GNG 2101 – Introduction to Product Design and Development

Design Deliverable 2

Group F1.3

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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. These concepts are then translated into a global design concept that was presented to the client for feedback. This feedback was gathered, summarized, and used to create a detailed design, initial prototype, and a bill of materials to facilitate final prototype design. Overall, this document guides the reader through the design process from initial concepts to detailed design, including the steps taken to get to the final point.

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

<u>Economic:</u>

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

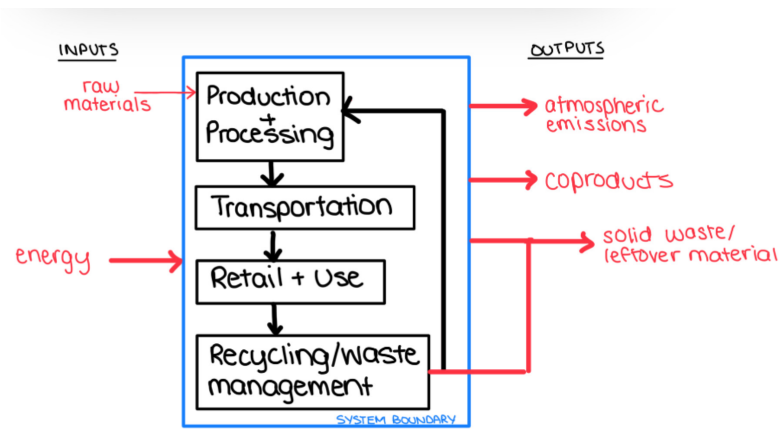


Figure 1

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.

1) Design for Safety
    a. Objective: Minimize potential dangers related to the use of the cane (particularly reducing risks of injury)
    b. Metrics: Maximum acceptable load (N), Safety factor (dimensionless)
    c. 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.
    d. Design criteria:
        i. Elastic (non plastic) deformation under expected loads
        ii. Non-slip (ex. Rubber) material for the handle and tip
        iii. Edges rounded to prevent injuries
2) Design for Manufacturing
    a. Objective: Design an easy to produce cane with minimal cost and complexity
    b. Metrics: Manufacturing cost($/unit). Production time (h/unit)
    c. Constraints:
        i. Assuming the tools are provided by the Makerspace, materials selection allows production within a budget of 75$
        ii. Assembly requires no more than 3 steps
    d. Design criteria:
        i. Use of off-the-shelf components where possible
        ii. 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
3) Design for Usability (and portability as a sub aspect)
    a. Objective: Enhance user experience by ensuring the cane is easy to use, carry, and store
    b. Metrics: weight (kg), foldability and compact storage dimension (cm)
    c. Constraints: weight is below 0.8kg, folded length is les than 30% of initial length

d. Design criteria:
    i. Ergonomic handle is designed for prolongated use
    ii. Lightweight but durable materials such as aluminum or carbon fiber
    iii. Foldable cane with a secure locking mechanism

4) Design for Speed
    a. Objective: Minimize the time required to bring the product to the market
    b. Metrics: Time to finish the ideation process. Time to complete the final prototype.
    c. Constraints: Choice of concept will be made in the next 2 weeks. Final prototype created and tested by the design day
    d. Design Criteria:
        i. Rapid prototyping using 3D printing to receive feedback fast.
        ii. Design multiple pieces at the same time in order to shorten the design process
5) Design for Reliability
    a. Objective: Ensure consistency and durability of the product throughout its life
    b. Metrics: Product lifespan in years, number of successful uses before failiure (cycles)
    c. Constraints: The cane maintains functionality for a minimum of 5 years and withstands 10000 successful uses without failure
    d. 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	Imp.
1	The cane is lightweight	4
2	The cane is useable with only one hand	5
3	The cane assembles and disassembles quickly	4
4	The cane assembles and disassembles using one hand	5
5	The cane comes with carrying pouch to store it	3
6	The cane resembles a walking stick	3
7	The grip of the cane allows for hand extension	3
8	The cane supports the user's weight	4
9	The cane is compatible with client's active lifestyle	4
10	The cane indicates that the user is disabled	2

***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 has an invisible disability, would like some form of	- 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

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

Figure 2

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

Figure 3

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

Figure 4

Figure 5

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

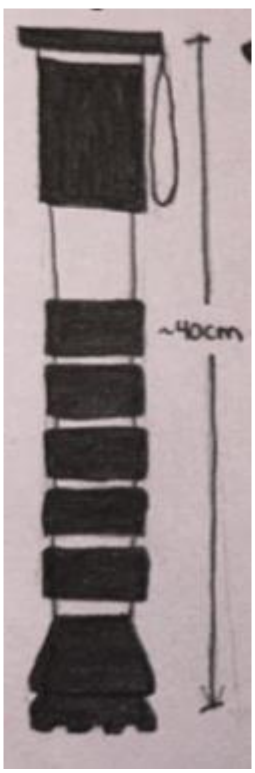


Figure 6

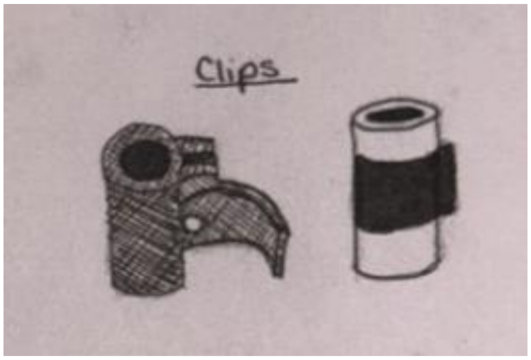


Figure 7

Design 2: Folding

Figure 7: Folding pole

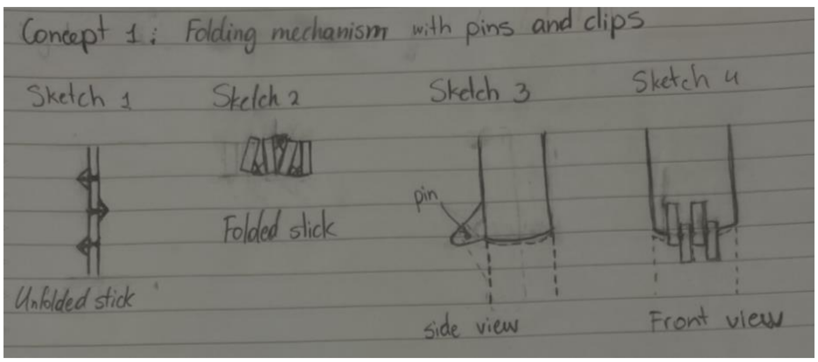


Figure 8

Design 3: Telescopic with button

Figure 8: Telescopic Pole with Buttons

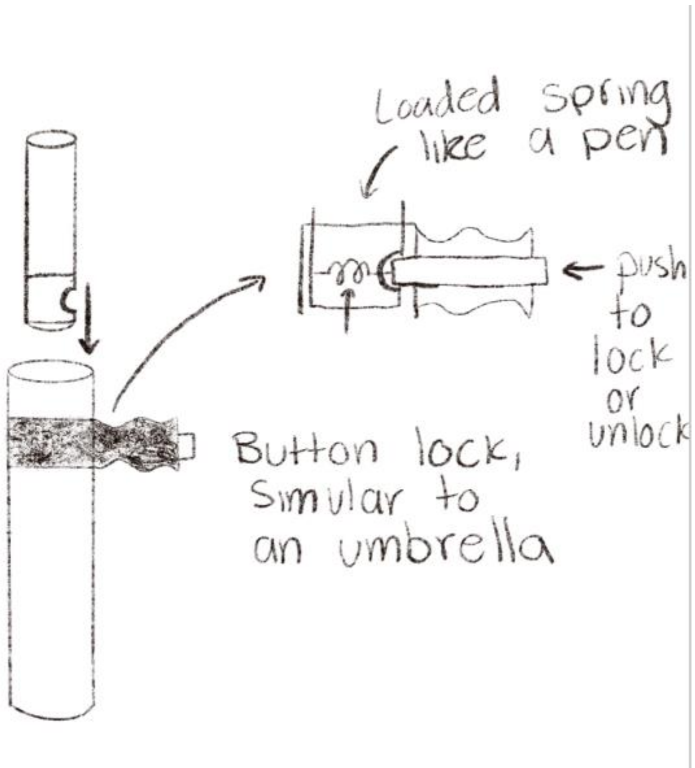


Figure 9

Design 4: Push-Push Mechanism

Figure 9-10: Push-Push Pole

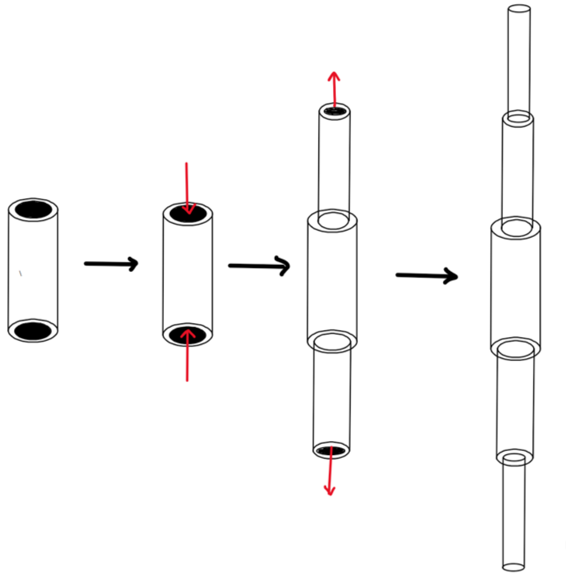


Figure 10

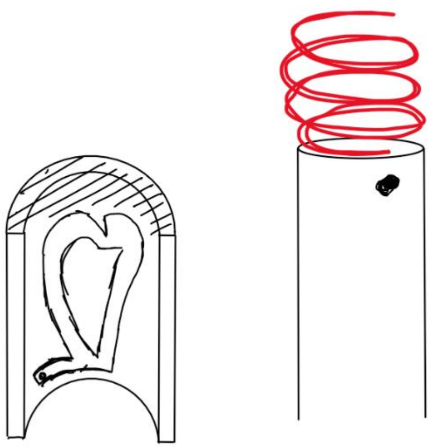


Figure 11

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

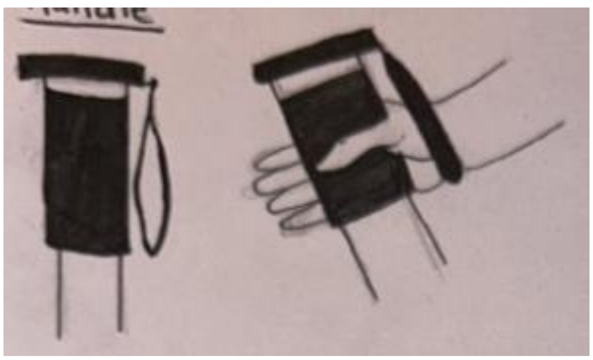


Figure 12

Design 2: opera/crutch grip

Figure 12: Opera/crutch Grip

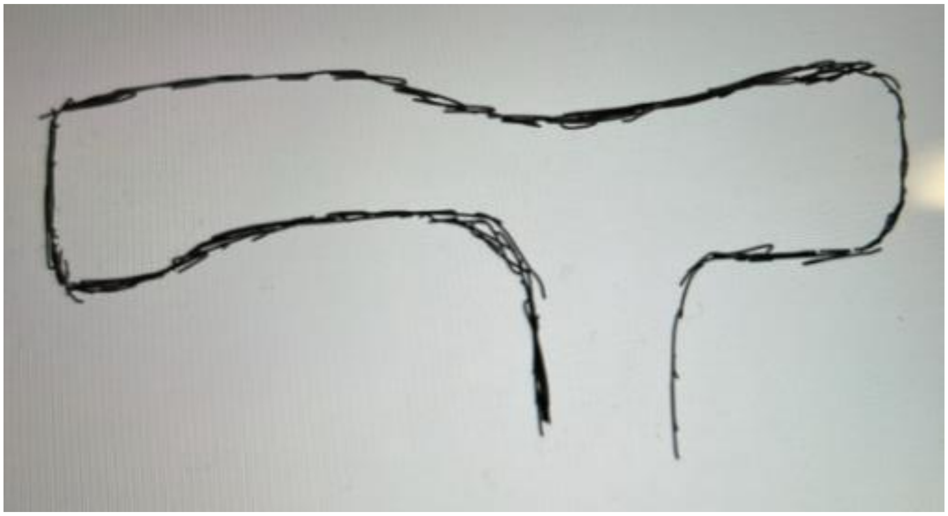


Figure 13

Design 3: Forearm Walker Grip

Figure 13: Forearm Walker Grip

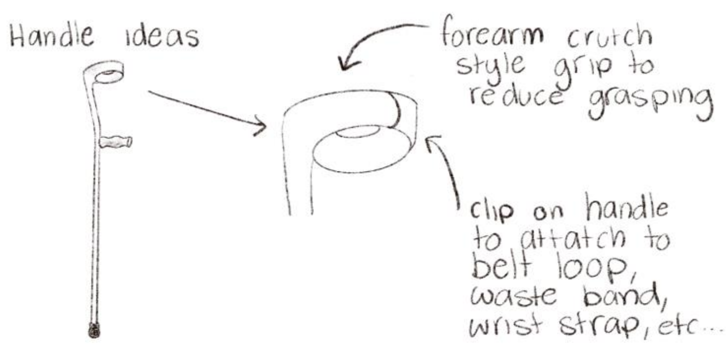


Figure 14

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

Figure 15

Design 2:

Figure 15: Round Tip

Figure 16

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

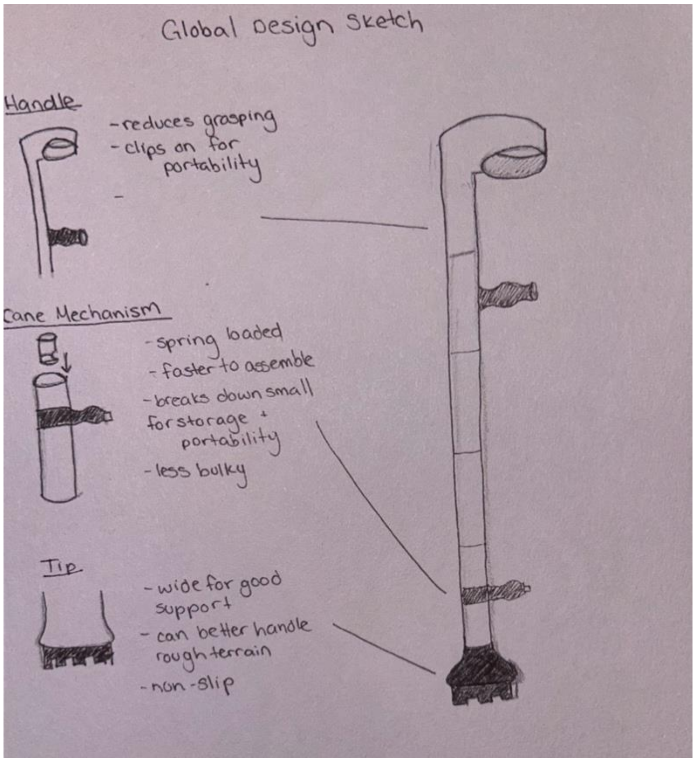


Figure 17

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.

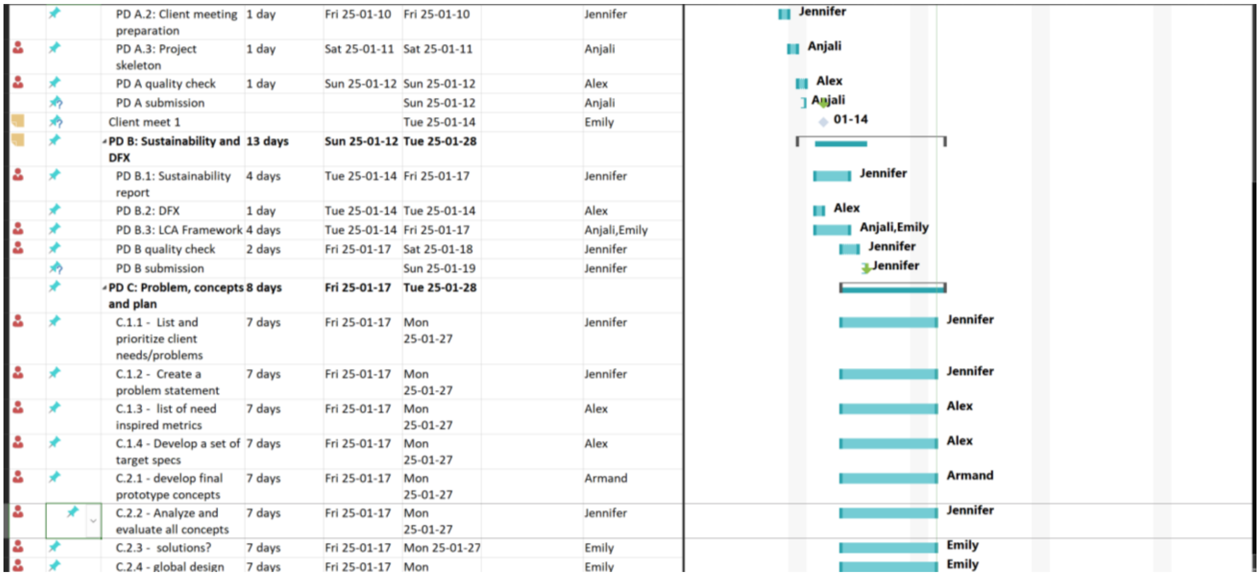
3.7 How the concepts relate to the DFX

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

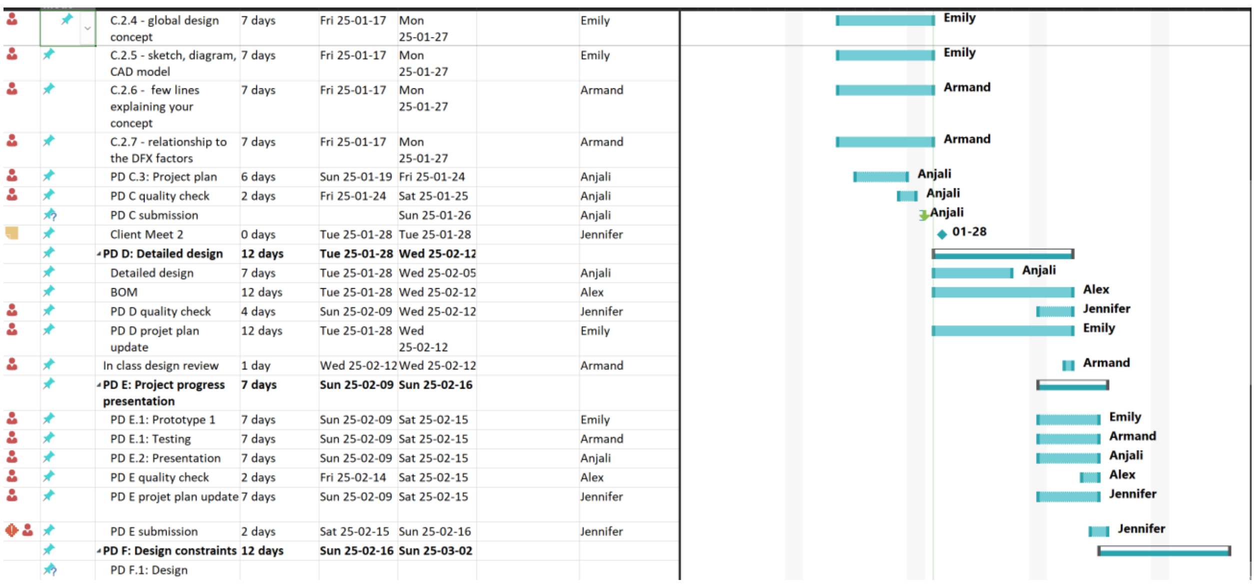
Project Plan

Figure 17: Project Plan



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	7 days	Fri 25-01-17	Mon	Emily

Figure 18



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				

Figure 19

3. 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.

4. <u>Detailed Design</u>

The detailed design for our project incorporates three main sections: the handle, the body of the cane, and the tip. The way we have designed our model, the handle is the most important and complex part of the cane, housing the entire retraction system, as you can see in figure 1. The design works like a tape measure, a string is attached to the bottom tip of the cane. Upon extension, the unravelling cord tightly wounds a spring that locks using the teeth and pin seen in figure 20. When the pin is released, the tension in the spring retracts the cane back quickly, returning the spring it's relaxed state, and the cane into a retracted position.

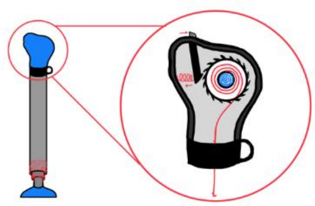


Figure 20: Retraction System Housing in Handle

The body of the cane is composed of three hollow aluminum tubes. The tubes have a thickness of 15 mm, and a length of approximately 30.5 cm in length. The first section has a diameter of approximately 5 cm, the second tube of 4.5 cm, and the last section around 3.8. The proposed design will roughly look like figure 21 when they are extended and retracted.

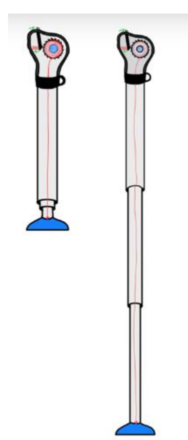


Figure 21: Extended and Retracted Cane

Upon extension, the cane will have a total length of approximately 120 cm, while in a retracted state it will be approximately 50 cm, as seen in figure 22.

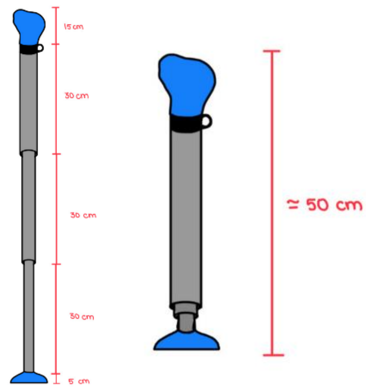


Figure 22: Extended and Retracted Cane Measurements

Since the retraction mechanism does not lock the rod sections in place, an external 3D printed locking system is bolted to the shafts. Figure 24 shows how the twist lock mechanism will be used to ensure that the cane does not fold upon pressure.

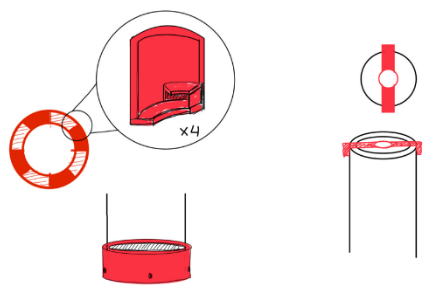


Figure 23: 3D Printed Twist Lock Mechanism

5. <u>DFX Factors</u>

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.

6. 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.

-

7. 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.

8. 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

9. Bill of Materials

Item name	Description	Quantity	Unitary cost	Total price	Link
Aluminum pipe	3 tubes in compatible diameters are needed to slide into each other	3	20.51	61.53	Amazon
Plastic gear	Component is part of the retracting mechanism	1	8.49	8.49	Walmart
Fishing Line	Attached between the bottom piece and the handle, it will help retract the cane	1	4	4	Decathlon
Steel compression spring	Component will help bring the button into the initial position	1	2.82	2.82	Homedepot
Extention spring	Component will be attached to the fishing line for the retracting mechanism	1	2.96	2.96	Homedepot
PLA/ABS filament	Material necessary for prototyping the tip and the handle, button and other	100	0.13	13	Makerstore
Silicone mold kit	Kit will be used to mold a handle that is soft to touch and comfortable to hold	1	25.62	25.62	Amazon
Spring Clip	Component will be used to fixate the telescopic tube in compacted position	1	2.14	2.14	Amazon
			TOTAL	120.56	

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.