GNG2101

Design Project Progress Update

F1.4

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Table 1. Acronyms

Acronym	Definition
BOM	Bill of Materials
DFX	Design for X
CAD	Computer Aided Design
FEA	Finite Element Analysis

Table 2. Glossary

Term	Acronym	Definition

1 Introduction

The purpose of this continuously evolving document is to provide updates on the progress of the foldable cane design project conducted by group F1.4 of GNG2101. The project focuses on accessibility, where the team aims to improve the day-to-day life of a user with a cane suited to specific needs.

For PD B, the sustainability report, LCA report, and the Design for X components will be completed. The sustainability report outlines economic, environmental, and social impacts the product has. The LCA report provides students with a chance to perform a basic report on a competing product available on the market, allowing analysis from cradle to grave about specific parameters related to manufacturing and energy usage, Lastly, the Design for X components will help keen in the scope of which the team will focus more deeply on. 5 DFXs will be identified for the team to help design the product around, ensuring each DFX is hit and evaluated properly in relation to our global concept design.

For PD C, the group focused on developing a concise problem definition. This required a clear definition of all known information derived from the first client meeting. By identifying and prioritizing noted metrics, the team will create a simple problem statement which provides what is needed to create an effective product for the client. Along with this need inspired metrics, the group will conduct further benchmarking against readily available products of similar caliber that are available on the market today. This will provide the group with a better understanding of what is feasible and realistic, as well as specific numerical metrics that can be directly compared to our targets. With a realized better understanding of what can realistically be developed. The team will further improve to a set of ideal target specifications that can be met.

Concept development will be based off our problem statement and target specifications. Through initial group discussion, 3 preliminary concepts will be chosen to briefly analyze. Out of the 3 preliminary concepts, one final concept will be derived and delved more deeply upon for further analysis. The choice of the final global design concept will be evaluated in depth. Lastly, the final global design concept will be visually represented to provide a clearer understanding of what is to be met.

For PD D, the team focused on the feedback provided through the second client meeting to further iterate on the initial global design concept developed in PD C. Based on this feedback, the team brainstormed iterative ideas and applied them to the detailed design. The detailed design consists of a CAD model that provides initial quantitative values reflected in our initial ideas. Each of the three subsystems are developed, and interlinked. Building upon this initial detailed design, considerations were made to reach the designated DFX factors outlined prior, as well as a list of skills and resources required to effectively create our design. A realistic time assessment is provided, weighing out the skills needed along with the team members’ abilities considered in the assessment. Critical product assumptions were defined as primarily the telescoping system, as the two remaining subsystems rely heavily on the overall functionality of this telescoping system. With a choice of materials weighed in our detailed design, a preliminary BOM is provided with initial choices of components. This preliminary BOM will be updated upon building and iteration of future prototypes, as the team aims to identify key components required and decisions for material choices. The team will aim to optimize the budget as efficiently as possible.

2 Sustainability Report and DFX

2.1 Sustainability report

At least three of your product's major social, environmental, and economic impacts, both positive and negative. Perform a simple analysis of these impacts and use this analysis to help you define the sustainability constraints of a triple bottom line tables. See the table in the appendix.

Table 3: Tripple Bottom Line

Triple Bottom Line	Positive Impact	Negative Impact
Economic	Inexpensive recycled materials	Local manufacturing, increased cost
	Design for durability, reduce replacement cost	
Environmental	Use of recycled materials	Requires use of energy
	Manufactured locally, no shipping	
Social	Product increases accessibility	
	Benefits quality of life	
	Safe and equitable labour practices	

2.1.1 Impact Analysis

In terms of economic impact, the team will attempt to optimize the effectiveness of the product by using low-cost materials to create a design that is durable. By designing for durability, the product lifecycle will remain as extended as possible, thus reducing the need for frequent replacements and ensuring long-term affordability for users. The use of low-cost materials also ensures it's initial costing of from cradle to gate remains apprehensible.

For environmental impact, the team will design in sustainability in mind. The product will utilize previously recycled materials. Though, it is notable that processes to extract raw materials from recycled products, then converting the materials to usable frameworks to manufacture our prototype uses significant energy. The team is aware of these energy consumptions and efforts will be made to optimize energy use during production methods to help mitigate the high effort required to process recycled materials.

When looking into the social impact of the team's product, the product aims to increase accessibility, thus promoting social equity and bringing upon a more inclusive community. This will improve the user's quality of life as the product aims to mitigate any practical issues, which relates directly to social issues.

2.2 LCA report

Life cycle analysis – road map

Product that you are evaluating: Canes Canada UltraLight CarbonFibre Cane [1]

Objective and Scope

Define the objective: *Determine the purpose of the analysis. Write a brief description here:*

We are writing this LCA analysis, as the team is committed to building a sustainable product.

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:*

We are analyzing the product from cradle to grave, meaning from the raw materials to the disposal of the product.

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:*

1 week

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

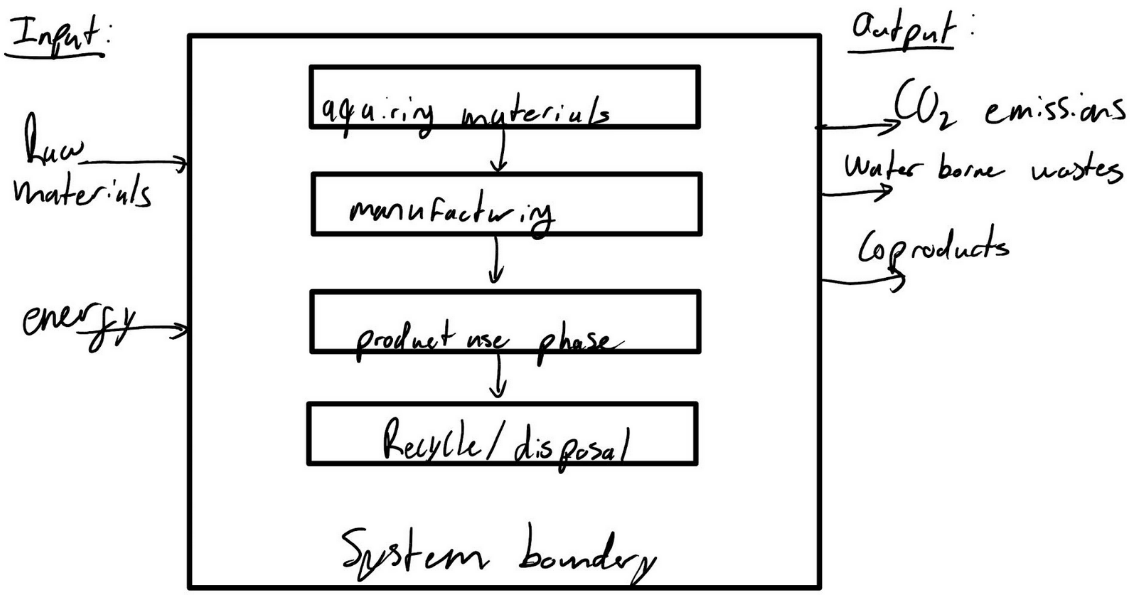


Figure 1: System Boundary for LCA

Inventory analysis

Step 1 Acquiring materials: Each material in a product has its own life cycle of use and waste.

List all the materials (metal, plastic) in your product. One point is awarded for each different material in the product.

Type of raw material	Points
Metal	**1**
Carbon Fiber	**1**
Rubber	**1**
	1
	1
Total points	**3**

Step 2 Material processing: Most metals and plastics must be processed before they can be formed into a useful form for manufacturing. Again, list the metals and plastics contained in your product. Award one point for each material.

Plastics or metals in the product	Points
Metal	**1**
	1
	1
	1
	1
Total points	**1**

Step 3 Manufacturing: All materials processed in your product must be formed and shaped into something useful for the product (such as a metal screw or a plastic lever). List here the different parts and pieces of your product that were made. Award one point for each part.

Different parts and pieces of the product	Points
Handle	**1**
Shaft	**1**
Base	**1**
Telescopic Mechanism	**1**
	1
	1
	1
Total points	**4**

Step 4 Packaging: How is your product packaged for sale? Check the boxes here that correspond to your product's packaging. Add up the total points for your product's 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	**15**

Step 5 Transport: Once a product is packaged, it must be transported to be stored or sold. Transportation by truck, plane, or ship requires fuel to produce energy and contributes to air pollution. Check the box if your product uses transportation in any way. List the total points for transportation of your product.

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

Step 6 Using the product: All products have a certain amount of time during which they can be used and reused. Check the box below that describes the usage time of your 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 5 years	**10**
The product can be used for more than 10 years	**5**
Total points	**10**

Step 7 Disposal: Once a product has been used, it can be disposed of or recycled. Check the box that describes your product below.

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

Add up your product's points to determine its overall impact on the environment:

Total points	**55/77**

Interpretation and improvement

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

Much of the environmental impact of the carbon fiber folding cane comes from distribution, specifically from the products packaging and shipping. This results in higher carbon dioxide (CO2) emissions. We would suggest using only cardboard or paper-based packaging, and including a QR code for digital instructions, instead of printing them out. Using overseas manufacturing to lower labor costs, increases CO2 emissions. We would recommend only using local manufacturing.

2. *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 suggestions described above, the new score would be 31/77, a significant decrease in the environmental impact of their walking cane.

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

After following the suggestions above, their environmental impact is already quite low. To further lower their impact they could design for durability, meaning the product would be usable for longer, and not be disposed of.

***Please note:** This activity gives students an idea of the usefulness of a life cycle analysis.

The numbers on the roadmap are fictitious and are only used to compare the environmental impacts of different objects on each other. In a real engineering life cycle analysis, the numbers for each step are determined using real measurable inputs and outputs of energy, electricity, raw materials, water, waste, and emissions.

2.3 Design for X

Based on your research and what you have heard from your client, list the 5 most important factors in your design.

1. Design for Functionality
2. Design for Speed
3. Design for Reliability
4. Design for Size
5. Design for Safety

2.3.1 DFX Justification

Justify the choice of each of those factors including: common objectives/needs for this DFX, examples of metrics, examples of constraints as well as examples of design criteria for each DFX.

Table 4: DFX Justification

DFX	Objective/Needs	Metrics	Constraints	Design Criteria
Design for Functionality	The product needs to function as a cane and provide support for the user while walking.	Load Bearing Capacity. Grip. Height Adjustability. Material.	Must support different user heights and weights.	Strong lightweight material (carbon-fiber).
Design for Speed	The opening and folding actions of the cane should be fast as to not impede with the user's daily activities.	Folding Speed.	Simplicity since the client can only use one hand.	Easy folding controls.
Design for Reliability	The design should be reliable and useable in various conditions and situations.	Durability.	Must maintain structural integrity. Limited budget for high-end materials.	Use of durable materials (carbon-fiber).
Design for Size	The design should minimize the size of the folded cane.	Folded Length.	Must fit in an average sized Fanny-Pack.	Cane sections collapse into each other.
Design for Safety	The design should prioritize safety because it's being used as a tool for assisting a person with a disability. One factor that is important is the chance of the	Material. Grip. Tip. Durability.	No-slip on wet surfaces.	Use of non-slip rubber for the tip.

	bottom tip of the cane slipping. This should be minimized as much as possible and is a focus for the design.			

The DFX justification table represents the objectives/needs, examples of metrics, examples of constraints, as well as examples of design criteria for each DFX. The metrics/specifications seen here can be found in table 7 with justification.

3 Problem Definition, Concept Development, and Project Plan

3.1 Problem definition

3.1.1 Client Meeting Summary

During the interview, we met with both the client and user. The user lives a very active life, they goes to the gym daily and cycle competitively, as well as being a student. The user has issues commuting. The user has 1 fully functioning hand which needs to be holding on to the railing during transit, but still requires a cane to walk. This creates an issue where the user has nowhere to put the cane down while standing on the bus/train.

The user would prefer the cane to be able to fold and unfold quickly, keeping in mind the use of 1 fully functional hand. A natural grip and walking motion of a walking stick is more comfortable, compared to a traditional cane. The user does not carry a backpack, so it would be ideal for to be store the cane in another method. A lightweight option remains a high priority. Lastly, the user prefers an extension grip rather than a firm grasp.

3.1.2 Needs Identification

Table : Importance Scale Reference

Importance	Definition
5	Critical
4	Highly necessary
3	Nice, but not necessary
2	Nice, but even more unnecessary
1	Not important

Table : Need Inspired Metrics

Group	Needs	Importance
User	Cane provides enough stability and support for normal walking	5
	Cane can be used throughout the day	4
	Cane can be used in various weather conditions	4
	Cane is easy to carry/hold	4
	Cane can open and close quickly	5
	Cane can be attached/held somewhere while dominant hand is in use	5

	Cane uses extension motion rather than grasping motion to open/close	3
	Cane is similar to a walking stick	4
	Cane can be used in a relaxed walking motion	3
Customer	Cane uses a flipping motion to open and/or close	2
	Cane is lightweight	3
	Strength of cane/walking stick isn't lost	5
	Cane is quick to fold	4
	Cane is electric	1
	Cane handle is comfortable/ergonomic and easy to hold	2

3.1.3 Problem Statement

A need exists for a cane/walking stick that provides support and stability for people with mobility impairments on one side of their body. This cane will be lightweight, quick and easy to fold with the use of only one hand, as well as durable across variable weather conditions. It will be simple to operate and be suitable for everyday usage.

3.1.4 Product Benchmarking

Table : Concept Target Specification

Metrics	Value	Justification
Weight (kg)	0.5-3 kg	Client wants it to be light
Folded Length (cm)	15-25 cm	Client wants it to fit in a fanny pack.
Load Bearing Capacity (kg)	Up to 136 kg	Client needs it to support a large load.
Durability	10000 Folding Cycles	Team discussion concluded that durability ensures functionality and safety over time.
Cost ($)	100	Market research and team discussions suggest that the cane should be affordable for the average person.
Folding Speed (s)	0-10 seconds	Team discussion concluded that folding speed is important for ease of use.
Height Adjustability (cm)	75cm to 100cm	Team discussion concluded that the cane should be suitable for short, average, and tall people.
Material	Carbon Fiber	The team concluded that this metric is important to increase the durability.
Grip	Straight/Staff Grip	Client wanted something comfortable to grip.
Tip	¾ inch	Market research suggests that this is a standard tip size for canes.

The above developed metrics will be compared directly to the metrics of known products available on the market. The above target specifications were derived after consulting with our client, doing some market research, and having team discussions about ease of use and practicality

Table : Metric Comparison Set 1

Metric	Our Cane	Canes Canada UltraLight CarbonFibre Cane [1]
Weight	0.5-3 kg	0.22 kg
Adjustable Height	Yes	No
Tip	¾ inch	¾ inch
Cost	100$	139 $
Load Bearing Capacity	140 kg	136 kg
Material	Carbon Fibre	Carbon Fibre
Summary	Better price and load bearing capacity but it's heavier.	Lightweight

Comparing our cane with the Canes Canada UltraLight CarbonFibre Cane from Figure 1. The cells in green mean that the values are preferable to the values in the red cells.

Figure 2: Canes Canada UltraLight CarbonFibre Cane [1]

Table 5: Subsystem Comparison Set 1

Subsystem	Our Cane	Comparison Set 1	Justification

Folding Method	The different sections of the cane collapse into one small cylindrical shape.	The sections of the cane that fit together are held by a string.	The string can wear out or tear over time leaving the cane unusable.

Comparing the folding subsystem for Comparison Set 1. The cells in green mean that the values are preferable to the values in the red cells.

Table : Metric Comparison Set 2

Metric	Our Cane	Adjustable 2-Piece Nordic Walking Poles [2]
Adjustable Height	Yes	Yes
Material	Carbon Fibre	Lightweight Aluminium
Weight	0.5-3 kg	0.972 kg
Foldable	Yes	No
Grip	Straight	Adjustable Hand Straps
Summary	Foldable and easy grip.	Lightweight, easy grip, but not foldable.

Comparing our cane with the Adjustable 2-Piece Nordic Walking Poles from Figure 2. The cells in green mean that the values are preferable to the values in the red cells.

Figure 3: Nordic Pole Walking Sticks [2]

Table 6: Subsystem Comparison Set 2

Subsystem	Our Cane	Comparison Set 2	Justification
Bilateral Support System	We only use one cane.	Two canes are used to provide support on both sides of the body.	For our client's needs, one cane is better because they need to carry it everywhere they go and do not require enough support to justify have bilateral support. Also, the client is unable to use both their hands.

Comparing the folding subsystem for Comparison Set 2. The cells in green mean that the values are preferable to the values in the red cells.

3.1.5 Target Specifications

Table 12: Target Specification and Verification

Design Specifications	Value	Verification Method
	Functional Requirements	
Load-Bearing Capacity	<136kg	We would test this initially in CAD with the frame of our design to find its failure point with a load pressing down on it. If this point is too low, we would make alterations to the design, potentially making the cane shaft thicker. We would also do similar stress tests to the prototype we develop.
Speed to fold	0-10s	To verify the cane can fold in a reasonable amount of time, we would test our design after building it.
Durability	10000-fold cycles	We would test failure points of the joints in multiple ways in CAD. We would run FEAs or similar failure analysis methods to perform fatigue analysis to determine the durability of the design. From there, if the results are not up to the functional requirements, we can iterate on the design and test again.
Height Adjustability	75-100cm	This will be determined during the design process and if done correctly, the mechanism in the cane will allow for a height adjustable from 75-100cm. This is also testable in real life.
Slip Resistance	High	We will test the friction the end of the cane makes with various surfaces with different roughness. It is important for the end to have a high static coefficient of friction to prevent slipping. This will be tested in CAD, as testing in real life might be difficult and result in inaccuracies.
	Non-Functional Requirements	
Grip	Comfortable/easy to hold	This will be verified based on feedback from using the cane in real life. From this, different variations of the grip can be made and attached to the cane to adjust and fix any problems.
Tip Length	¾ inch	The tip of the end of the cane will be measured in CAD and in the preliminary sketches, and if the assembly is done correctly the length will be correct.

Grip Shape	Staff/ski pole	This is easily verifiable during the design phase, where the grip shape will be decided and implemented into a CAD software.
Constraints		
Cost	\$100	The budget of the project will be regularly updated and managed, and all decisions relating to the design will be influenced by the budget. Ideally, the budget is as low as possible while maintaining the design's requirements.
Weight	0.5-3kg	The Design will be modelled in a CAD software before assembling. In CAD, materials can be selected with appropriate weights, so the weight of the design can be determined before assembling in real life.
Operating Temperature	>-40C	This will be done in real life. We want to know the hinges function at lower temperatures because of the potential for the metal mechanism to change shape or get stuck.
Folded Length	15-25cm	Similar to the overall height of the cane, this will be determined in the design phase, and if assembling goes correctly, the real product will meet this requirement.

3.2 Concept development

3.2.1 Subsystem Identification

To design the foldable cane, the following three subsystems were identified:

1. **Handle Subsystem:**

Focuses solely on the ergonomics of the handle of the cane to ensure a comfortable hold for the user. It also includes any optional controls, like a button, which the design may require. The team will ensure the interaction with the prototype will be as enjoyable as possible.

2. **Folding Mechanism Subsystem:**

Responsible for allowing the cane to collapse. Additionally, responsible for ensuring the cane remains in a secure position while in its folded/collapsed configuration.

3. **Structural Subsystem:**

Provides structural stability to the cane and ensures durability. This system includes the main body members and joints of the cane.

3.2.2 Preliminary Design Concepts

Three preliminary designs concepts were created to align with the problem statement, and each including descriptive elements of each subsystem to be implemented:

1. **Telescopically Collapsible Cane with Button**

Description: The cane folds down telescopically where each element of the cane slides into the one above it. The cane will only be collapsible when a button on the handle is pressed. With the button engaged, the cane can be flipped upside down to allow gravity to collapse each segment down. Each segment will then be held in place through the use of a locking mechanism like a pin.

Subsystems:

- **Handle:** Ergonomic rubber handle with button to enable collapsibility.
- **Folding Mechanism:** Gravity will fold the cane, and it will be secured with pins.

- **Structural:** Segments will be manufactured with aluminum or carbon-fiber to create strong and lightweight tubing.

Benefits: Lightweight, simple operation, and low cost.

Drawbacks: Multiple moving parts creating a lot of complexity and potentially increased wear.

*Preliminary Sketch Design can be found in the Final Design Choice, as this design was iterated and improved upon. (Figure 6 & 7).

2. **Hinged Cane**

Description: The cane folds down at designated joints using hinges and a locking mechanism. The cane will only be foldable when a switch on the handle is flipped.

Subsystems:

- **Handle:** Ergonomic rubber handle with switch to enable collapsibility.
- **Folding Mechanism:** The cane will be folded manually while the switch is flipped into the on position, and it will be held in place by a locking mechanism.
- **Structural:** Segments will be manufactured with aluminum or carbon-fiber and joints will be reinforced with either aluminum or steel.

Benefits: Simple and low-cost design.

Drawbacks: May be difficult to fold with a single hand, and wear on the joints.

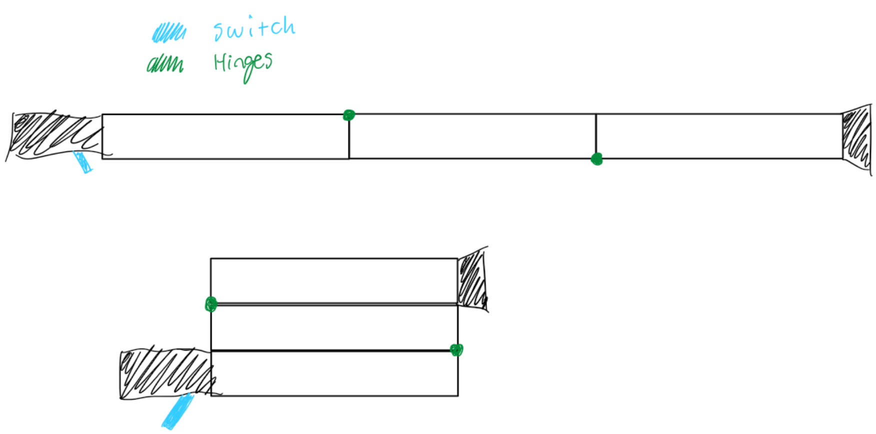


Figure 4: Hinged Cane Preliminary Design Sketch

3. Collapsible Cane with Magnet

Description: The cane will be folded telescopically using magnets. A magnetic belt will be tapped to the cane and that will enable magnets inside the cane to collapse the cane by pulling each segment up. The segments will then be locked with a pin once fully collapsed. This is a two-piece system.

Subsystems:

- **Handle:** Ergonomic rubber handle with built-in magnet.
- **Folding Mechanism:** The cane will automatically fold with the use of magnets once the magnet on the belt comes into contact with the handle and then held in place with a pin.

  Structural: Segments will be made of a non-magnetic material like aluminum or carbon fiber to reduce interference with the magnets. Each segment will also have a magnet inside with opposite polarity to the magnet adjacent so that the magnets will pull each segment into each other.

Benefits: Easy to fold with one hand and intuitive to use.

Drawbacks: Expensive due to magnetic components, complex to design, potential drawbacks when operating the cane near metallic objects.

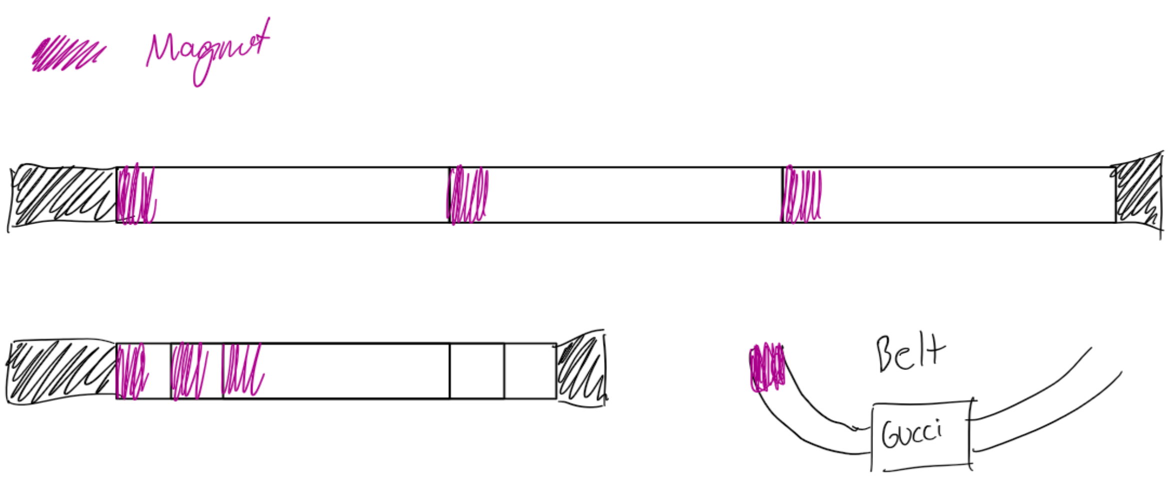


Figure 5: Magnetic Cane Preliminary Design Sketch

3.2.3 Concept Evaluation

Three preliminary design concepts were developed by the group, each presenting benefits and drawbacks due to design characteristics.

The three design concepts:

Telescopically Collapsible Cane with Button (A)

Hinged Cane (B)

Collapsible Cane with Magnet (C)

Table 11: Weighted Decision Matrix for Initial Concepts

		Design Concept A	Design Concept B	Design Concept C
Criteria	**Weight (%)**	**Score(1-10)** **:Weighted Score**	**Score(1-10)** **:Weighted Score**	**Score(1-10)** **:Weighted Score**
Speed to Fold	**15%**	**8**	**4**	**9**
Durability	**15%**	**8**	**9**	**6**
Feasibility	**20%**	**9**	**10**	**5**
Ease of Use	**30%**	**9**	**5**	**8**
Cost Effectiveness	**10%**	**8**	**9**	**6**
Weight	**10%**	**8**	**7**	**7**
Total:		**50**	**44**	**41**

Design concept A provides a simple, yet effective approach to meet the needs of the project statement. It is the most realistically feasible option, offering a trivial solution that is easy to operate. Design concept B, while similar complexity to Design concept A, it presents some issues that may be a dealbreaker for our client. The hinge mechanism may be difficult to operate with solely the use of one hand, thus the team has opted to move away from this concept. Lastly, Design concept C would be an extremely effective option, though due to its extreme complexity, many issues could arise with the development of this concept. For example, the moving mechanisms may operate differently than intended, which could result in malfunctioning of the prototype. This would be detrimental to the client, as lost of use of the cane would critically impact the quality of life. In the spirit of keeping the cane mechanisms, design, and operation as simple as possible, the team had decided to advance with the development of Design concept A.

3.2.4 Final Design Choice

The final design choice will be built upon the initial design concept of the Telescopically Collapsible Cane with Button.

Additions to the design:

- A cane carrier belt attachment
    - This belt attachment will provide a temporary storage solution that is quickly accessible and usable with one hand. It will grant the user freedom to use their one hand without having to leave the cane at a potentially unreachable distance or having to store the cane in an enclosed storage element.
    - The belt attachment ensures the cane is readily available to use whenever needed.

Initial Concept Design:

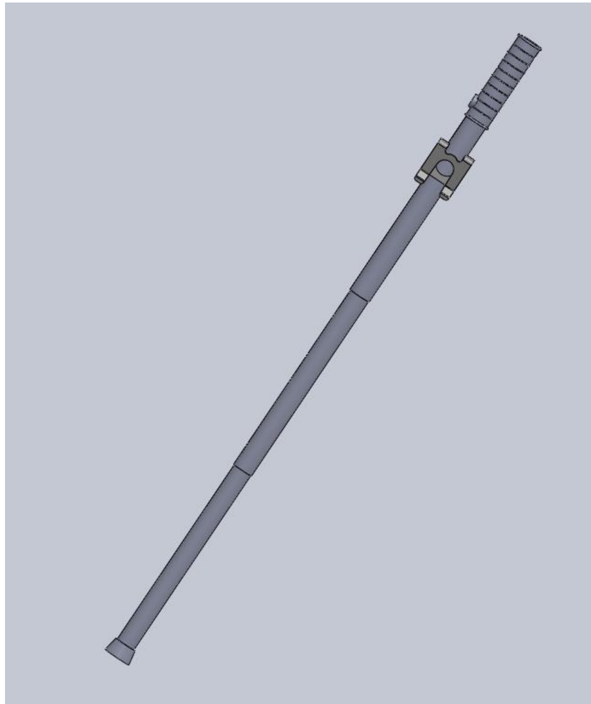


Figure 6: Initial CAD Design of Final Concept

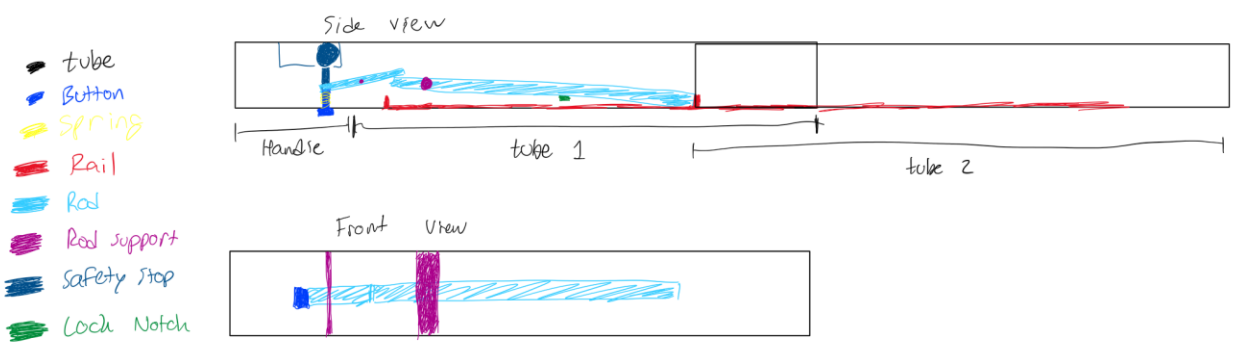


Figure 7: Initial Concept of Folding Mechanism

Notable Design Choices:

- Segmented cane structure allows for a telescopically collapsable design, for easy manipulation while not in use.
- Staff-style grip, as preferred by the user.
- Belt/pocket holster, for temporary storage through attaching to the side of the user's pants. Relieves the cane from the one-hand to allows full usage of the hand, while ensuring the cane remains in a readily available position.

The telescopically collapsible cane is designed to meet all target specifications with an emphasis on functionality, durability, and user safety. It features an internal rail system connecting the telescoping tubes, as seen in Figure 7. A push-button mechanism is used for collapsing the stick. Pressing the button moves the locking rod out of place, allowing the telescopic tubes to collapse on themselves with the aid of gravity. To provide consistent support, a ball mechanism ensures the button can only be pressed when the stick is upside down, preventing accidental activation while walking and reducing the risk instability and product failure.

The global concept's relationship to the target specifications (presented in Table 9) aims to meet these metrics as realistically as possible.

Functional Requirements:

- Load-Bearing Capacity
  - This metric can be met using strong materials within the cane structure subsystem, as well as with the internal locking mechanisms to ensure support under load.
- Speed to Fold
  - Speed to fold can be increased through design of the locking mechanism and assuring dimensions of telescopic segments are properly measured to bring upon smooth subsystem interaction.
- Durability
  - This metric will rely on the material choice for internal mechanisms, along with even force distribution along locking pins to ensure a durable setup.
- Height Adjustability
  - The height adjustability may be chosen to serve the needs of a user of a particular height or may introduce different locking pin locations to provide a short-range adjustment. Will be further explored.
- Slip Resistance
  - Slip resistance will be met using a cane tip that provides traction/stability in various climate conditions.

Non-Functional Requirements:

- Grip Style + Shape
  - A staff grip style shape has been chosen as preferred by the client. This promotes the extension grip rather than a grasping mechanism.

Constraints:

- Cost
  - Cost has been allocated to a budget of $100 as provided by the course GNG2101

- Weight
  - This metric must remain ideally < 2 kg, but the team will reach for better margins. This will be done using lightweight materials.

- Folded Length
  - Folded length will depend on the user's height, as longer segmented sections will affect the folded length. The team will optimize this constraint.

The following DFXs were defined for the initial design criteria of the project.

Design for:
Functionality
Speed
Reliability
Size
Safety

In terms of Design for Functionality, the concept delivers by providing a simplistic approach to serve the needs of a regular walking stick, while its collapsing mechanism remains as easy as possible to operate with the use of only one hand.

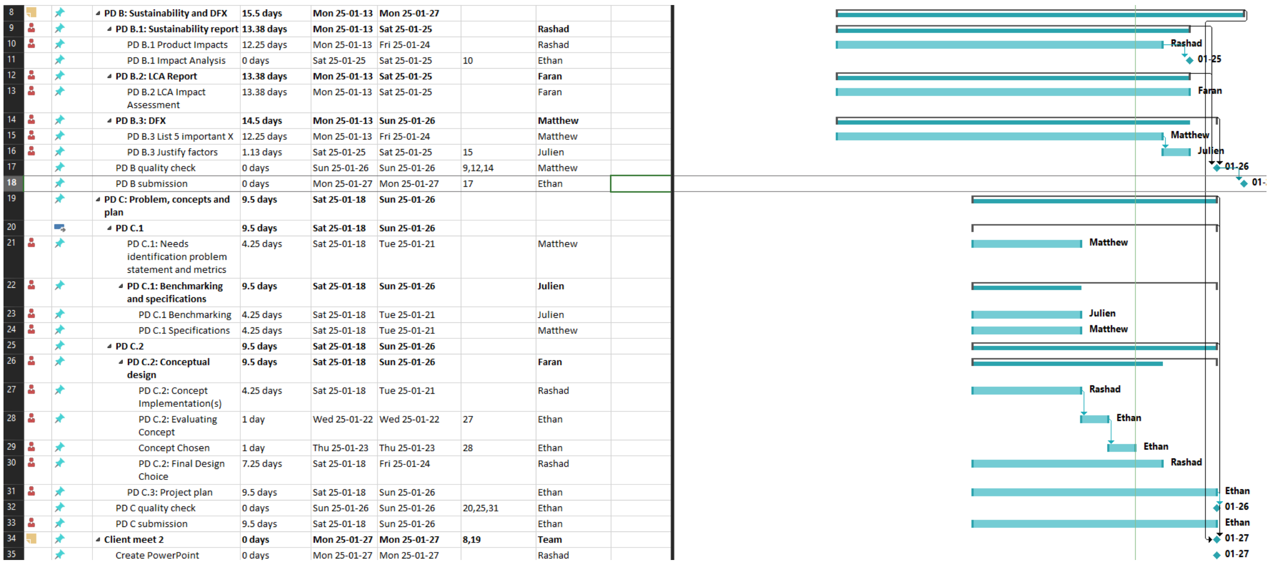
Design for Speed relates directly to the proposed collapsing mechanism, where the use of gravity ensures quick transitioning in between states. The tolerances placed on the segments and the collapsing mechanism in Figure 7 are vital to ensure speed is met.

Design for Reliability is crucial as any drop in reliability would be detrimental to the user experience. This DFX is of great importance, and the choice of material used for the structural subsystem, and smooth operation of the collapsing mechanism are critical for longevity of the product.

Design for Size relates to the collapsable size of the cane, where it can be safely stored away from the user's hand, whether this is in a bag, or through the use of the built-in pants hook. The size is strictly dependent on the length of the chosen segments. Though a constraint on size is dependent on the user's height. Introducing more segments dependent on height would not be ideal, as this would delimit the stability and load bearing of the product.

Design for Safety relates to the grip comfort, safety locking of the collapsing mechanism, as well as the slip resistance provided by the tip of the cane. Ensuring an ergonomic design of the grip, strong safety locking to prevent accident collapsing, and slip resistance through uneven/slippery terrain is essential to keeping the user safe and confident while using the product.

3.3 Project plan



8	PD B: Sustainability and DFX	15.5 days	Mon 25-01-13	Mon 25-01-27		
9	PD B.1: Sustainability report	13.38 days	Mon 25-01-13	Sat 25-01-25		Rashad
10	PD B.1 Product Impacts	12.25 days	Mon 25-01-13	Fri 25-01-24		Rashad
11	PD B.1 Impact Analysis	0 days	Sat 25-01-25	Sat 25-01-25	10	Ethan
12	PD B.2: LCA Report	13.38 days	Mon 25-01-13	Sat 25-01-25		Faran
13	PD B.2 LCA Impact Assessment	13.38 days	Mon 25-01-13	Sat 25-01-25		Faran
14	PD B.3: DFX	14.5 days	Mon 25-01-13	Sun 25-01-26		Matthew
15	PD B.3 List 5 important X	12.25 days	Mon 25-01-13	Fri 25-01-24		Matthew
16	PD B.3 Justify factors	1.13 days	Sat 25-01-25	Sat 25-01-25	15	Julien
17	PD B quality check	0 days	Sun 25-01-26	Sun 25-01-26	9,12,14	Matthew
18	PD B submission	0 days	Mon 25-01-27	Mon 25-01-27	17	Ethan
19	PD C: Problem, concepts and plan	9.5 days	Sat 25-01-18	Sun 25-01-26		
20	PD C.1	9.5 days	Sat 25-01-18	Sun 25-01-26		
21	PD C.1: Needs identification problem statement and metrics	4.25 days	Sat 25-01-18	Tue 25-01-21		Matthew
22	PD C.1: Benchmarking and specifications	9.5 days	Sat 25-01-18	Sun 25-01-26		Julien
23	PD C.1 Benchmarking	4.25 days	Sat 25-01-18	Tue 25-01-21		Julien
24	PD C.1 Specifications	4.25 days	Sat 25-01-18	Tue 25-01-21		Matthew
25	PD C.2	9.5 days	Sat 25-01-18	Sun 25-01-26		
26	PD C.2: Conceptual design	9.5 days	Sat 25-01-18	Sun 25-01-26		Faran
27	PD C.2: Concept Implementation(s)	4.25 days	Sat 25-01-18	Tue 25-01-21		Rashad
28	PD C.2: Evaluating Concept	1 day	Wed 25-01-22	Wed 25-01-22	27	Ethan
29	Concept Chosen	1 day	Thu 25-01-23	Thu 25-01-23	28	Ethan
30	PD C.2: Final Design Choice	7.25 days	Sat 25-01-18	Fri 25-01-24		Rashad
31	PD C.3: Project plan	9.5 days	Sat 25-01-18	Sun 25-01-26		Ethan
32	PD C quality check	0 days	Sun 25-01-26	Sun 25-01-26	20,25,31	Ethan
33	PD C submission	9.5 days	Sat 25-01-18	Sun 25-01-26		Ethan
34	Client meet 2	0 days	Mon 25-01-27	Mon 25-01-27	8,19	Team
35	Create PowerPoint	0 days	Mon 25-01-27	Mon 25-01-27		Rashad

Figure 8: Project Plan PD B & C

34	Client meet 2	0 days	Mon 25-01-27	Mon 25-01-27	8,19	Team
35	Create PowerPoint	0 days	Mon 25-01-27	Mon 25-01-27		Rashad
36	PD D: Detailed design					
37	Detailed design	7.25 days	Tue 25-01-28	Mon 25-02-03		Faran
38	Client Feedback + Modification	2 days	Tue 25-01-28	Wed 25-01-29		Rashad
39	Updated Detailed Concept Design	2 days	Thu 25-01-30	Fri 25-01-31	38	Ethan
40	Physical Prototype Design	2.13 days	Sat 25-02-01	Sun 25-02-02	39	Faran
41	Considerations to meet DFX	3.25 days	Sat 25-02-01	Mon 25-02-03	39	Julien
42	Skills + Resources to meet Design	3.25 days	Sat 25-02-01	Mon 25-02-03	39	Julien
43	Realistic Time Assessment	1.13 days	Sun 25-02-02	Mon 25-02-03	40	Matthew
44	BOM	1.13 days	Sun 25-02-02	Mon 25-02-03	40	Matthew
45	PD D quality check	8.25 days	Tue 25-01-28	Tue 25-02-04		Ethan
46	PD D projet plan update	7.25 days	Tue 25-01-28	Mon 25-02-03		Ethan
47	In class design review					

Figure 9: Project Plan PD D

4 Detailed Design and BOM

4.1 Detailed design

4.1.1 Client Feedback + Modification

The second meeting with the user and client has passed, the team received helpful feedback, and insight. The team discussed the state of the project, design priorities, previous designs, and the current design. In regard to our design priorities, the user was pleased with the team's major considerations in the design, being fully operational with one hand, the 'walking stick' staff-like grip and motion of the cane, being lightweight, opening and closing quickly, and providing an option to store when not in use. The user wanted to add to our design priorities, to make sure the cane resembles a standard cane used for disabilities, as to alert those around that the user indeed has a disability.

The user spoke on the team's current design, shown in PD C. They were generally happy with the design, specifically the opening and closing mechanism. Their only critique was that the folding mechanism halved the total length of the cane. The user thought the folded length of the cane was still a bit cumbersome to attach to her belt and keep on her waist.

The team then gathered specific details about the user to refine the design to their needs. Our user is 5'3" and left-handed, which will help us determine the final dimensions of the cane. The user later added, the handle should sit slightly above their waist when in use. The user thought a wrist strap on the cane would be a good idea, adding that it would be helpful if the strap relieved some of the stress on their hand when gripping the cane. The user did not have any specific requirements for the material of the handle, other than it not being metal on the grip, so it doesn't get too cold in the winter. When asked about the bottom of the cane, and its level of traction, the user did not say much, but the client suggested a modular bottom, with different caps so the cane would maintain traction for different types of terrain.

4.1.2 Updated Detailed Concept Design

After our second client meeting, the team took some feedback and channelled it into an updated global design concept. The updated global design concept is still comprised of three subsystems: the Handle Subsystem, the Folding Mechanism Subsystem, and the Structural Subsystem.

The handle subsystem focuses primarily on the ergonomics and user interaction with the cane directly. The handle subsystem will be designed as a staff-like vertical grip, fitting the preferences of the client. It will be ergonomically shaped providing comfort while holding. The handle will also feature a button control to interface directly with the folding mechanism subsystem. Additionally, preferences revealed in the second client meeting brought upon the addition of a wrist strap, allowing for an easier grasp of the cane. The team will also ensure that grip is made of a non-metallic material, as use in the cold temperatures with a metallic grip would prove troublesome.

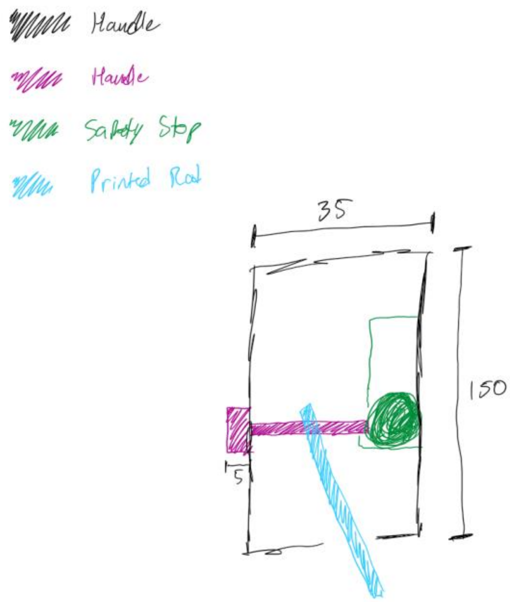


Figure 10: Locking Mechanism System

The folding mechanism subsystem remains extremely like the initial detailed concept, and we are continuing to use a rail system. There are going to be steel rods pushing down on the rail to prevent it from collapsing and these rods will be free to rotate through 3D printed bearings

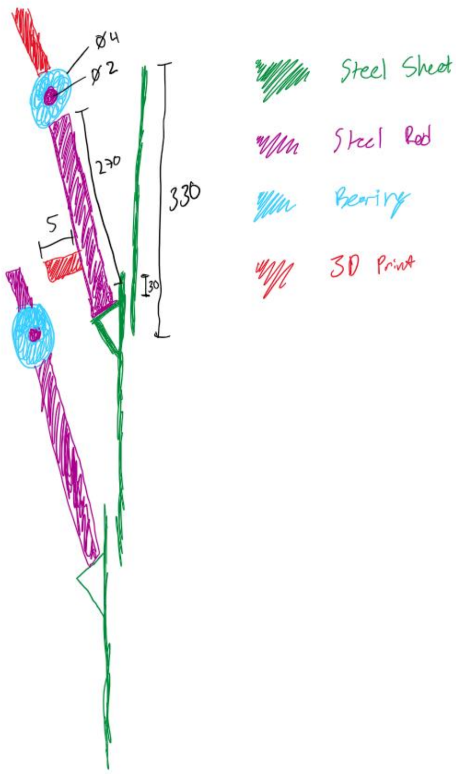


Figure 11: Push Rod Extension System

The structural subsystem had originally been designed as a two-segment system, where the telescopic retractability of the system only reduced the overall length by half. In the updated detailed design concept, client feedback pushed us to introduce a three-segment system, where the retractability of the system allows an overall length reduction by two thirds. The addition of a segment increases the complexity of the support provided by the folding mechanism, as well as potentially reducing the load bearing capacity of the prototype. Trade-offs will be made to ensure the product remains as functional as possible. With the described user preferences of the cane usage, a lowering in weight bearing functionality in trade with a higher collapsable ability will be made.

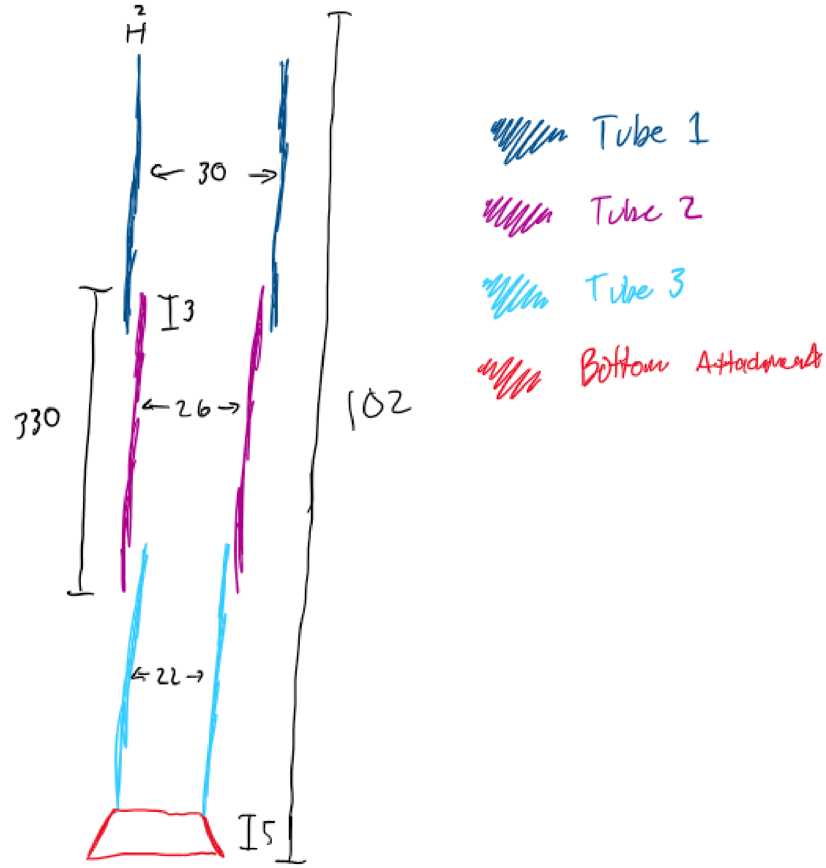


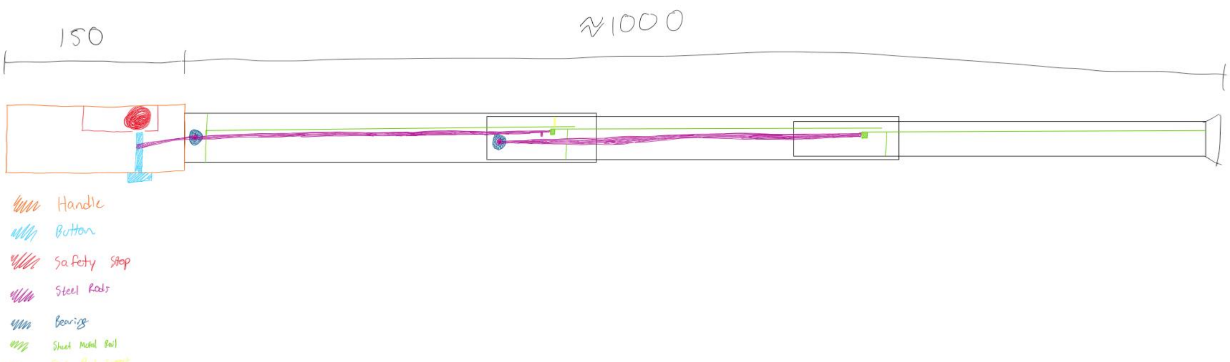
Figure 12: Segment Extension System

A comment of the client's new design suggestion:

At the end of the user/client meeting, the client had suggested a new design that would target more broadly the audience of customers with the need of a general use cane. It comprised of the idea of using hinged cane pieces that could form the main structural system of the cane, with a rod that telescopically expands through the hinged pieces to maintain rigidity and cohesion. With deep discussions within the team, the group has opted to not move forward with this preliminary design concept. The main concerns addressed by this option presented by the client is the question of load bearing on the cane and durability, while maintaining the collapsibility.

As this option may provide for a good prototype that serves a broader audience, in the use case of our client specifically, the team believes that pursuing this option would detract from the benefits that it could provide for the special use cases of our user. For our user, the team focused on making a product simple to operate with one hand, lightweight, and readily collapsible at any moment to free the use of one hand. With the client proposed design, the hinged based mechanism will result in a difficult to collapse mechanism with solely the use of one hand. The product will also be significantly larger due to the hinged mechanisms folding upon each other, and the products weight will also be increased. For these reasons, and the teams focus on solving the needs of our user, not for a broader audience, the team will not move forward with the client suggested concept.

4.1.3 Physical Prototype



The handle is going to be connected to the telescoping tubes below via bolts. The number of bolts needed will depend on the actual tripod leg that is purchased which will be decided based on structural integrity and cost. The button, safety stopper, bearings, and handle will all be 3D printed using PLA. The main rail system will be made of steel sheets and supported with more steel sheets welded perpendicularly. The steel rods will be press fitted onto the bearings and the bearings will be on more steel rods that will be welded to the inside of the tube.

4.1.4 Considerations to meet DFX Factors

Many things must be taken into consideration when designing and manufacturing the product to ensure that we meet our DFXs stated earlier in this document.

Design for Functionality:

- Certain materials should be considered for their lightweight and strength properties
- A comfortable handle material should be considered to ensure easy and comfortable use (easy to hold in hot and cold environments)
- The cane should be able to support different user weights. The team should consider reinforcing the joints.

Design for Reliability:

- Durable materials for each cane component but be carefully considered to ensure long lifetime.
- Added joint support should be considered to avoid unwanted collapse.

Design for Speed:

- Low friction materials for joints should be considered to allow quick folding.

Design for Size:

- Different folding sizes should be considered to allow different users to store it in different sized locations

Design for Safety:

- A tip with a high friction coefficient should be considered
- Joints should be tested for a safety factor (a multiple of the recommended weight before the cane breaks or collapses).
- Added joint support should be considered
- Secure locking mechanism should be inspected during manufacturing to ensure proper functionality (avoid any non-wanted collapsing of the cane)

Out of all these DFXs, the most important one is design for safety. There are many companies out there that often release products to the market knowing that they have some serious safety flaws. For example, Ford released a car called the Ford Pinto knowing that the gas tank placement in the car was unsafe. As a result, a bunch of those cars would explode upon a simple rear-end collision. This is obviously immoral, which is why the design for safety factor is the most important.

4.1.5 Skills and Resources to meet Design

The team is comprised of very skilled individuals in different fields of engineering. As for the resources, the uses whatever is as their disposal due to budget constraints.

Skills:

- **CAD Designing**: Proficiency in CAD software is essential to be able to design the final product.
- **Materials Selection & Testing:** Choosing materials and testing requires great mechanical engineering knowledge.
- **Project Management:** This project cannot be realized and organized unless a highly skilled project manager (Ethan) steps up to the task.

Missing Skills:

- **Manufacturing Knowledge:** An experience manufacturing engineer can help see the entire manufacturing process from beginning to end.

Resources:

- **Money:** The team has a 100$ budget
- **Lab equipment:** The team has access to 3D printers, CNC machines, Electronics equipment, Drills, Drill Presses, Lathes…
- **Amazing Guidance:** The team has access to some of the absolute best guidance ever, the TAs.

Missing Resources:

- **High-end Materials:** The team has a low budget and therefore cannot afford very expensive materials to realize the project.
- **Manufacturing:** Product cannot be mass-manufactured without a manufactory.

4.1.6 Realistic Time Assessment

The team will have a basic prototype designed in CAD software before Tuesday, February 11th, 2025. This will detail the button mechanism in the handle, which uses gravity to allow the button to press. After this, a full design of the cane will be completed in CAD. This phase will take 2 weeks altogether. During this phase, the design will be weighed against 2 important constraints chosen by the group. Adjustments based on these constraints will be implemented into the design. After the design is tested in CAD, the team will begin to implement it in real life through physical prototyping. The first real world prototype will be of the mechanism, which will be printed in 3D. This will take 2 weeks to complete, accounting for adjustments, iterations and testing.

4.1.7 Critical Product Assumptions

A critical functionality that is a critical product assumption that the team has made includes the properly functionality of the telescoping mechanism. The overall functionality of the design concept relies on the telescoping mechanism operating in an optimal manner, where the rods can be released from tension to collapse under the force of gravity, and to release to a locked manner where structural load can be placed on the mechanism and provide support for the user. For this critical aspect, the team will focus the first low fidelity prototype on identifying any potential issues related to this mechanism.

The first low fidelity prototype will be an analytical simulation mode designed via CAD. With this analytical model, the team will identify the functionality and integration between the components within the telescopic subsystem. Additionally, the team will be able to test the load bearing capacity via FEA, with simulation based of a load bearing point, as well as a variation in material of the subsystem to determine the best trade-off between load bearing capacity, price point, and weight of the material itself.

In summary, of the critical product assumptions made for our design, the overall functionality of the telescoping mechanism remains the only critical point. The other two subsystems of the handle and the structural shaft subsystem rely on this critical assumption working. The handle subsystem will have the telescopic trigger embedded into the handle. The structural shaft system will not provide any significant load bearing properties, though rather simply encompass the telescoping mechanism, which provides both the load bearing ness, and the retractability property.

Included in this critical assumption, lies the target specifications indicative of the load bearing capacity, as well as the retractable/collapsed length of the design.

4.2 BOM

Table 7: Preliminary Bill of Materials

OBJ

Product	Description	Quantity	Unit Cost	Full Cost	Link
Steel Round Rod	1/8 x 48-inch	1	$9.56	$9.56	https://www.homedepot.ca/product/
Tripod Leg(s)	Telescopic tripod leg	1	$25.00	$25.00	https://www.amazon.ca/REDCAMP-Extension-Ceilings-Lightweight-Telescopic/dp/B0D2HPY6F4/ref=sr_1_2?crid=38DNG0AD2LW0Q&dib=eyJ2IjoiMSJ9.SBm7DaQx6lp0rlAY1L51UsXcLgQCoQ6tuPRU5kHImd-tP9iu7c23UgHWN0TG9LQPzJbACqtn1u61QzLQ6mqtFeTx-JbXSfvoy6Kj9uzUabHCd55l8Hko6GChJNt-uJXV2Da_jiIWm8zfxkYjg5826-F5iRpw3l99Uir1x5bqzZuZZJxCbK3fISFVuysndflg.dPIQcsIzBkN27WuBbQ_nvvmZFtFXG0rqCa0rljbsd1o&dib_tag=se&keywords=REDCAMP%2B12ft%2Bextension%2Bpole&qid=1738775868&sprefix=redcamp%2B12ft%2Bextension%2Bpol%2Caps%2C85&sr=8-2&th=1
PLA	3D Printing	1	$3.00	$3.00	Makerstore

Steel Sheet Metal	Cold Rolled ASTM-A366 0.024”	1	$3.68	$3.68	https://quote.metalpros.com/
Bolt	Depends on tripod leg purchased	1	$0.50	$0.50	Makerstore
Glue	Gorilla glue to connect 3D printed pieces	1	$8.79	$8.79	https://www.amazon.ca/Gorilla-Fast-Setting-Controlled-Cyanoacrylate-112441/dp/B0BZ9YWN35/ref=sr_1_7?crid=110AWLOM4PD7C&dib=eyJ2IjoiMSJ9.vnHzrHHKnyKKdVLsg8ulyMyJwTE91ucJsH_bWU1KOr1Xkn2u80iy1zJpXqjZ3yvK8DAi9JNshn65O5k2Eea8ubvRWekqcGb5DVlyfUjS4HJM7qK5kBWtk1kroaz92_pfAnsM8HiucxJMkwX2mWGPLeqENS5mW0BA0pkPIh60p6lwvi6r13hOC_3dM789TjiW7lk5ZeLZP4iCfzeuJq1pdxRAPTzpdqbIOZPnX_oHVncyPV-wmFtOOF205de-VLMq6uOZncFH8Z-NpYsQblnVC2YK2sW5tFSMPCaSsDWr7Z8wuR50eoFeJgNp-tHAkvuS-iioXDDxIzIDvB3H-YqUNiPBF6TT5Awgy0LGoS-NAPEvTWr-VqTC0wTBINhEdycmccT-F5ZrT8FE1x8mZma0ePG44KHpvHwVzHwM9YVL6eWTMGo-T946-NCMXpO7eFDt.534uDFnXLSpgtSVyn4eaojde5Jo9BZK5VdEXg3s3hEE&dib_tag=se&keywords=Glue&qid=1738927093&sprefix=glue%2Caps%2C146&sr=8-7
Clip	Clip	1	$9.99	$9.99	https://www.amazon.ca/Heavy-Duty-Curtain-Photos-Decoration-Display/dp/B07FXT769J/ref=sr_1_17?crid=LZDH1UE03CU2&dib=eyJ2IjoiMSJ9.V6gJOUbcm2rCQNWNUeg0KLeDk_AJCgoF7zyC10oDDo5qWSsF0HysHr6AxshzHrNjVuXe-w1j0SInl7Ls9OxbiQvdoJqJ_jxL4NBLLdSvWrJGVVU0IHnpy7h1wOz8wsQu4D8qVBMYwMkJ0-S9hCoHTw2vrgtvt-pytsr7pCde87Y0nQjKzMWGg1T59wwKhNjCRJ4MHqY9tqHcuaJ4ytpRQvjR613h32Tcf1EuLuub7WD9jMEhD30WdDynjz6d7QcBsdt3Ntjl9Fn5_962VptsVbouE2d-JwP0K4lfGFSbhcNpU8uUqDpDU6rJIkPCj4RN1ZuASTexcUymbdQqGLuXqfv4RFb1qEflWuRpXQ8njAwnKZDpyoj7Vv5uSokcT_JNasHo3gzCHImgAbCoFfvnttQhh3znxERcKZ6B-QE1AcncSRLsMN_XJ0jN6jidgE0o.rUWFVIbZYGwGaRaZMfJcyJgeLgxX5PGNBoCS_9-sh6g&dib_tag=se&keywords=Clip&qid=1738927119&sprefix=clip%2Caps%2C103&sr=8-17

Spring	Return spring for button	1	$2.98	$2.98	https://www.amazon.ca/Springs-Inner-14-2mm-Outer-16-6mm/dp/B01NH5ERVN/ref=sr_1_5?crid=1B0TT9KK591K5&dib=eyJ2IjoiMSJ9.xHS340IstQP_XkCIbJ8byNJMlgMjf1o7691HiS-9b75CLKm1aSb2xLFe7TI5XWMlpDHLgmlf0ltIERH9PZ_z20AmrZkT3T2NBXRHZzVQ9yiyU8jQQJQUltY_ZoPXxL0nIR1OOsoDJ0egL3NqCmH_WhXMscTHVLtSR71jIl-7utoCcLqNAClymAwvT2lMoOirYdswF7YO0-ZhsRC3WTELSjX80ePOYKr2JdXcCK0BkFth_cmOXm4DBgMXQEkTFuba1dl2IH8tJg3DDKojMuP-qlBDf_ZtURwERB5upKkot6gb7Ika_8U05om7Qpa4OCTlogH50CjjcHS_EBNIpWtHAXvO4V3XssyB41iVGxlV0SatI1CtoiKYGDcu0ODSrXIz7wsRS6AT8r5Qjf7s3k2hpTGYYT84I921IDqLjwV9LvDevax4LSBhluGDsjh_l4mg.5XmuvcCE1-hxbOeeB9wby1xsvQaGpE6DszTzDnLUQ78&dib_tag=se&keywords=Spring&qid=1738927199&sprefix=spring%2Caps%2C106&sr=8-5
				Final Cost	
				$63.50	

4.3 Project plan update

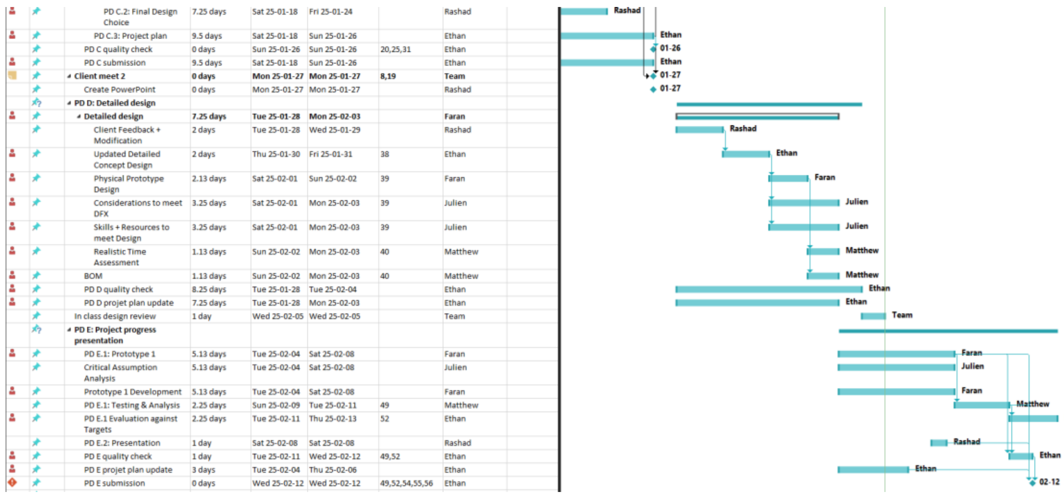


Figure 13: Gantt Chart for PD D and PD E

5 Conclusions

In conclusion, the first section of deliverables was completed effectively, providing a comprehensive review of the overall project and its metrics to be met. Through lecture content provided by Professor Lakhani, the team was able to successfully build upon the concepts taught during class periods.

PD B involved the development of a sustainability report based on our products' major social, environmental, and economic impacts. Its report is formatted in a triple bottom line table, which aims to explore the impacts beyond solely economic. Additionally, a life cycle analysis was conducted on a competing market available product. This provides an opportunity for students to analyze a pre-existing product and observe its impact through a cradle to grave lifecycle. Lastly, for PD B, the DFX criteria were outlined, where the team will focus its impacts upon a few key criteria decided based on importance to the client and user.

PD C surrounded primarily around the preliminary design of our product. As a team, the problem definition was defined, outlining the key performance criteria that the group would like to achieve with our product. Further on this, concept development was created for presentation to the client and user for basic feedback and insight into the possibilities of further development of these concepts. After gathering feedback from our meeting with the client and user, the group picked one global design concept to further iterate and develop further.

PD D focuses on the detailed design and BOM of the design concept of our product. Diving deep into the detailed design provided a representation of the model in a CAD analytical model. For the first prototype, the team will focus on a low fidelity analytical model to ensure proper functionality of the telescoping mechanism, as this is defined as the group's most critical product assumption. The assumption providing the telescoping subsystem operates as intended. With this prototype, an FEA will be conducted to evaluate the prototypes load bearing capacity, along with variations in materials of the structure to optimize this constraint. The retractability will also be measured, providing a retracted length suitable for efficient usage by our client.

In summary, the preliminary design deliverables provided organized targets to be met which sets the team up for a smooth development process the rest of the semester.

6 Bibliography

[1] Canes Canada, "Ultra-Light Carbon Fiber Folding Canes." [Online]. Available: https://canescanada.com/Ultra-Light-Carbon-Fiber-Folding-Canes_p_651.html. [Accessed: Jan. 25, 2025].

[2] Nordic Pole Walking Ontario, "2-Piece Nordic Walking Poles by Nordixx." [Online]. Available: https://www.nordicpolewalkingontario.ca/product/2-piece-nordic-walking-poles-by-nordixx/.[Accessed: Jan. 25, 2025].