuals with mobility challenges.

Design Day Presentation Material

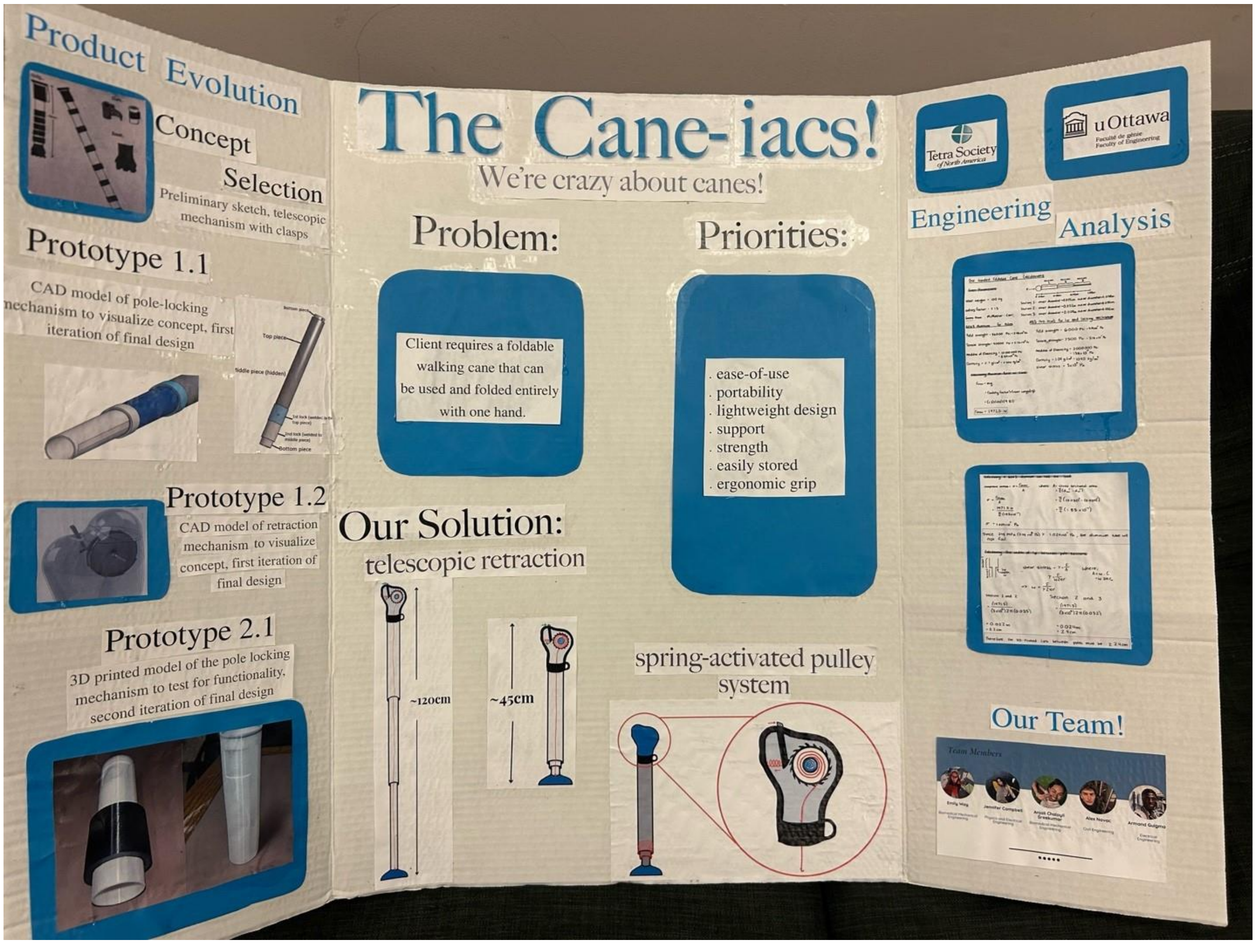


Figure 1: Poster Board

Figure 2: Final Prototype

Table 3. Referenced Documents

Document Name	Document Location and/or URL
Project Proposal	https://makerepo.com/project_proposals/286
Cane-iac's MakerRepo	https://makerepo.com/jcamp203/2410.caneiacs
Product Video	https://youtube.com/shorts/17FIQ5Lyg2w

10 APPENDIX II: Other Appendices