

GNG2101

Design Project Progress Update

Walker Loading B2.2

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
BMC	Business Model Canvas
BOM	Bill of Materials
CAD	Computer Aided Design

Table 2. Glossary

Term	Acronym	Definition

1. Introduction

The document at hand outlines the comprehensive plan and approach taken by our team for the design and development of a device capable of effortlessly lifting and lowering heavy items, such as a walker, in and out of the trunk of a car. For this project, it is necessary to gain an understanding of user experience aspects as well as considerations for vehicle adaptability, weatherproofing, usability, and cost. Our goal is to create a versatile solution that minimizes any potential damage to the car, is user-friendly, and adaptable to different car models.

Assumptions:

In the context of this project, we assume that:

1. The primary user base consists of individuals with limited user mobility who use walkers for assistance.
2. The device is capable of lifting and lowering heavy items in and out of a variety of car trunks without causing any damage to the vehicle.
3. The device can withstand various weather conditions and function as designed.
4. Installation and maintenance, if any, should be straightforward and easy for the user to perform.
5. The device should aim for universality, being adaptable to different car makes and models.

This deliverable structure starts by providing an overview of the project and its goals, outlining the assumptions made for the project and describing the document's structure and purpose. It contains the selected Business Model Canvas and DFX. For this deliverable the document states and explains our value proposition, discusses the BMC, market analysis, revenue streams, etc. Also, highlighted are the core assumptions made in the BMC, a sustainability report that analyzes the pros and cons of the project's social, environmental, and economic impacts and a selection of five Design for X (DFX) principles and how they will be integrated into the project.

Purpose and Scope:

The purpose of this document is to provide an overview of our project to design a walker loading system for car trunks. Our scope encompasses the entire project cycle, from defining objectives to design, testing, and usability considerations. The goal is to create a system that

improves the quality of life for individuals with accessibility limitations, ensuring their ability to transport walkers or heavy items with ease and independence while accommodating various car models.

2. Business Model Canvas and DFX

2.1 Business model and sustainability report

Value proposition:

Providing the ability to overcome limitations with loading heavy items into the car trunk. Our product's main goal is to give people with accessibility limitations the opportunity load/unload the trunk of the car without relying on the assistance of someone else.

2.1.1 Business model Canvas:

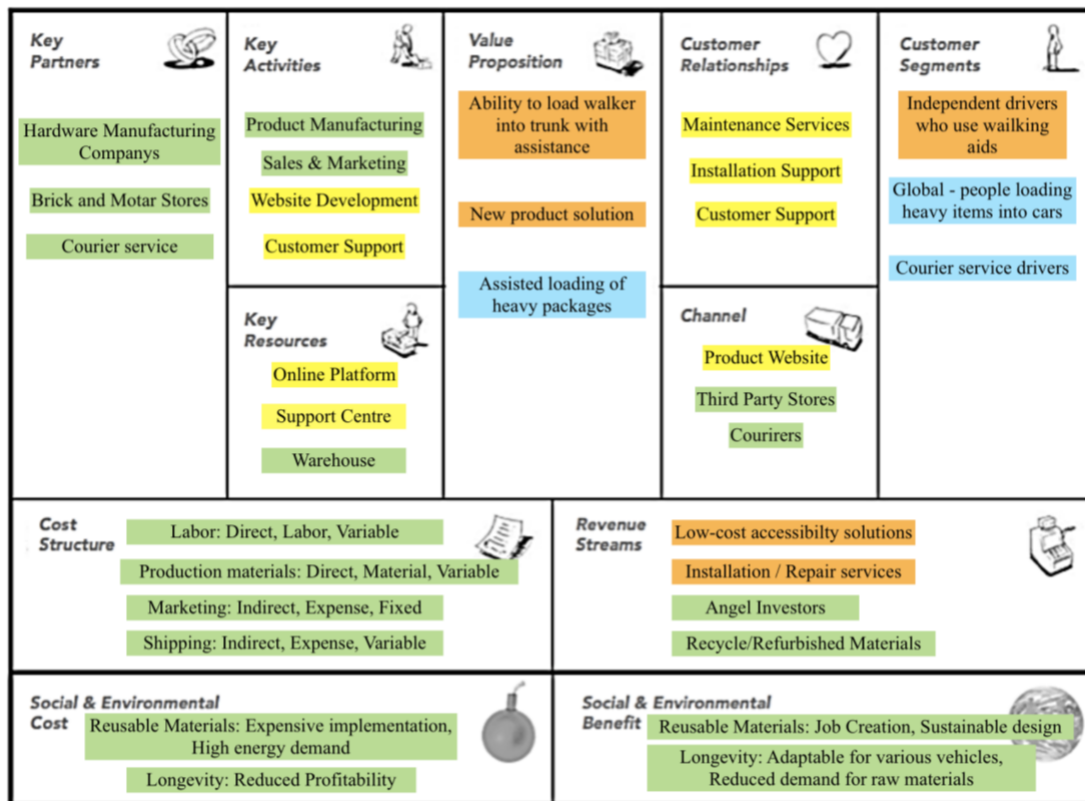


Figure 1 - Business Model Canvas

Value Proposition:

The value proposition addresses the main goal and a common problem that individuals with accessibility issues face. When people with walkers need to drive alone, they often have problems

with lifting their walkers into the trunk. The product offers a solution to loading and unloading the walker without the assistance of someone else and this will allow user to have the ability to drive without requiring someone to assist them with loading the walker. The target audience are people who struggle with lifting their walkers into the trunk without assistance. Currently there are not many options available to help with the loading and unloading of walkers. Hence, the product will fill the gap in the market and give people a better option to resolve this limitation. A lack of alternative solutions means that customers who face this problem have limited options making them more likely to purchase this product. In addition to loading walkers, it could also assist with the loading and unloading of heavy items into the trunk. It's versatility enhances potential by allowing it to load other items into the trunk besides walkers and this attribute will make the product more appealing to other audiences both with and without mobility limitations.

Customer Segments:

The primary customers are independent drivers who use a walking aid. The intended goal of the product is to help people load and unload their walker from the trunk. They are the ones who we are creating the product for. However, since the product is versatile, it could be adapted and used in different situations. It could be adapted to help people with loading heavy items into their trunk or assist courier service drivers with their jobs.

Customer Relations:

To develop strong customer relationships, we would offer repairs, provide installation assistance, and customer support. Including these three vital factors will help develop strong customer relations with loyalty and trust. Providing repairs will ensure that the products' quality is upheld, and satisfy customers as they would be able to extend the lifespan of their product. Providing installation assistance would guarantee that our product is properly secure and safe to use while allowing customers to easily integrate the product into their vehicles, minimizing any potential installation errors. This is important for troubleshooting issues, addressing any questions, and providing real time assistance. Given that the target audience are people with accessibility limitations, having readily available support ensures that customers can receive immediate help.

Channels:

There are 4 main ways that we will deliver the product. The first way is through shipping our products. Using courier service partnership, we would be able to ship the loaders to customers. We will also have loaders in developed stores that we partner with. People will be able to physically view and buy the loaders inside Brick-and-Mortar stores. Using an online platform, customers will be able to view specific details, purchase the walker loader online and have it shipped to their homes.

Key Partners:

Partnerships with brick-and-mortar stores would involve agreements with physical stores that would sell our walker loader. The device is designed to aid individuals with physical limitations by loading their walkers into the trunk. Having our product displayed in a physical store would allow potential customers to test out our product to see if it would be able to assist them. Only having our product online would limit the number of customers we would attract. We would also be able to increase the visibility of our product and utilize existing store relationships. Majority of businesses require manufacturers to function. Since we would need to build many walker loaders, manufacturers would ensure the same quality and specifications are upheld while our product is being built. Having manufacturers would ensure that our product is being built with minimal cost, efficiency, and quality. Developing a relationship with manufacturers can also guarantee that we are able to meet demand. We plan on having a website for our product and having a courier service would allow us to ship our product efficiently to our customers. Having a relationship with a courier service is vital because it would allow us to save money as we ship more products. Advertisers would help with the marketing of the product. They would develop and execute various promotional campaigns to increase the products' visibility. Effective marketing is vital to the product by helping us reach the target audience and build brand recognition. The target audience is people who struggle with loading and unloading their walkers from the trunk without assistance.

Key Activities:

Having an online platform is essential to the survival of a business. Having an online platform would allow us to sell the product directly to our clients, provide information about the

walker loader, and provide support to customers. An online platform would provide a more convenient and accessible option for customers to view our product remotely and access important information regarding the product. The online platform would also allow us to expand the audience and gain attention. Maintenance of our product is important because it will ensure that the product is working correctly, and any defects will be resolved quickly. By providing maintenance on the product, it would guarantee customer satisfaction and ensure the products' quality is upheld. Regular maintenance would also extend the lifespan of the product, which would lead to stronger customer relationships. Extending the lifespan of the product benefits the environment because we would not need to make as many loaders. Sales and marketing would involve the promotion of our product, generating revenue, and gaining customers. An effective sales and marketing campaign is important to gain product awareness. Marketing activities will allow us to target our intended audience and build strong customer relationships. Customer support involves addressing customer issues, providing technical support, handling customer feedback, and ensuring customer satisfaction. Excellent customer support is important when building loyalty and trust between our business and our clients. Customer support would allow us to resolve issues quicker, thus keeping our customers happy.

Key Resources:

Some of the key resources that we will use are an online platform, a warehouse, a HR department, and a customer support call center. An online platform is crucial to the success of our business. It will allow us to sell our product online, provide customers with important details about the product, and assist customers with any questions they have. A warehouse is important because we would use the warehouse to build, store, and ship the products. Having a warehouse will also allow us to store all the materials required for building the loader. The HR department will help us manage the business by hiring employees and finding suitable managers to manage the business. HR will also ensure that the safety protocols are being followed, and the department will properly train employees to be effective in the work force. Finally, having a customer support call center is important to address all our customers' needs and questions. Customer support is important because it will allow for seamless communication between our business and our customers. Plus, we would be able to help our customers in real-time if they are having problems with the product.

Cost Structure:

There are 4 main costs that would be involved in our business. The costs are labor, materials, marketing, and shipping. labor is a direct cost because it directly relates to the production of our product. It is a labor cost and would be variable because the salaries would vary based on production levels. Materials is the next cost which would be direct since it is a part of production. It is a material cost and would be variable since it depends on production levels. Marketing is indirect because it does not directly relate to production. It is an expense that is fixed because it does not change based on production levels. Shipping is indirect because it relates to the distribution of the product. It is an expense that is variable because it depends on how many walk loaders we ship.

Revenue Streams:

There are many ways that we could generate our revenue streams. The first way would be to lower our manufacturing cost then price the product a bit higher than the manufacturing cost. This would be how we price the product, and the product sales would be a major revenue stream. There are also other fees that we would implement to make money. Some of the fees would include installation and repair service fees. We could also use angel investors to finance our company in the beginning.

Core Assumptions:

One of our main core assumptions is the type of customers. Currently our primary customers are independent drivers who use walking aids, people loading heavy items, and courier service drivers. The assumption is feasible because there are not many products currently that target loading and unloading walkers from the trunk. There is a clear need for our product among people who use walking aids. However, more research would need to be done regarding whether our other target audiences would integrate this product into their lives.

Market demand is another core assumption that we have made. Our assumption is that there is a significant demand for our product. This assumption is probably feasible since there are people who struggle with loading heavy items into the trunk. Although there are people who struggle with

this problem, we cannot be sure whether there would be a high demand for this product. Some people might not want to purchase this product and store it in their trunk.

Adding to our list of core assumptions is profitability. Our assumption for profitability is that we would make enough revenue from our product and services to stay profitable. This is feasible if we have proper financial planning and adequate streams of revenue. There would need to constantly be marketing campaigns to ensure that we sell enough products and have visibility. However, we cannot know for sure if people will purchase our products and services.

Another assumption we made is that we will have a dedicated customer support call center. This is feasible and completely possible; however, it will require vast amounts of planning and logistics. It would take a lot of resources and training to make the support center a success and have it function effectively. Throughout our business canvas model, we state how the support center would be an important part of the business. The support center would complete a variety of tasks such as providing real-time help and addressing any concerns. For the support center to accomplish these tasks the workers would need a thorough knowledge of the product. This might be hard to accomplish if they do not have the right educational background.

2.1.2 Sustainability Report:

In the past, environmental concern was not strongly considered when developing a product. Generally speaking, it requires a significant amount of resources, time and money, ultimately impacting the company's profit. But there is a way to conserve positive net profit and become environmentally conscious: through the lens of sustainability. A sustainable business must consider the "triple bottom line", a balance of the environment, society and economy. In other words, a successfully sustainable business must focus attention on the planet, people and its profit. As such, our most significant impacts are detailed under groupings of *Recyclable Materials* and *Product Longevity*.

1. Recyclable Materials (RM:

As a company or as an engineer, one should be responsible for their product and its life-cycle, accounting for what will happen at the end of the product’s life. It is evident that many companies only consider their profit when choosing their product’s materials.

Table 3 - Environmental Impacts (RM)

Positive	Negative
<p>The most predominant benefit is that recyclable materials can produce new products. Although self-explanatory, the reuse of “old” materials can drastically diminish the quantity of virgin materials that the company consumes. This could decrease involvement in creating new waste products sent to landfills, which in turn generate green gas emission as mentioned by the government of Canada Department of Environment and Climate Change (Government of Canada, 2023). For example, Apple Inc. estimates that nearly 20% of all materials used on Apple phones in 2021 was recycled, and that 59 – 100% of products shipped with aluminum enclosures was recycled aluminum. (Apple Newsroom, 2022).</p>	<p>More often than not, products consist of a variety of different plastics in an effort to reduce manufacturing cost-per-unit. However, recycling plastics is an extremely expensive endeavor. Due to the nature of plastics, each has a slightly different composition which requires that each piece be exhaustingly sorted. The process requires lots of energy to generate heat that melts the plastics down. Also, in the case of some plastics, less than pleasurable gasses are expelled into the air. Though from an economical perspective plastics are low-cost, ethically and economically the recycling process does not provide a valid solution.</p>
<p>When materials are sustainably sourced, not only do they respect guidelines for the workers, but also environmental regulations. Sourcing raw materials from these suppliers can reduce the impact generated on the environment and ensure the clients get the best materials. When sourcing materials that are sustainable, the</p>	<p>While recycling is always a good idea. It does have a few negative points. Recycling requires a lot of energy. From transportation, separation, cleaning and sent to new factories. Not only that, but many chemicals and metals leach into the surrounding environment where the recycling is taking place.</p>

Table 4 - Economic Impacts (RM)

Positive	Negative
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<p>When designing a product at a certain consumer price point, there are likely to be customers who fit below the target price and cannot afford to purchase the product. Thus, claiming and refurbishing our previously owned products at a discount opens up the possibility of more people getting to use the product. The discounted price incentivizes buying refurbished as: “consumers are willing to pay approximately 16% less for a remanufactured camera than for a new one” (Harms and Linton, 893, 2016). Having a lower environmental impact is also a by-product that may attract customers who are “eco-friendly”. To those who bring their old products back to us, credit can be distributed, incentivizing them to recycle and continue to purchase from us.</p>	<p>As a business committed to recycling and proper disposal of waste, it is clear that on top of all our regular business expenses (warehouse rent, machinery, salary, etc.) we must consider infrastructure for recyclability. Several factors play into the cost for an in-house recycling facility; however, it is estimated that to fully equip a recycling facility in the United States would cost upwards of 20 million dollars (ICTSD). While our recycling facility would not amount to the same level as a general-purpose facility, there would remain an incredible initial cost to start recycling.</p>
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Table 5 - Social Impacts (RM)

Positive
<p>While our company would need to overcome the initial cost of starting a recycling platform, it would create job opportunities in the surrounding area. It is estimated that “recycling creates on average nine times more jobs than trash”, where the EPA’s 2020 Recycling Economic Information Report states that recycling and reuse accounted for 681 000 jobs in the United States (Eco Cycle, 2022). The benefit to creating jobs in a possibly low-income area is that it would inject the neighborhood with income and infrastructure, with the potential to grow.</p>

2. Product Longevity (PL):

Almost every customer investing in some product would request longevity. For example, household appliances come at a usually high consumer price point, and with that the customers expect 10, 20 or even 50 years of use, and possibly retain their functionality in a new house after a move. It is clear however that products are not always “made-to-last” as it can negatively impact profits.

Table 6 - Social Impacts (PL)

Positive
Creating a product that is made to last much longer than others on the market will incentivize people to buy a product and transition it between vehicles when needed. Typically, people transition between cars every 2-10 years, thus having a product that will endure a decade worth of abuse creates a positive reputation for our company, and a customer that will surely come back.
When we source our sustainable materials ethically, we are ensuring that the workers are paid fairly and no kids are working. We are also making sure that the workers are not around harmful chemicals.
We can create more jobs when recycling. While recycling does take quite a few steps, each step is conducted by people. This would mean creating more jobs not only nationally but even in other parts of the world.

Table 7 - Economic Impacts (PL)

Positive	Negative
Having one product for a long duration of time, wearing the product down, means the product will likely require repairs at some point in the product's lifespan. For our company to create a repair service for older models means we can continue to receive profit off the same sale. The repair service would have to be offered at a premium, but considering our business model centers around longevity, the customer is likely to pay for repairs.	While ethically creating one “do-it-all” product is beneficial from a societal standpoint as you build a fundamental customer relationship, and environmentally less product will be made to counteract less demand, ultimately hurting profits.
Normally, when companies think of ethically sourcing and sustainability, we believe the costs of production are higher, but if done right, we can reduce costs in the long term. We could decrease these costs by up to 16% while boosting brand value by up to 30%, as mentioned by World Economic Forum (2015).	

2.2 Design for X

Design for Adaptability:

In the client interview, the client had highlighted the value of being able to adapt the solution to different car models and to address this, design for adaptability is selected as a vital element to consider. The device will be designed to be adaptable with the intention of allowing the user to be able to implement the product when switching to a different car. This is an ideal concept that would be accounted for when generating solutions and is related to the client's statement. Additionally, taking into account that the client has recently purchased a new walker, the device would also need to accommodate such situations. In terms of implementing this to design a universal solution, the device would fit into different vehicles and be useful for different walkers.

Design for Reliability:

With the understanding that this project aims to offer accessibility solutions, another vital element that the solution would focus on is the design for reliability. The main requirement of reliability that would be incorporated into the design of the loading system includes function, performance, lifespan and environment. The user will be driving around without assistance and needs to be able to make use of the preferred solution independently. To this end, the device is to be dependable, secure and consistently in good performance. Also, the loading system would operate normally in different weather conditions and would not cause any damage to the car during use. The system would be designed to require minimal planned maintenance during its lifespan. Ensuring reliability would involve defining and collecting metrics that reflect the key indicators of the system's behavior and performance. This will be done in the next stage of this project.

Design for Usability:

Usability in the design of the loading system will be defined as a measure that assesses how easily the user can use it effectively and satisfactorily to lift the walker in and lower it out of the trunk of a car. An important criterion to satisfy usability is that the use of the device is easy to understand and learn. It also has to be memorable, which implies that it will be easy to remember

how to make use of the loading system. The design process would ensure efficient use when performing the loading task, account for possible errors during use, and how to recover from them. Additionally, user satisfaction is another criterion that would ensure that the device is easy to use. To test this design element, it would be beneficial to have the user make use of a prototype which would allow observation of successes and difficulties faced. The user has specific limitations that need to be considered for them to be able to use the device.

Design for Sustainability:

The design stage is the most influential in determining how a product will affect the environment, so it is necessary to review how the loading system will be built that promotes sustainability. Evaluating the lifecycle of the device through its raw materials, manufacture, distribution, usage, maintenance, and disposal would help reduce most of the negative impacts it could have on the environment. Selecting sustainable materials such as recycled materials for the components of the loading system would help reduce carbon footprint. The system could also be designed to be improvised for other uses or to meet the needs of consumers beyond the initial user it was designed for. Additionally, use of modular design would promote sustainability as it allows design with components as modules that can be used in multiple products. Modules are predesigned components with a specific function and the advantages of this include cheaper and easier manufacturing, assembly, replacement, repair and disposal.

Design for Cost:

The client is seeking an affordable solution and to meet their needs the fifth element selected to guide the design of the loading system is the design for cost. For this project the expected cost is estimated at \$100, hence it is essential that the design technique controls the cost of the device development and manufacturing. By considering the overall cost of the product and lower engineering costs of the product from the initial stages of design, unnecessary costs can be prevented.

3. Problem Definition, Concept Development, and Project Plan

3.1 Problem definition

Problem Statement: Design a weatherproof, safe, durable and adaptable system to lift a walker in and lower it out of the trunk of a vehicle. It is to be used independently by an individual who uses a walking aid without causing damage to the car or to the walker.

Mobility limitations prevent some people from loading and unloading heavy items to and from the trunk. The solution could be a device that secures to the trunk which automatically loads and unloads the items.

Known Variables: Budget, Weather requirements,

Unknown Variables: Car dimensions,

Table 8 - Customer Needs

#	Need	Imp	
1	The loading system	operates normally in various weather conditions	5
2	The loading system	is adaptable to different vehicle types	3
3	The loading system	can lift various folded walker models	1
4	The loading system	preserves the quality of the car	4
5	The loading system	is easy to install	3
6	The loading system	is affordable and within budget	1
7	The loading system	lasts a long time	5
8	The loading system	is safe to operate	5
9	The loading system	allows for easy maintenance	3
10	The loading system	does not take up all the trunk's capacity	2
11	The loading system	preserves quality of the walker	5
12	The loading system	does not require a high degree of mobility to operate	5

*Rating used: 1-5 (1 being worst, 5 being best)

Table 9 - Interpreted Metrics

Metric #	Need #	Metric	Unit
1	6	Price (CAD)	\$
2	2,10	Dimensions: Length x Width x Height	in
3	4,11	Exterior Storage of Walker	Y/N
4	2	Exterior-Mounted Device	Y/N
5	12	Degree of Mobility Required	level
6	3,8	Load capacity	lbs
7	1,7	Material	list
8	9	Degree of Recyclability (of Materials)	level
9	8	Weight of Unit	lbs
10	5	Ease of Use	level
	5,9	Tool for installation	list

Table 10 - Benchmark on Metrics: Competitive Products

Metric #	Need #	Metric	Imp	Unit	Exterior Hitch Carrier	Hitch-Mounted Lift	Trunk-Mounted Arm/ Hoist	Ramp
		Company	-	-	Steady Carriers	Viking Solutions	MillerCare	Ganggend
1	6	Price (CAD)		\$	399.00	355.99	Unknown (Requires a Quote)	159.99
2	10	Dimensions Length x Width x Height		in	Length from hitch 12 x 19 - 26	60 x 36.5 x 52	N/A (Inquired)	36 (closed position) – 60 (open position) x 7.4
3	4,11	Exterior Storage of Walker		Y/N	Yes	No	No	No
4	2	Exterior-Mounted Device		Y/N	Yes	Yes	No	Only in Use
5	12	Degree of Mobility Required		level	High	Moderate	Low	High
6	8	Load Capacity		lbs	Unknown	300	176.4 – 220.5	600
7	1,7	Materials		list	Steel Tubing and Stainless-Steel Hardware	Steel Tubing and Stainless-Steel Hardware	Unknown	Aluminum Alloy with plastic non-slip portions
8	9	Degree of Recyclability (of Materials)		level	High	High	N/A	Moderate
9	8	Weight of Unit		lbs	< 9	54	Unknown	12.71
10	5	Ease of Use		level	Moderately Easy	Moderately Easy	Easy	Easy

*All product's images and specifications are listed below:

Benchmarking:

Product 1: Steady Rollator Carrier – Single – SRC-30



Figure 2 - Exterior Hitch Carrier

Mounting occurs as rear wheels fit into mount, then fold up. Requires front to back folding walker. Attaches to hitch, and due to the materials generally speaking can support the weight of many different walkers. But requires high degree of mobility.

Product 2: Swivelift – Hitch Mounted Games Swivel Lift



Figure 3 - Hitch Mounted Lift

Although not directly related to accessibility, serves similar purpose. Walker would rest on the platform and raise up to comfortable level. Not listed but looks like steel tubing and stainless-steel hardware. Lifting mechanism is a winch, thus may require a moderate degree of strength and mobility.

Product 3: Millercare Autochair Car Boot Hoist



Figure 4 - Trunk Mounted Arm Hoist

Product 4: Wheelchair Ramps for Steps 3 to 5 ft, Adjustable Aluminum Ramp 2 pack



Figure 5 - Wheelchair Ramp

The ADA (American with Disabilities Act) provides a guideline on ramp slope for occupied and unoccupied wheelchairs. We only require that of the unoccupied ramp, which states that the recommended slope be for every 3 in vertical rise there is a 1 ft of ramp (approx. 14.5 degrees). Retractable design, allowing it to slide into a trunk for storage. In addition, boasts non-slip tracks.

Table 11 - Marginal and Ideal values

Metric		Unit	Marginal Value	Ideal Value
1	Price (CAD)	\$	159.99 < x < 399.99	200.00 < x
2	Dimensions inside vehicle: LxWxH	in	36 x 7.4 x H	< 37.8 x 43.3 x 35.4 (Dimensions of Trunk)
3	Exterior Storage of Walker	Y/N	N/A	N/A
4	Exterior-Mounted Device	Y/N	N/A	N/A
5	Degree of Mobility Required	level	Low < x < High	Low
6	Load capacity	lbs	176.4 < x < 600	26.5 (weight of walker) <
7	Material	list	N/A	N/A
8	Degree of Recyclability (of Materials)	level	Moderate < x < High	High
9	Weight of Unit	lbs	9 < x < 54	9 < x < 54
10	Ease of Use	level	Easy < x < Moderately Easy	Easy

Table 12 - Final Target Specifications

Metric		Unit	Value
1	Price (CAD)	\$	200
2	Dimensions: Length x Width x Height	in	< 37.8 x 43.3 x 35.4
3	Exterior Storage of Walker	Y/N	No
4	Exterior-Mounted Device	Y/N	No
5	Degree of Mobility Required	level	Low
6	Load capacity	lbs	26.5 <
7	Material	list	N/A
8	Degree of Recyclability (of Materials)	level	High

9	Weight of Unit	lbs	16
10	Ease of Use	level	Easy

3.2 Concept development

Concept 1

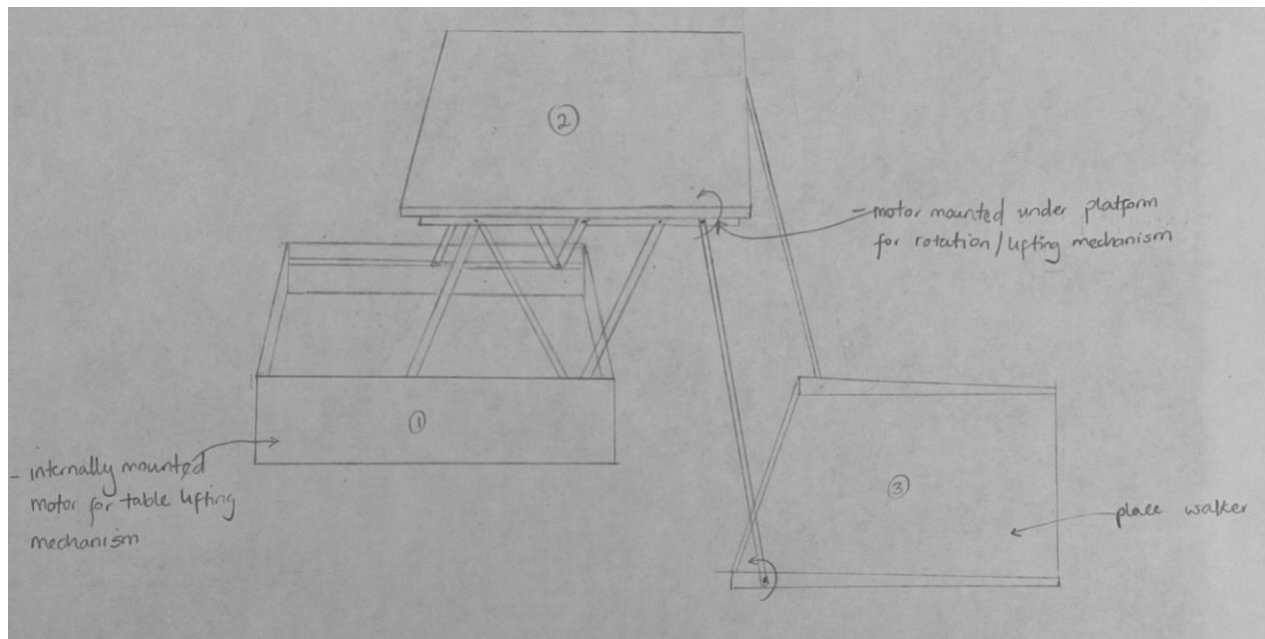


Figure 6 - Walker Loading System Concept 1

Subsystem 1: Power

System would require 2-4 actuators with each pair having equal capacity and power requirements. Power supply for the system would ideally be from the car system, however there may be need for extra power supply.

Advantages:

- Makes use of vehicle power system

Limitations:

- High power requirement for 3 actuators that can handle the target load capacity.

- High-cost requirement.
- May require additional power supply to power actuators

Subsystem 2: Lifting mechanism

Platform 2 is raised and pushed outward using a similar mechanism to that of a lift top hinge. The links from platform 2 to 3 is then rotated to bring platform 3 to the ground while keeping it constantly in a horizontal position. After walker is folded on platform 3, the reverse motion of the links from platform 2 to 3 lifts and places platform 3 on top of platform 2. Lastly, the links between platform 1 and 2 is lower to bring the walker currently placed on platform 3 to a stable position from the base of the trunk.

Advantages:

- Easy to use with 2 automated controls for each subsystem

Limitations:

- Requires estimations to accurately decipher actuator and link mechanism requirements that allow the platform 3 remain horizontal during the lifting process

Subsystem 3: Mounting

Platform 1 is attached to the base of the vehicle

Advantages:

- Parts can be designed using sustainable materials.
- Does not cause damage to vehicle and walker.
- Preserves storage capacity of trunk as items can be placed in platform 1.

Limitations:

- Dimension limitation to adapt design to vehicle trunk.
- Securing the platform to the base of the trunk may require vehicle modifications

Concept 2:

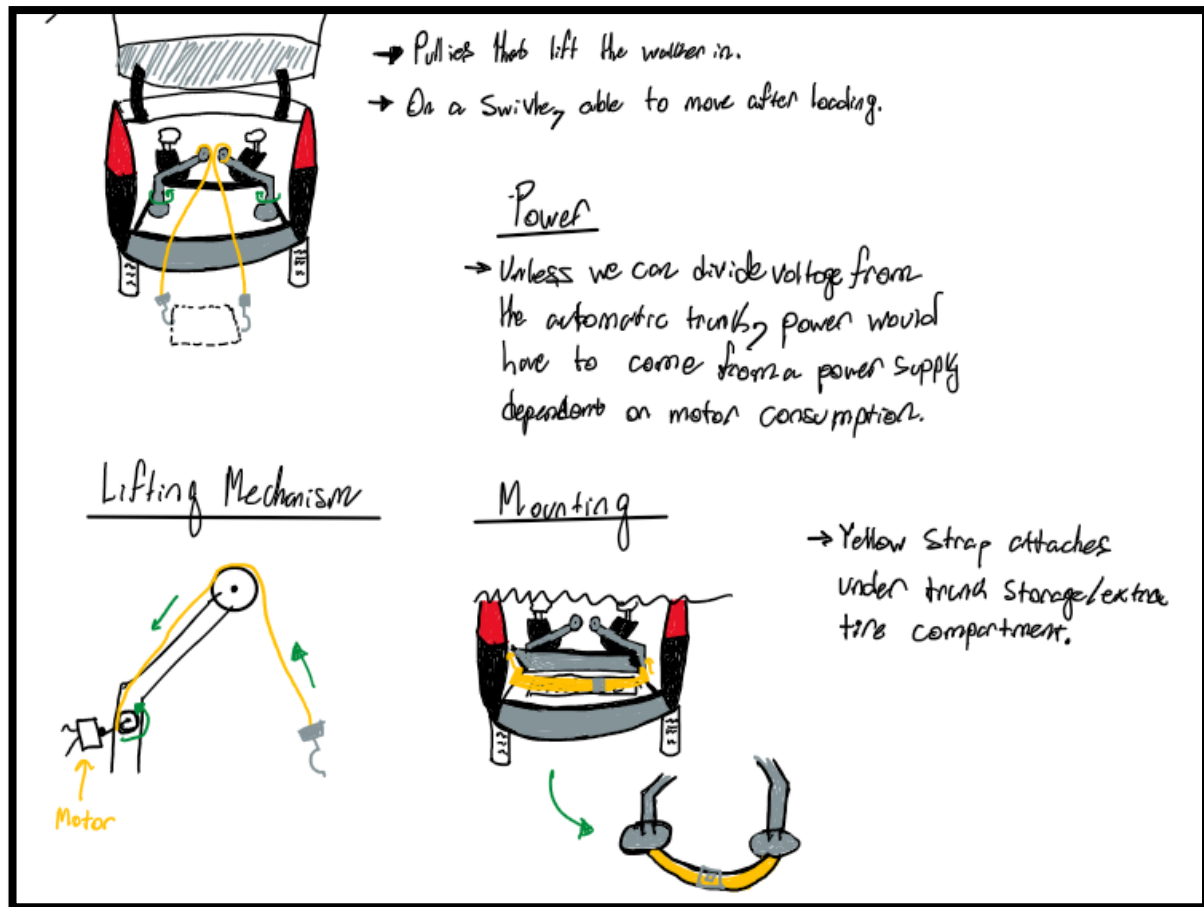


Figure 7 - Walker Loading System Concept 2

Subsystem 1: Power

Power of the system will be handled by either a splitter cable separating the trunks power into two sources or a cable coming from the vehicles centre-console 12V outlet.

Advantage:

- Very general solution, allowing adaptability for many vehicles.

Limitations:

- A long cable may have to be run from the centre console, disturbing passengers of the vehicle.

- Power may only come from a 12V outlet, restricting power.
- Splitting the trunk power may result in more battery usage if the car's alternator is not running.

Subsystem 2: Lifting Mechanism

Lifting will be done through a set of pulleys, each on a swivel being able to move out of the way when not in use and extend past to the car's trunk to reduce damage to the fender. Each pulley will be powered by a motor in the base connected to a wheel that will rotate clockwise and counterclockwise to lift and lower respectively.

Advantages:

- Due to having two pulleys, the less powerful and power-hungry motors are required, reducing power consumption and dispersing the load by a factor of ½.
- Pulleys on a swivel, enabling small footprint when not in use (retracted).
- Almost entirely automated lifting.

Limitations:

- Must use with caution as heavy objects may have the tendency to swing.
- Load capacity is average as all the translation occurs in the y-axis only.
- Moderate easy of use, but the user would be required to bend and attach hooks.

Subsystem 3: Mounting

Mounting of the devices is done by a strap that slides underneath the spare tire/ extra storage compartment.

Advantages:

- Can be easily removed and adapted to a new vehicle. No permanent modifications.
- Mounted inside the vehicle, not directly impacted by the elements, reducing maintenance.

Limitations:

- May cause inconvenience if spare tire/ storage compartment is accessed often.
- May move/ slide if object is on the limit of its load capacity.

Concept 3:

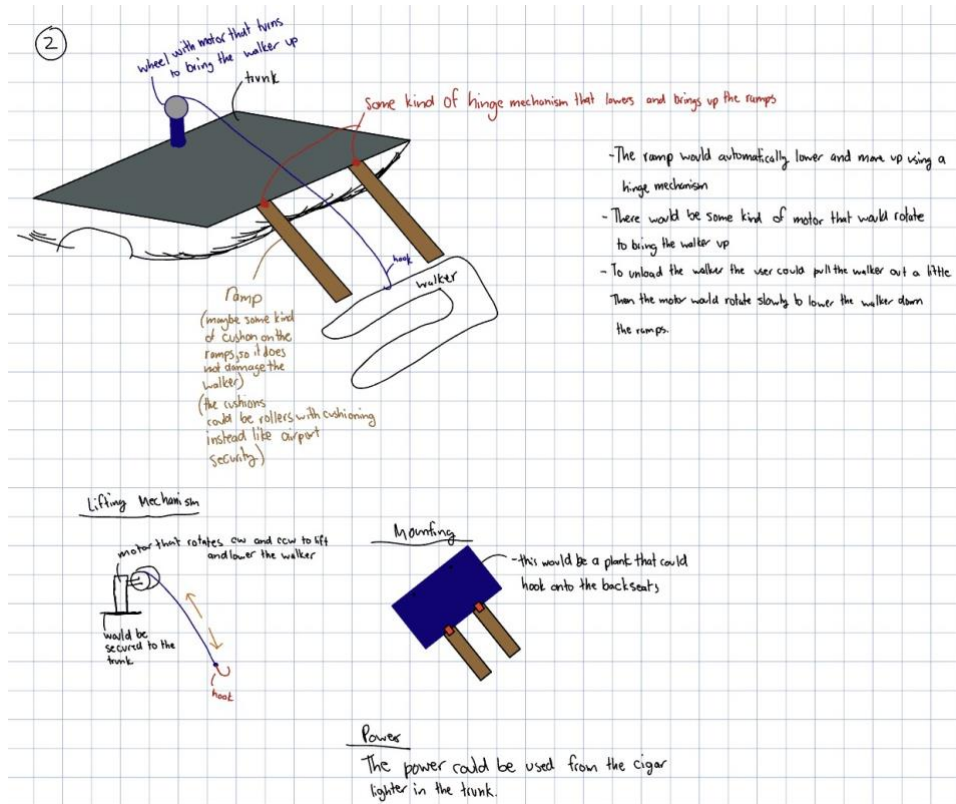


Figure 8 - Walker Loading System Concept 3

Subsystem 1: Power

The loader would get its power from the cigar lighter port in the trunk. It would power the hinges and the motor, so they could move automatically.

Advantages:

- The loader would be mostly automatic and would not require a lot of manual force.

Limitations:

- The car would need to have a cigar lighter in the trunk otherwise the loader would need to be changed.
- Depending on how much power the different subsystems would require the cigar lighter may not be able to handle the power consumption.

Subsystem 2: Lifting Mechanism

The walker will be loaded and unloaded using a motor which has rope or some type of strong material. The rope would be attached to the motor on one side and have a hook attached to the other side. The motor would rotate clockwise and counterclockwise to lift and lower the walker. The motor would be attached to the back of the plank.

Advantages:

- The ramp would not use too much trunk space.
- It is a simple design, so it would be easy to maintain.

Limitations:

- To unload the walker the user would have to pull the walker out of the trunk a bit. Once the walker is out enough the motor would rotate slowly to unload the walker.
- There would be a weight limit.

Subsystem 3: Mounting

The ramps would be attached to a large plank. The plank would be latched onto the hooks in the trunk which would hold the loader in place.

Advantages:

- The loader would not be permanent, so it could be used in different cars.
- When the loader is not being used it would use minimal space and it would be quick to remove.

Limitations:

- The loader would only function in cars with a SUV trunk style.
- Since it is not permanently fixed there would be a weight limit for the loader.

Decision matrix:

Selected Criteria	Weight	Concept 1	Concept 2	Concept 3
Ease of use	0.20	4	2	3
Cost	0.05	3	3	5
Dimensions	0.10	2	2	1
Load capacity	0.10	6	4	4
Degree of Mobility Required	0.15	6	3	2
Lifespan	0.10	4	2	3
Maintenance requirements	0.10	3	5	4
Safety	0.20	5	4	4
Total	1.0	4.35	3.10	3.15
Rank		1	3	2

Table 3.6 – Decision Matrix

*Rating 1-6 (1 being worst, 6 being best)

Global Concept – Concept 1:

First, the user adjusts the walker onto the lower platform. Then, the walker is secured to the lower plank to prevent it from rolling off. Next, the user clicks a button so that the lower platform goes on top of the second platform. Lastly, the second platform will go on top of the third platform. The user can then close the trunk of the car.

This concept was chosen since it is the safest and easiest model for the user. This concept requires minimal to no effort to put the loader in the trunk. The chosen concept can also lift the most weight since the links are made of metal and the system is sturdy, unlike the pulley system and the ramp. The chosen concept would also last the longest of the 3. The ramp only has two support points that hold all the weight of the loader. Thus, would break over a short period of time. The pulley system would quickly become weak as the rope gets used and dirtied by the outside weather.

3.3 Project plan

<https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=WXuwVV0jveAYzau1nl22VWIT3Aex3knJ%7CIE2DSNZVHA2DELSTGIYA>

4. Detailed Design and BOM

During the second client meeting, several key points of feedback were gathered for improving the design of the loader. The client prefers to load the device from the passenger side of the car, indicating a need for accessibility and ease of use from the righthand side. It's important for the design to allow the use of the right hand as a brace against the side of the car, implying that the device should provide support for bracing. The user prefers using their left hand to fold the walker, indicating a preference for left-handed accessibility. The button for operating the device should be on the right side for ease of use.

The client expressed interest in the use of pulleys as part of the design but raised concerns about the pulleys being too labor-intensive on the user, as well as potential damage to the car. The client preferred the global concept over the two designs with the pulleys and liked the idea of a box inside the trunk, as long as there is something the user can hold onto for support. The borders around the lowest platform would need to be removed so the user can roll the walker onto the platform more freely. The client has no preference on a power source for the device.

4.1 Detailed design

In summary, the device should prioritize ease of use, accessibility from the passenger side, support for bracing, and minimal obstructions. Considerations will also be given to pulleys and adaptability for the global concept. After the client meet, our group had concerns about staying within budget and software difficulties, which will also be considered to improve the design.

Based on client's feedback on presented concepts, the following figures contain the detailed design of the loading system:

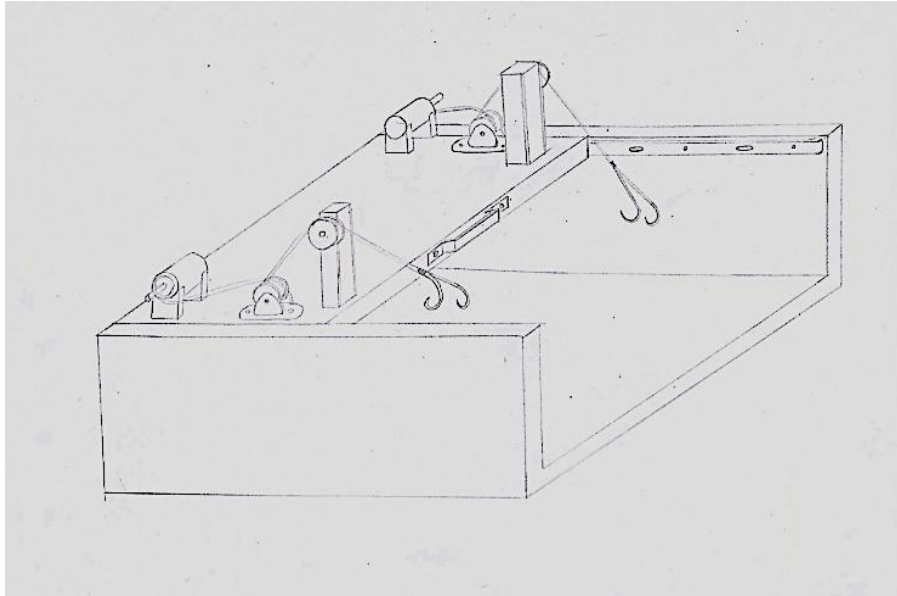


Figure 9 - Detailed Design Assembly View

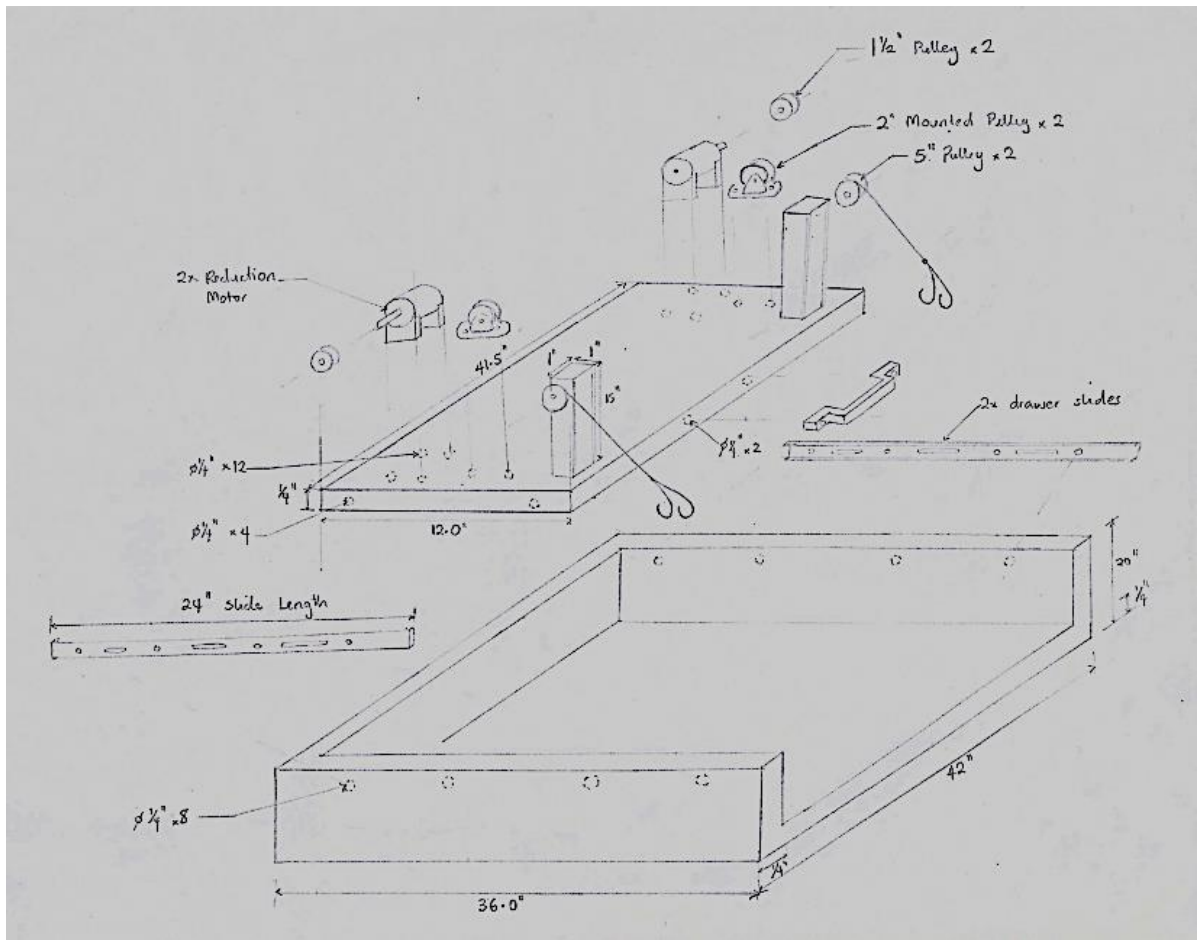


Figure 10 - Detailed Design Exploded View

The loading system design consist of two main subfunctions: the push/pull drawer top and the automated pulley system. It consists of two platforms, drawer slides, a drawer handle and a 3-pulley system with hooks. The steps to apply the system in the loading and lowering of a walker is as follows:

- Using handle, the top platform that houses the pulley system is pulled out. This section uses a similar mechanism to a clothing drawer.
- The walker is then folded on the ground in front of where the top platform was pulled to.
- Using the automated system, pulley hooks are lowered close enough to allow hooking on to the walker. The hooks are placed on four points on the walker that allow for a balanced lift.
- The automated system is then used to lift walker to a height just above the base platform.
- Lastly, the handle is used to push the top platform back into the vehicle. This allows the walker to be placed on the base platform.

4.2 Critical Product Assumptions

When creating the detailed design, several variables were and still remain unknown, prompting justified assumptions:

1) Make of Vehicle/ Trunk Space Available

Although our client has not yet committed to a vehicle, they require the product to be adaptable for different makes and models, as they plan to continue using our product into the future. It is assumed that our client would recommend we base our design off an SUV or hybrid, such as a Honda CRV or equivalent. Thus, conducting research, a Honda CRV hybrid has 39.3/ 76.5 (seats up, seats down) cubic feet of trunk space, acquainting to approximately 37.8 inches in length, 43.3 inches in width and 35.4 inches in height with the seats up. With this assumption, we are able to create marginal values for the bounds of our dimensions. But, it is critical that we acknowledge that if our client plans to implement the product in something other than an SUV, it is possible that our product collides with the frame of the vehicle and malfunctions.

2) Power assumption

When determining which motors/ electronics we plan to implement, we had to consider our power budget. In many standard SUV's and Hybrid vehicles, there tends to always be a cigarette lighter and/or a 12V standard outlet towards the rear of the vehicle. This limits our motors to only 12V and depending on the current output for our power budget, we may get anywhere from 120W to 240W of power. This is unlikely, so we would rather a motor with low current draw and high torque. The current motor priced out requires 12V at 0.68A, allowing for plenty of headroom, but at the cost of speed.

3) Lifting/ Load Capacity

The current walker listed by the client has a weight of approximately 26.5 pounds, equating to roughly 12kg. With this in mind, the approximate force needed to lift the walker will be $> 117.9\text{N}$, thus our system must be able to lift more than 12kg. With this in mind, we estimate that the current motor specified will have enough torque to lift the walker.

4) Mounting Mechanism

When considering mounting for the device, the weight of the device may not be enough to restrict any rotational motion when it is in operation. Thus, we will assume that there are two mounting points (for loops) to the rear of the trunk, as shown in almost every SUV. These mounts will enable us to mount a strap or clamp to counteract the possible moment that can occur due to the device's operation.

5) Availability of Components

Many of the components for this project have been taken from Amazon or Makerstore, two very reliable sources for fast shipping/ pickup in the Ottawa region. That being said, items such as the motors may take longer than expected as they ship from overseas, requiring a few days to a week before they arrive. Although we can easily acquire most of the electronics, the motor arrival may disrupt our prototyping cycle. Thus, we are to assume that the estimated shipping dates are exact, giving us a proper timeline of when to expect each component.

4.3 Skills /Knowledge Required and Time Assessment

4.3.1 Skills and Knowledge Required

CAD:

We all have experience at different levels with 3D modeling, this will help us better visualize our project, not only for further steps but also for the client. It will help them understand our concept and will ensure better feedback.

Materials and manufacturing:

We will need to be familiar with multiple different materials to be able to find the right one that will fit our needs for this project. There are a multitude we can choose from, but finding the right one to accommodate our needs will be difficult. We do have a mechanical engineer in their last year who has work experience that can help the team with choosing the right products.

Constructing various circuits:

Our design will require electricity. In our team, there are three electrical engineers. During the assembly of the design, with the experience of multiple team members creating various projects, we will have an easier time designing the circuit and building it.

Power supply:

We will need to design and create a power supply for the loader to be automated.

Automation:

We need a clear understanding of automation to be able to design and develop an efficient loader.

Coding/Programming:

We will need codes to provide the Arduino information. All team members have previous coding knowledge.

Engineer mechanics:

During the project, we will need to apply multiple physics laws to find which motor or different accessory will be needed to lift a certain load. We will apply the laws of equilibrium of rigid bodies as well as friction laws.

Communication skills:

To be able to have a successful project, we need hands-on skills but communication skills as well to be able to communicate our ideas/ design with the rest of the team. We often must use drawings or pictures on the web to ensure that the rest of the team is on the same page.

Safety regulations:

During the whole process, we need to respect certain rules to not injure any team members while using machinery.

Cost and budgeting:

While creating a project can seem simple, when having to respect a limited budget, it can complicate things. We will need to create a BOM (bills of materials) to ensure the respect of the budget.

Teamwork:

All members need to show great teamwork to ease the workload of the project. There also can't be miscommunication between team members and if any arguments ensue, team members need to display professionalism and respect to be able to come to an agreement.

4.3.2 Time Assessment

Creating a time assessment for the project is an important step for project management. It will allow us to understand and better plan our schedule and phases for the project. Developing a walker loader will be an interesting, but challenging experience. To provide a realistic assessment of the time we have there are many factors to consider such as the time it takes to receive parts and how long to make parts. The time it takes to create our product is heavily impacted by the complexity of our product. Creating a walker loader requires many phases such as benchmarking, creating a final design, and developing and testing each subsystem and prototype.

Project Parts:

Receiving the required parts for our design is important. The time for finding specific parts can vary significantly, especially for complex parts. Some parts might have to be shipped from another country which could take between 1-4 weeks. Realistically all the parts would need to be received within 2 weeks and 3 weeks at the latest. We would need to find parts that would take the least amount of time to receive. Some of the parts might have to be 3D printed. 3D printing usually takes between 30 minutes - 12 hours to print items. Sometimes it could take much longer than that depending on the size and complexity of the part. For 3D printing, there are many time factors to consider such as printing errors and how long we can use the printer. Since there are 3D printers on campus it would be convenient to print parts because we would be able to use it within a couple of hours. The parts would need to be simple parts that would not cause printing errors and that fit within the makerspace time restraints.

Assembly and Subsystems:

Once we have all of the components needed, assembling the prototypes and subsystems would be the next step. Our project has many subsystems that require constant testing and modifications to function properly. Once each of the subsystems is complete, we have to combine all of them to create the final product. This will take a long time because we have to make sure that the systems function synchronously. Building each subsystem and connecting them would probably take a few days. We have 1 week to develop prototype 1, and approximately 3 weeks to develop prototype 2 and 3 each. However, we should aim to finish developing each prototype earlier to account for any possible building setbacks or errors. After each prototype is complete, we would have to test it to ensure safety and proper functionality. Thus, it would probably take a few extra days to complete each prototype. We would probably use the full 3 weeks when developing the final prototype and prototype 2. To reduce time when building the prototypes, we could make a list of all the supplies and tools we have. This would make building the prototypes more efficient because we will not waste time looking for items that we do not have. We could also assign different team members to different subsystems to ensure that we are using our time more efficiently.

Team member availability:

Another factor that needs to be considered when making a time assessment is the team's availability. Not everyone can contribute an abundance of time towards the project. Also, most of the team has different schedules and commitments. Everyone's schedule is constantly changing week to week, which can affect their time commitment to the project. Due to these factors, it greatly affects the amount of time we have at our disposal. However, we do not always need to meet to work on the project. Some parts can be done individually and at home. Working on individual tasks alone would allow us to use our meeting times to work on the parts that require team effort. This would allow us to use our time more efficiently. It is important to coordinate and communicate to ensure we do not waste time and distribute tasks evenly. When assigning tasks, we could distribute them based on the team members skills and availability. We could also be more flexible with the schedule and meetings. Not everyone needs to be at each of the meetings unless they are required. This would allow us to find more meeting times. For example, if 3 people are working on subsystem A, then it would be easier to schedule a subsystem A meeting because only 3 schedules need to be considered. The other members could still join if they are available during the meeting time. Everyone would need to allocate a minimum of 2-3 hours per week towards the project. However, this will change based on the current deliverable and project phase.

In conclusion, a realistic time assessment and effective mitigation strategies are important for the development of our product. By estimating the time, it would take to complete various tasks it allows us to plan more effectively. Also, addressing any possible errors allows us to come up with potential mitigation strategies. The strategies will allow us better to handle any potential errors and issues we might face through the development process. Using the time assessment, we are able to figure out ways on how we can maximize our time and how to be more efficient. Constant communication and effective time management is key to the success of our walker loader.

4.4 BOM

Table 13 - Bill of Materials

Part Name	Cost Per Unit	Quantity	Total Part Cost	Link
L298N Motor Driver Controller	\$9.99	1	\$9.99	Link
30RPM DC 12V Reduction Motor	\$16.20	2	\$32.40	Link
Arduino Uno	\$17.00	1	\$17.00	Link
5 ft Jumper Wire	\$1.60	1	\$1.60	Link
Buttons	\$0.25	2	\$0.50	Link
Male-Side Cigarette Jack	\$9.99	1	\$9.99	Link
T-Slotted Framing (Stand in)	\$5.53	2	\$10.06	Link
Steel Drawer Slides (Stand in)	\$31.79	1	\$31.79	Link
OBS (Stand in)	\$22.34	1	\$22.34	Link
Pulley Block	\$12.25	1	\$12.25	Link
Hooks and Rope	\$18.99	1	\$18.99	Link
Total	N/A	N/A	\$167.31	

4.5 Project plan update

<https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=TSh4T8xYWmPYf7WY7WkbWNOJiT2V8I6s%7CIE2DSNZVHA2DELSTGIYA>

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

5.1 Prototype 1

After meeting with our client and gathering feedback from our in-class design reviews, we gained insights on the mounting system, lifting system and overall simplicity of the design. Thus, it was clear that several aspects of our design would need to be analyzed and iterated upon.

In Class Design Review Feedback:

When discussing our detailed design with the TA, we gained feedback and critical points on our design that had to be prioritized and reconsidered. Some of these points include the platform being far out enough to avoid causing damage to the bumper of the car, how we would prevent the loader from tipping forward, and how to correctly mount the device to the car in order for it to be secure. The feedback we received included minimizing our design to use only one motor instead of two so that we wouldn't have to worry about the polarities of the motors, as well as a lowered cost. Our idea of mounting the device to the top tether anchors in the car was a good idea, however, not all car trunks have top tethers. Securing the device with bolts was something for our group to consider to ensure our device would be sturdy, however we eventually decided against this. We were encouraged to look into saving money by obtaining materials secondhand or from Princess Auto since we were over budget, as those options are a cheaper alternative to ordering materials from Amazon.

During the second design review, we were encouraged to take a step back when thinking about how to provide the easiest solution for our client. We were heavily inspired to figure out a

way to make our device both fold and pull the walker into the trunk because loading the walker is more challenging when it is folded on the ground. The TA reminded us that there might need to be a compromise in our design and the client's needs since our design was complicated. In order to simplify our design, we would possibly need to ignore one or more client needs such as car adaptability or damaging the car to secure the device in place. The TA also mentioned that it was okay for the backseats to be lowered because if the user was travelling with passengers, then the passengers could help load the walker. With this added trunk space, we were able to think of loading the walker into the trunk from the top instead of the sides. Another idea that we received was possibly using a winch or crank with a cable, but we would need to consider potential damage to the car if the walker were to be dragged into the trunk. To solve such a problem, vinyl wrap and even a cheap carpet are being considered to prevent possible damage when sliding the walker up and into the trunk. We were again encouraged to lower the cost of our materials and look at websites like Kijiji and Facebook Marketplace for lower cost alternatives.

Analysis of Critical Assumptions:

We decided to re-analyze the structural systems and electronic systems critical assumptions. Structurally, we assessed the feasibility of mounting hooks on the bottom and to the rear of the device that would fasten to the "baby seat" hooks in the trunk and back seats. Although they would provide a stable connection when mounting to counteract the moment generated when the platform was extended, adapting the hooks for different vehicle types proved too difficult. In addition, the dimensions of the box when fully extended proved to be too great and would contribute to a large moment and strain on the rails, creating a possible point of failure in the device. Analysis of the electronics proved to also not be a viable option. We initially noted that we would need to lift approximately 12.02Kg (weight of the walker) to be in at minimum equilibrium, amounting to 117.92N, requiring a motor torque of 1.179Nm at a 1cm radius (unlikely to have a 1cm radius for pulleys, simplified calculations). A single motor in the BOM outputs a torque of 0.79461Nm, thus doubling them up would theoretically be a viable option, but from the size of the motor to their power input, it was clear without the analysis that they would not generate the power needed to lift the walker, thus there must have been an error in the calculations or the listed torques were incorrect (combination of both as the product reviews are less than pleasant). Looking for a different motor

for our system came with other challenges. Firstly, our power budget from the car is very low, only around 12V at 3-6A if we are lucky, providing a power output of at maximum 72 Watts. There were no motors on the market (that we found) that work in this in-between state of 72 – 120 Watts without completely exceeding half the budget alone. Although the analysis states we would be provided 10.2V at 10A, this is wishful thinking and still too little. Also, with no load, the motor in the BOM would take 32 seconds to make rotations equivalent to a meter, with load would be excruciatingly slow. The analysis can be found in the *Sample Calculations for Electronics* sections of the **Appendix**.

Purpose of Prototype 1:

Considering all this and the feedback received, we decided to re-iterate our conceptual design focusing primarily on the structure and power input. Thus, the purpose of our first prototype was to integrate all the new subsystems together, and visualize the relative scale of our re-iterated design (1:5 scale).

We decided to remove the box design and extendable base in favor of hollow square steel tubing that runs from the trunk of the car to the center/ front of the back seat. While we would like to keep as much back seat space as possible, a compromise had to be made in the newest iteration that required the middle-center seat (larger seat) be folded down to accommodate the device. A driveshaft mounted at the top of the device will rotate freely about the axis with the rope attached to it, acting similarly to a spindle for thread, rotating one way to lift and the other to lower.

We also decided that a new system would have to be developed for the lifting mechanism. The old design was unreliable and expensive (power and money), thus we instead pivoted to utilizing a boat hand crank and series of bike chains as well as bike sprockets to transfer force from the crank to the driveshaft. Not only is this mechanism more reliable, but it will also certainly be able to accommodate larger loads other than the walker. In addition, the new system allows for the user to roll their walker directly to the rear of the trunk, without bending down to attach hooks but still maintaining left hand accessibility. A rough sketch of the new design with dimensions is shown below:

To get a relative scale of our prototype (1/5th scale) we decided to 3D print each component of our prototype. Although the prototype is non-functional, the physical model provides a better representation of scale to help us not only communicate our plans to our client but also for the team to understand what steps we need to take next to achieve a fully functioning device. Prototype image shown below:

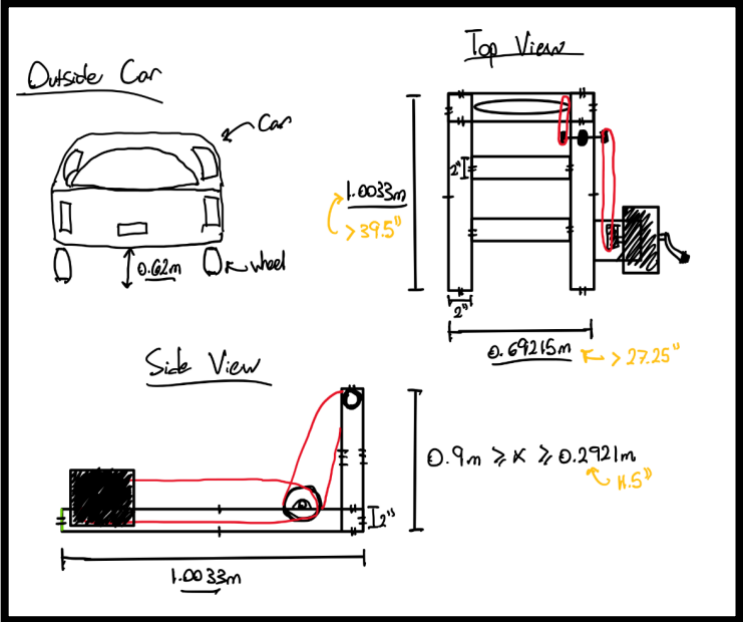


Figure 11 - Design Iteration 3

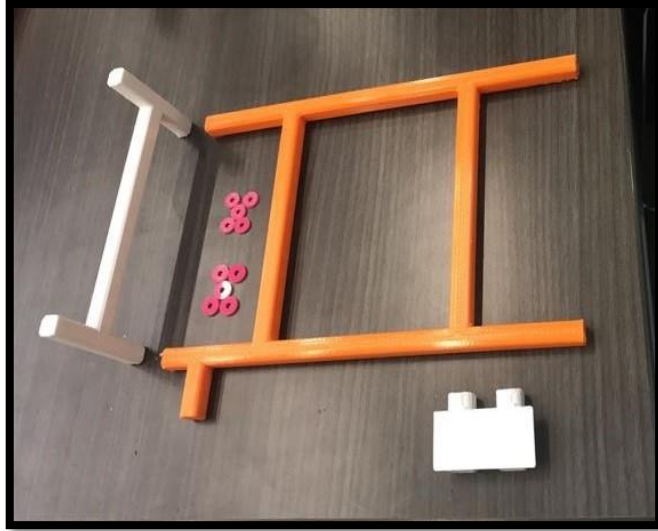


Figure 12 - Printed Pieces of Prototype

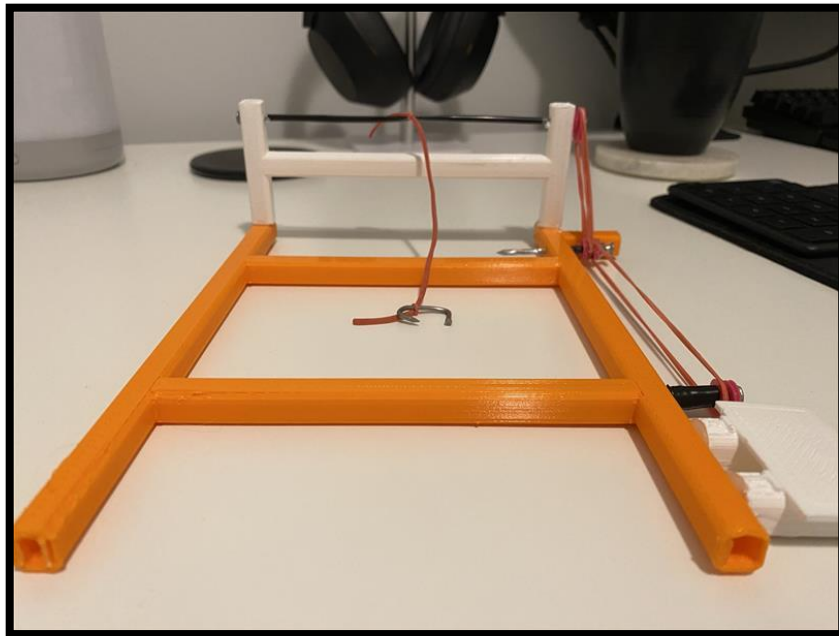


Figure 13 - Prototype 1 in One-Point Perspective

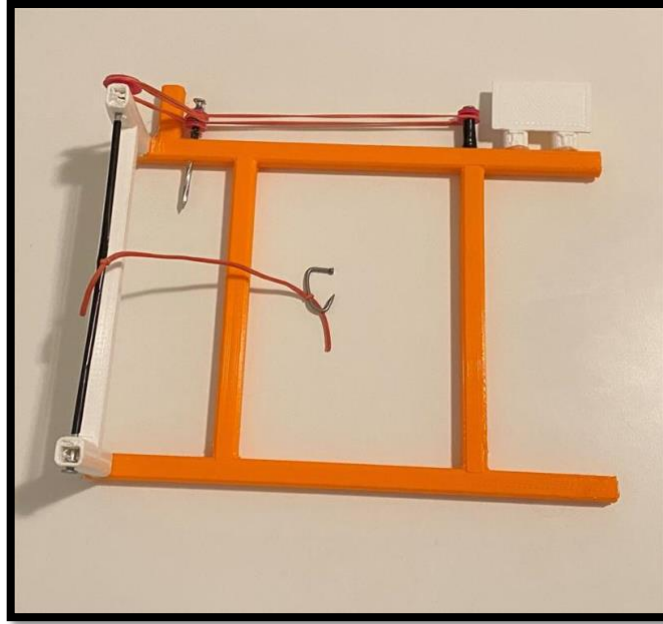


Figure 14 - Prototype 1 from bird's-eye view

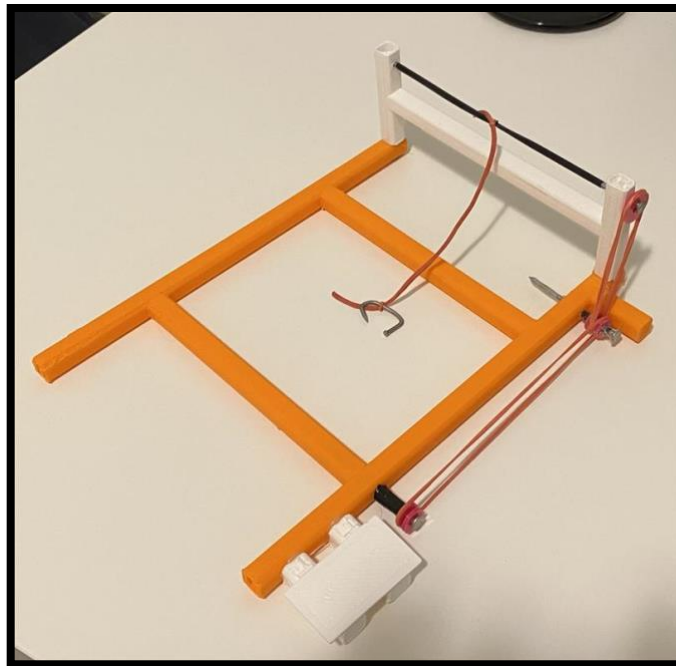


Figure 15 - Top View Prototype 1

In addition, a new BOM has been created to better represent our newest iteration:

Table 14 - Updated BOM

Part Name	Cost/ Part (\$)	# of Parts	Total Part Cost (\$)	Link for Part
Double Sprocket Gear	18.49	1	18.49	Link
Bike Chain	15.99	2	31.98	Link
Crank and Cable	5.00	1	5.00	Marketplace
Single Sprocket Gear	11.29	2	22.58	Link
PVC Pipe	4.71	1	4.71	Link
5/8" x 5/8" Steel Tubing (6 feet)	17.16	3	51.48	Hyperlink
Total			134.24	

5.2 Project Progress Presentation

<https://docs.google.com/presentation/d/1qm3Ysxplc2WTuVhbBKvmfkivvWLTvkYP4h7j62KzMX4/edit?usp=sharing>

5.3 Project plan update

<https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=kV2OOZyKMVxjV2sP3jzMvPybQGbcjOfQ%7CIE2DSNZVHA2DELSTGIYA>

6. Design Constraints and Prototype 2

6.1 Design constraints

The weight capacity is a crucial non-functional design constraint for our prototypes. This requirement is essential to ensure both the safety and functionality of the device and analyzing this constraint involves understanding the maximum weight the device can handle to accommodate the model of walker that the user owns. This analysis will help in selecting the appropriate materials and mechanisms to ensure our device can reliably and safely lift a minimum weight of 30 pounds. For our device to lift the required weight, we have previously changed our design from being motor-powered to using a pulley and crank system.

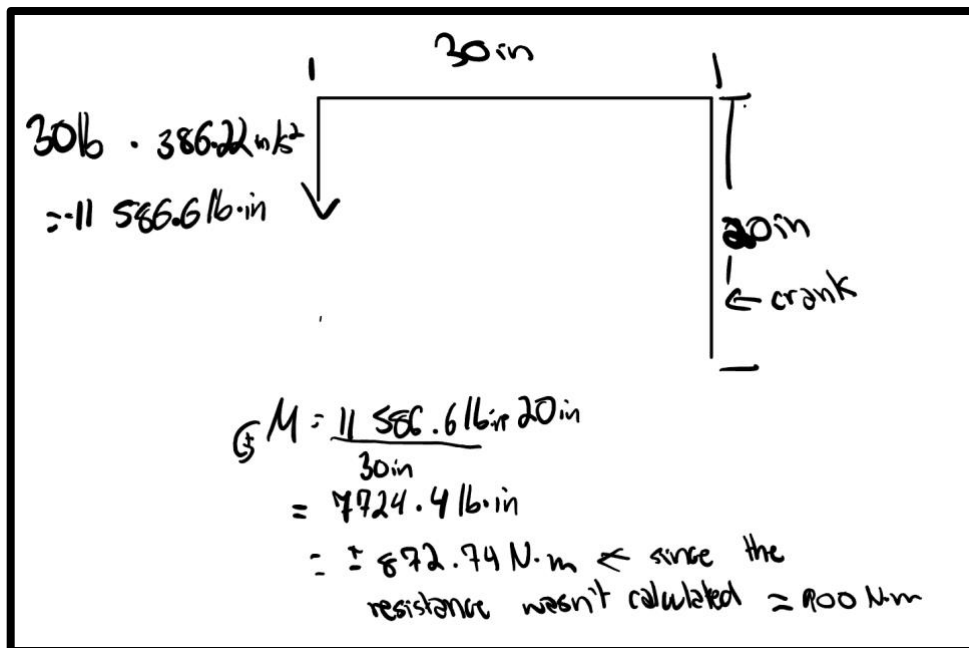


Figure 16 - Analysis and Calculations of Torque

We calculated the theoretical force that would be needed from the user. It is within the capacity of the user and wouldn't take too much effort.

Another significant non-functional design constraint is the safety and usability of the device. The previous design had many concerns regarding its usability. Since our client uses his

walker every day, we need to ensure that the walker does not get damaged when using the loader. The previous design required the walker to be pulled up using the back end of the car. The walker would rub against the back end of the car. This meant that there was a high probability that the walker would get damaged over an extended period of time. To make sure the walker would not get damaged we changed our design, so it would lift the walker off the ground first. This would reduce the risk of damaging the walker. The walker would be lifted up then moved into the car. We changed the design to a loader similar to a crane which would allow the walker to be lifted. We will also add 4 hooks to the end of the crank so the client can attach 4 sections of the walker to the crank. This will help keep the walker steady as it's being lifted and make sure it does not tip over or hit anything. We will test these critical assumptions in our prototype. Below is an image of the proposed simulation that we will conduct.

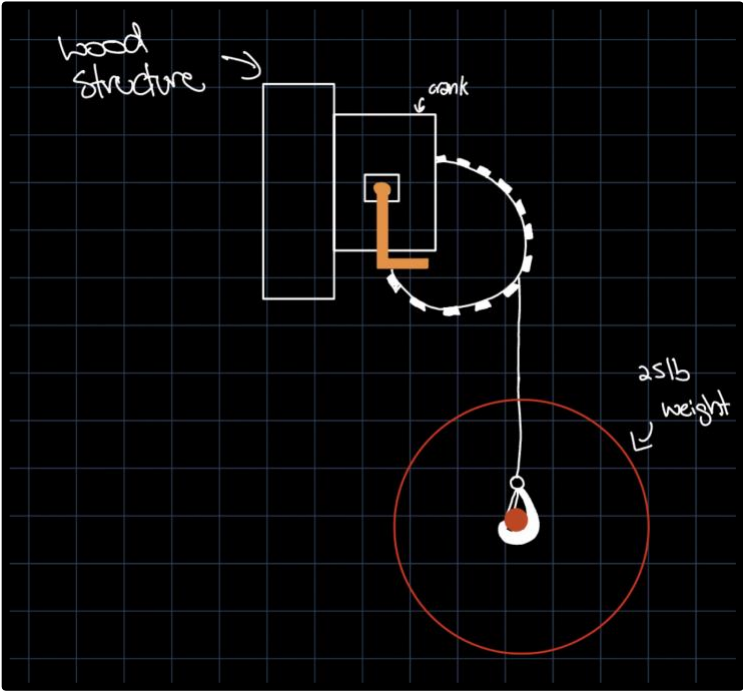


Figure 17 - Crank Testing Methodology

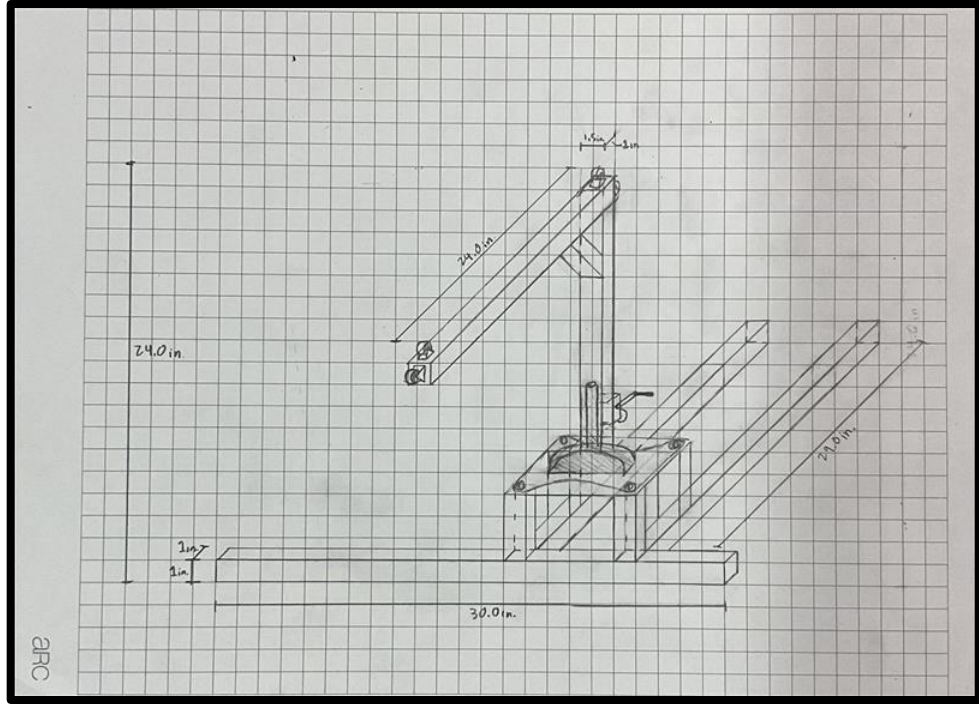


Figure 18 – Updated Detailed Design in Isometric View

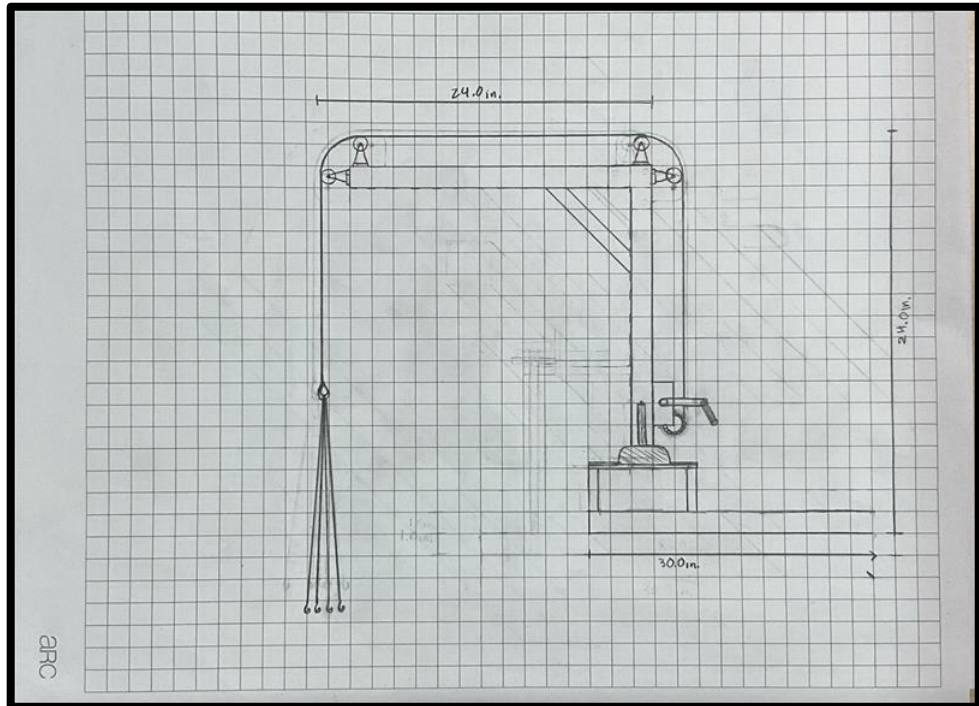


Figure 19 - Updated Detailed Design in Side View

6.2 Prototype 2

We have not yet received any new feedback from the client as we have not had another client meet. However, we are looking forward to the next client meet as we have several questions, specifically on trunk measurements, we would like to ask the client to better modify the design to their needs. We will also present our updated design to the client and user and gain feedback on their opinions as well as answer any questions they may have.

For the new design, we have not yet tested the tipping of the loader or the stability. We are assuming that the cross base of loader will provide enough stability and support for the loader to stay up-right without the tipping over. We are also placing straps that are attached to hooks behind the back seats. This would further prevent the loader from tipping and provide stability on a higher y axis and create an equal force to the one applied by the loader. To test the stability, we are simply putting weight that simulates the walker, and creating an environment that recreated a car ride. As we get closer to the final product, we will better assess the situation, and make adjustments as required to provide security and stability.

When updating our design for this prototype, we were mainly focused on how to diminish our BOM as we are slightly over our budget, as well as maintaining a priority on accessibility and safety for the user. In our updated design, or this prototype, we have done a complete redesign on how our system will complete the required task for the client. Instead of pulling the walker into the car we have switched to essentially using a crane that will lift the walker and rotate into the vehicle. This will still use the same crank that we planned on in the original designs. This system will be mounted in the right corner closest to the trunk. All frame and structural crane components will be manufactured using metal bars. This material is lightweight and easy to work with, making it a good choice for our design. To use this system the client will open the trunk, then swing out the crane arm, lower the cable with the crank, secure the walker, raise it back up, rotate it into the car and close the trunk. To create the crane portion of the design two pieces of extrusion will be mounted at 90 degrees to form an upside-down L-shape. From here, the crank will be mounted near the bottom of the vertical segment, allowing the client to reach and turn the crank easily. The crank will be mounted to the metal bar by using a small steel plate. To guide the cable from the bottom of the

crane to the other end we will use a series of four pulleys that will allow for a smooth transfer of cable. To mount the pulleys on the metal bar we will weld them in place. To pick up the walker we will have the cable split into four ends that each have a carabiner that the client will use to secure the walker. The use of a four-point connection allows for improved stability when raising the walker.

There will be three main subsystems to the loader. Firstly, for rotation, we will use a chair rotating system to allow for smooth, circular rotation and will mount it along the vertical arm of the crane. Additionally, to make sure that the moment created by the crane picking up the walker isn't too much, as well as lock the rotation we will use a system like that seen in an adductor machine that limits the angle of rotation with a pin. This system will extend from the bottom of the crane and have a pin on the end that can be raised and lowered. On the base of the frame, there will be a plate with holes machined in it that will limit the rotation by dropping the pin when the crane is at the desired angle. To keep the crane stable, the bottom frame will have arms that extend into the trunk and across the trunk (made of aluminum extrusion). For mounting, it was decided that ratchet straps can be used to secure the system to the car. The connection would be between hooks mounted at a respectively high point along the vertical arm of the crane and the hooks behind the passenger seat.

For our second prototype we will be creating some of the major components. The first prototype will test the crank. This was discussed in the critical assumptions. From the crank prototype we were able to learn a lot about the crank. The crank is a ratcheting crank, so it does not require the user to continually hold the handle when lifting or lower items. However, from our testing we learned that the user should always hold the handle to ensure maximum safety.

To test this, we vertically mounted the crank to a piece of wood and secured it with a bench press. At the end of the crank, we attached a 25lb which would represent the walker. The walker is around 25lbs. Since we do not have all of our supplies such as pulleys and aluminum bars, we used the bench press instead. Below are the images from testing the crank, we also took a video of the simulation which is in our shared drive.

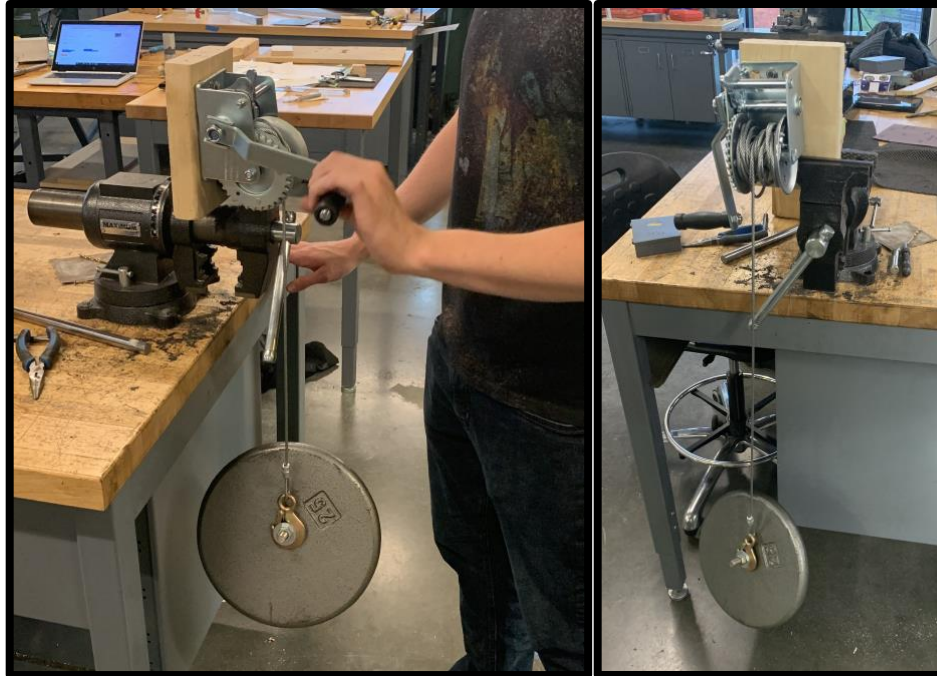


Figure 20 - Crank Testing with Weight

When testing the crank, for lifting and lowering of the weight, we were able to get better insights on the crank. We were able to lift the weight 3ft in 12 seconds with a moderate speed, and we lowered the weight in 14 seconds. These results are crucial because we learned that it does not take a lot of time and force to lift the weight. The force required to lift the weight was minimal. The crank also ratchets, so it reduces the force when lifting and lowering items. If we did the previous design, there would need to be more force required because there would be a lot of friction between the walker and back of the trunk. This test simulates the loader because the crank will also be vertically mounted. This is most accurate simulation that could be done since we do not have all of our materials.

The second prototype was to determine the feasibility of the chair as the base. The main objective was to figure out how to connect the swivel base and the crane structure. We determined that we would need to 3D print a filler to sit between the 1.5 square steel tubing and the rotating metal rod connected to the swivel base. This 3D piece will be rectangular with a 1.09-inch diameter hole in the center to provide a tight fit between the rod and the steel tubing. We also determined

that we would build the base to be 30 in by 30 in. Below is an image of the box that needs to be 3D printed.

For the rotation, we took apart the chair, and kept the rotation device. We attached it to the metal bars and assessed the solution. The rotation only happened at the top of the device, so we need to 3D print a few things, like mentioned previously, and attach the metal rod into the 3D printed device.

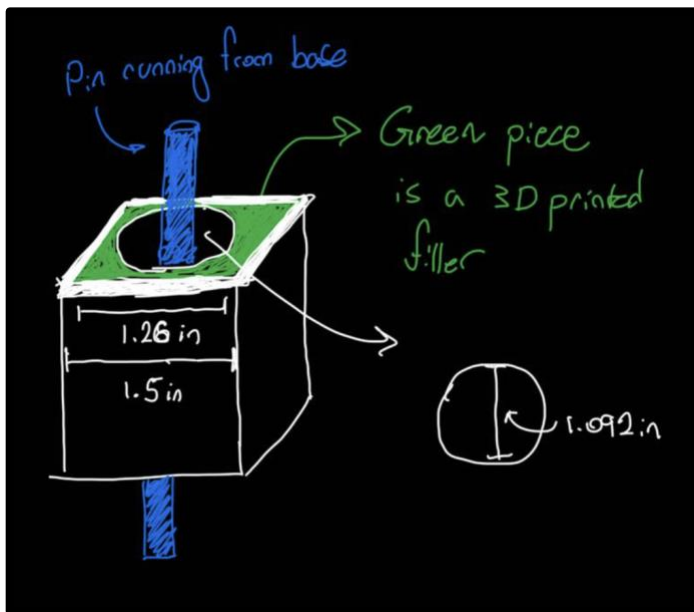


Figure 21 - Swivel Mechanism and Measurements

Table 15 - Updated Metrics Table

Metric	Unit	Value	Test Results	
1	Price (CAD)	\$	200	N/A
2	Dimensions: Length x Width x Height	in	< 37.8 x 43.3 x 35.4	Base 30 x 30 Height 24
3	Exterior Storage of Walker	Y/N	No	N/A
4	Exterior-Mounted Device	Y/N	No	N/A
5	Degree of Mobility Required	level	Low	Low
6	Load capacity	lbs	26.5 <	30lb with ease
7	Material	list	N/A	Metal
8	Degree of Recyclability (of Materials)	level	High	High
9	Weight of Unit	lbs	16	N/A
10	Ease of Use	level	Easy	Easy

From the prototypes we were able to figure out some of our target specifications. From the crank prototype we determined that the degree of mobility required is low and that the crank would be easy to use, which was our expected value. We also used an old chair to create the base prototype. This means that we have a high degree of recyclability. We determined the dimensions of the loader will be 30in x 30in for the base and 24in for the height which is smaller than expected. The crank is able to easily lift 30lb. For the prototypes we mainly used metal and a piece of wood. We exceeded the expectations we set during deliverable C and were surprised with the ease of use of this prototype.

During our next client meeting we will present to client the CAD model, the videos we took during testing, and our updated detailed design in a slide presentation format. Depending on their feedback, we may make adjustments to the detailed design.

6.3 Modified BOM

Table 16 – Modified BOM

BOM				
Item	Price/ Unit (\$)	Quantity (#)	Price (\$ + 0.13%)	Hyperlinks
Makerstore (Brunsfeld Metal)	5	1	5	Hyperlink
Steel Tubing (1.5in x 1in x 0.065in) for horizontal crane	7	3	23.73	Hyperlink
Steel Tubing (1in x 1in x 0.065in) for base (recycled)	0	0	0	
Used Office Chair (recycled) for swivel	0	1	0	
600lbs Hand Crank	32.99	1	37.99	Hyperlink
Block Pulleys	29.99	1	33.8887	Hyperlink
Hitch Pin (can utilize scrap)	0	1	0	Hyperlink
Carabiner	11.99	1	13.5487	Hyperlink
Metal Sheet (can utilize scrap)	0	1	0	Hyperlink
Ratchet Straps for Tie Down	14.99	1	16.9387	Hyperlink
D-Ring and Soft Loop Rope	12.95	2	29.267	Hyperlink
Hardware (from brunsfeld)	0	0	0	
Total			160.3631	

Questions for the client:

- Will the user be able to stabilize himself while using the crank?
- Considering push and pull force required, will user be able to rotate the crane into the vehicle?
- Are there mobility concerns when accounting for clipping the carabiners onto the walker?
- How long is an acceptable time to raise the walker/lower the walker?
- What are your overall thoughts on the design?
- Are there any other safety features you would like to see applied to the design?
- Do you have any further updates on the vehicle you may be choosing?
- Do you have any concerns with the design?

6.4 Project plan update

<https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=li9pKDJ0CNnDZ8qqq9mvixJ26BvAcyW4%7CIE2DSNZVHA2DELSTGIYA>

7. Other Considerations

7.1 Economics report

To develop the walker loading system to the manufacturing and production stage various cost are incurred and some have been selected to develop the income statement. Craniacs inc. is a company that manufactures a walker loading system. It is estimated that 800 units would be sold in the first year of production and an increase of 100 units each subsequent year. Unit sale price is estimated at \$500 based on benchmarked products, cost of production and other expenses. Some cost associated with the business include advertising, electricity, salaries, rent, production material, depreciation of manufacturing equipment and overhead.

Table 17: List of showing various cost associated with production

	Material	Labor	Expense
Direct	<ul style="list-style-type: none"> ▪ Production material 	<ul style="list-style-type: none"> ▪ Salaries 	
Indirect		<ul style="list-style-type: none"> ▪ Salaries 	<ul style="list-style-type: none"> ▪ Advertising ▪ Electricity ▪ Heating ▪ Rent ▪ Overhead ▪ Depreciation of equipment
Fixed			<ul style="list-style-type: none"> ▪ Advertising ▪ Electricity ▪ Rent ▪ Depreciation of equipment
Variable	<ul style="list-style-type: none"> ▪ Production material 	<ul style="list-style-type: none"> ▪ Salaries 	<ul style="list-style-type: none"> ▪ Overhead ▪ Heating

The Income statement was generated using estimated values for various components such as labor and cost of manufacturing one loading system. These can be seen in the following tables:

Table 18 - Craniacs Inc. Income Statement

Craniacs		Income Statement		
		Year 1	Year 2	Year 3
Financial Statement in CA Dollars				
Revenue				
	\$/Unit	\$500	\$500	\$550
	Unit	1,000	1,300	1,600
Installation Service		\$50	\$50	\$50
Gross Revenue		\$550,000	\$715,000	\$960,000
Less: Sales Returns and Allowance		\$10,000	\$13,000	\$17,600
Total Revenue		\$540,000	\$702,000	\$942,400
Cost of Goods Sold				
Direct Material		\$332,921	\$332,797	\$382,673
Direct Labour		\$137,696	\$172,120	\$172,120
Indirect Labour		\$68,848	\$68,848	\$68,848
Cost of Goods Sold		\$539,465	\$573,765	\$623,641
Gross Profit (Loss)		=Revenue - CoGs	\$535	\$128,235
Gross Profit (Loss)			\$318,759	
Expenses				
Advertising		\$10,000	\$10,000	\$10,000
Depreciation		\$10,000	\$10,000	\$10,000
Electricity		\$1,680	\$1,680	\$1,680
Online platform maintenance		\$200	\$200	\$200
Overhead		\$30,000	\$25,000	\$15,000
Rent		\$164,400	\$164,400	\$164,400
Salaries		\$68,848	\$103,272	\$103,272
Operating Expense		\$285,128	\$314,552	\$304,552
Operating Income/Earnings Before Interest (EBIT)		=Gross Profit - Operating Expense	(\$284,593)	(\$186,317)
Operating Income/Earnings Before Interest (EBIT)				\$14,207

Table 19 - Payroll estimate for labor cost

Payroll				
Minimum wage/hr: \$16.55				
		Year 1	Year 2	Year 3
Cutting		1	1	1
Assembly		1	1	1
Welder		1	2	2
Packing		1	1	1
Direct Labour	Total	\$137,696.00	\$172,120.00	\$172,120.00
Supervisor		2	2	2
Indirect Labour	Total	\$68,848.00	\$68,848.00	\$68,848.00
Sales		2	3	3
Salaries	Total	\$68,848.00	\$103,272.00	\$103,272.00

Table 20 - Cost estimate to make just one loading system

Cost of making one loader				
Item	Price/ Unit (\$)	Quantity (#)	Price (\$ + 0.13%)	Hyperlinks
Steel tube (1.5in x 1.5in x 0.065in)	\$6.78	15	\$114.92	Link
Sheet metal	\$49.80	1	\$56.27	Link
Bearing kit	\$9.38	1	\$10.60	Link
Steel rod for swivel	\$17.88	1	\$20.20	Link
Plastic filler for swivel		1	\$0.00	
600lbs Hand Crank	\$32.99	1	\$37.28	Hyperlink
Block Pulleys	\$29.99	1	\$33.89	Hyperlink
Carabiner	\$11.99	1	\$13.55	Hyperlink
Ratchet Straps for Tie Down	\$14.99	1	\$16.94	Hyperlink
D-Ring and Soft Loop Rope	\$12.95	2	\$29.27	Hyperlink
Total			\$332.92	

Graphs representing the revenue and total expenses:

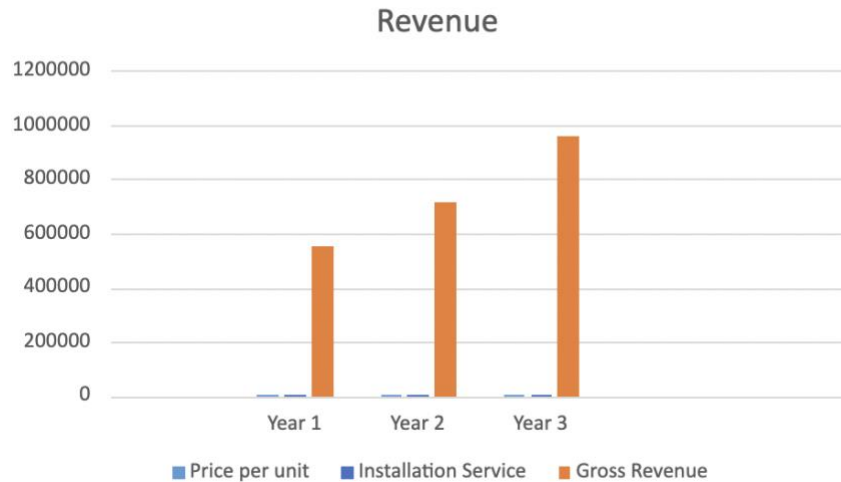


Figure 22 – Plot of Annual Revenue



Figure 23 - Plot of Annual Expense

The income statement shows that the precise break-even point is between the second and third year. Here are the calculations:

(using a rate of 10%)

NVP representation using a table:

Period	Cash Flow (\$)	Net Present Value(\$)
Year 1	-274,593	-249,630
Year 2	-173,317	143,237
Year 3	31,807	23,897

Cash flow calculations:

Formulas: Gross Revenue - Total Expenses = Cash Flow

Total Expenses (from income statement) = Costs of Goods Sold + Operating Expenses

Year 1: $\$550,000 - (\$539,465 + \$285,128) = -\$274,593$

Year 2: $\$715,000 - (\$573,765 + \$314,552) = -\$173,317$

Year 3: $\$960,000 - (\$623,641 + \$304,552) = \$31,807$

NVP calculations:

Formula: $NPV = \text{Cash flow} / (1 + i)^t$

Year 1: $NPV = \$-274,593 / (1 + 0.1)^1 = \$-249,630$

Year 2: $NPV = \$-173,317 / (1 + 0.1)^2 = \$-143,237$

Year 3: $NPV = \$31,807 / (1 + 0.1)^3 = \$23,897$

Finding the **precise break-even point**:

NVP = 0 which in return means the cash flow is 0. This would require the Gross Revenue to be equally opposite to the total expense. This happens during the third year.

Gross Revenue = \$928,193

Unit price: $\$550 + \50 (obligatory installation) = \$600/unit

Find the **number of units** = $\$928,193 / \$600 = 1,546.98 \approx \mathbf{1,547 \text{ units}}$.

One of the main assumptions for the economics report is the demand. When researching how many people use a walker in Canada it stated that 465,340 people aged fifteen and older use a walker (Charette et al.). There were no statistics about how many people with walker's drive, so we assumed that at least half of the people who use a walker drive. From these assumptions and research, we assumed that at least eight hundred people would purchase a walker loader. We also assumed that as the product becomes more used and known an additional one hundred walkers would be sold each year. Also, the number of walkers sold is set to increase over the next 5 years, so the demand will increase (Charette et al.).

Another assumption made is the various costs involved with the business. We strategized that the price for each loader should be \$500. This number was calculated based on the cost of materials, cost of labor, other expenses, and current benchmarked products. Plus, a markup which would allow the company to increase profits and grow. We assumed that all the materials required for the loader would be similar to the prototype. The total cost of materials to make one walker is around \$330. Based on research most companies usually markup their products between 20% to 25% to provide the best profit margins (Shopify). Including labor and other expenses required to make one walker loader would cost around \$400. We are assuming that there will be other expenses to create the loader besides materials and labor. Applying a 25% markup would price our product at \$500. The pricing strategy used to price our product is applying the 25% markup that most companies recommend.

For walker loading devices there are not many current products in the market. If we join the market, we will probably make up a small percentage of the market. We would make up about 2% of the market. As we grow and sell more loaders our percentage in the market will increase. We could be able to achieve 10% of the market within 5-8 years.

While developing the economics report we made many assumptions to achieve a better estimation. The price for the product is based on benchmarked items and the price is marked up to account for any other expenses. We will produce an additional three hundred walker loaders each year to account for possible extra demand. The base installation cost is estimated to be \$50. Another assumption made is that we will receive a 2% return on the goods sold. While building loaders there

will most likely be extra supplies that can be carried over reducing future expenses. For power, we assumed that we would use 1000kW/h and according to the Ontario power website, the estimated cost would be \$0.14/kWh (“Hourly Ontario Energy Price (HOEP)”). Based on research we assumed that we would need a 10,000 square foot warehouse (wmxadmin). The average cost per square footage is between \$7 to \$20 per year (“Industrial & Warehouse Space for Lease | Toronto | Canada | Cushman & Wakefield”). This allowed us to estimate our average rent cost.

7.2 Intellectual property report

Identifying intellectual properties similar to our product is a crucial step when producing our product. Learning about existing products and patents influences and places constraints on our product. We found two designs that are similar to our product using the intellectual properties databases. The first design resembles our design because they are both a crane that mounts to a car ([link here](#)). They have similar components meaning that their patents might cover similar mechanisms. The second design is the base for a swivel chair ([link here](#)). Our design heavily relies on a chair swivel as it serves as the base for our product.

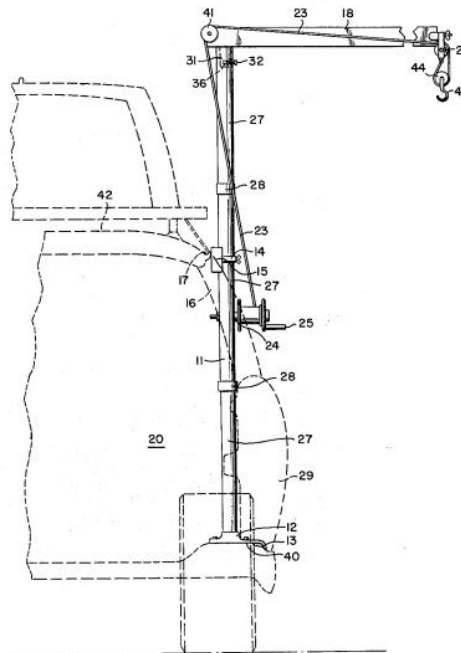


Figure 24 - Car Crane Design Patent

If there are existing patents for a car-mounted crane with a crank and pulleys, the patents might already cover specific components of the functionality or design. It is especially important to fully understand the patents in detail to know what components the patents cover. The patents could cover specific mechanisms, components, operations, or features. It is essential that we comprehend these patents to determine which features our product might infringe upon existing intellectual property. It also offers us insight into the areas that we might need to differentiate to avoid infringing on existing patent rights. If our suggested design closely resembles or mimics patented features without permission, it could result in patent infringement. This could lead to legal actions, such as requests for royalties or licensing fees to use the specific components. This is an important intellectual property to consider because it is similar to our design. They are both a car-mounted crane that swivels inside and outside of the trunk. They also utilize pulleys and a crank that are used to hook items, so they can be lifted and lowered into the trunk. However, there are some differences regarding the designs, such as the number of pulleys, the frame, and other functional details. It is important to consider this patent when developing our business, so we do not infringe on intellectual property patents. We need to ensure that there are enough differences in the designs to avoid legal trouble. This patent causes legal constraints as we would need to ensure our designs are different enough to not break any patent laws.

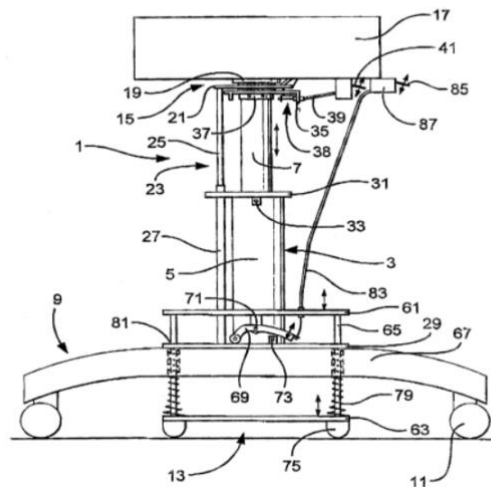


Figure 25 - Chair Swivel Design Patent

The second intellectual property we chose was a chair's swivel base. In order to increase our sustainability, we opted to use a chair swivel as the base for the crane. This will cause legal constraints because the chair swivel most likely has a patented design. We were not able to find the exact chair swivel design, however we found a swivel chair similar to the one we used. This design has significance to our business because our design heavily relies on a chair's swivel base to function. Thus, it is important to understand the patents because it will cause legal constraints when producing our product. Finding chair swivel patents allows us to gain insights into existing patents about swivel mechanisms. By researching chair swivel patents, we gained a deep understanding of the mechanisms, and design features protected with swivel chair bases. The legal constraints connected with these patents significantly influence our design development. There are limitations and constraints if the chair swivel intellectual property includes patented elements that are essential for the swivel base of our loader. The most important of these difficulties is to avoid infringing upon the protected components of the chair swivel mechanism. This means that in order to prevent future legal issues and infringement claims, we must carefully review our designs to ensure that our loader does not illegally replicate a patented component.

7.3 Project plan update

<https://www.wrike.com/frontend/ganttchart/index.html?snapshotId=XYCk0pf15cFGiixWcAM9PJ6ybMAtlBlz%7CIE2DSNZVHA2DELSTGIYA>

8. Design Day Pitch and Final Prototype Evaluation

Write your design day pitch and plan your prototype demo.

9.1 Video and User Manual

Video pitch

Add link to video.

User manual

Refer to user manual in project [Makerrepo page](#).

Conclusions

The project involves the design of a walker loading system and the document highlights the different stages that lead to the final product. It commenced with identifying the project objectives, scope, and assumptions as well as the selection and development of a suitable Business Model Canvas. The selected business model canvas used the triple bottom line format, and this required a sustainability report which was also completed in the first deliverable. The inclusion of sustainability considerations highlights a commitment to environmental and societal impacts. This approach not only fills a market gap but also aligns with broader sustainability goals, positioning the product for long-term success and societal influence.

This second deliverable is a modification of the first to include the next stage which involves problem definition and concept development. Based on the target specifications generated using the identified customer needs, various concepts were generated and screened to result in three main concepts. These main concepts were then evaluated on a design matrix to result in the selection of a final concept. The next stage would involve using customer feedback to modify the concept and create a detailed design with a Bill of Materials (BOM).

For this deliverable, the feedback received from the client was summarized and applied in generating a modified global concept. Detailed design drawings were created for the system and a bill of materials was generated. To establish the detailed design, certain critical assumptions were made and have been highlighted. Additionally, to aid in the smooth progression of this project, an assessment was conducted on the skills, knowledge and time required to accomplish this project. For each of these, an evaluation of the team's level for the required skills and time availability was conducted.

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12. [Wheelchair Ramps for Steps 3 to 5 FT, Adjustable Aluminum Ramp 2 Pack, Non-Skid Surface Wheelchair Ramp with Storage Bag, _](#)
13. [Wheelchair Ramp for Stairs, Steps : Amazon.ca: Health & Personal Care](#)

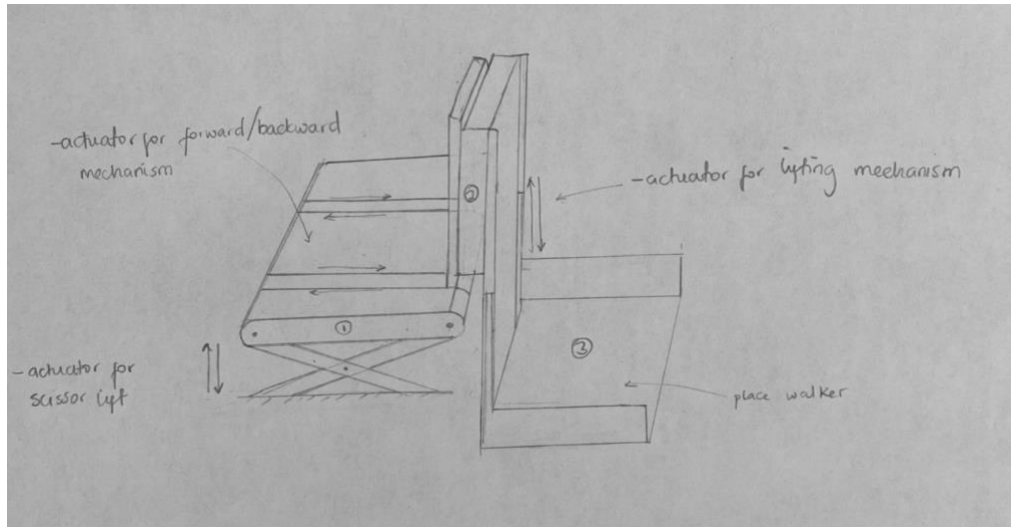
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APPENDIX

Brainstorming Concept:



Platform 1 is raised, using a scissor lift system, to allow platform 2 and 3 move forward without interference from the base of the trunk. Conveyor mechanism pushes forward platform 2 and platform 3 is lowered to the ground using a modified forklift mechanism. After walker is placed on platform 3, the modified forklift mechanism is lifted to be at the same level with platform 2. Then the conveyor mechanism pulls platform 2 and 3 into the trunk with the walker loaded on 3. Lastly, the scissor lift is lowered and platform 1 is returned to a balanced position from the base of the trunk.

Sample Calculations for Electronics:

Motor Calculations
Thursday, October 5, 2023 7:12 PM

$$\vec{U} = F_r \sin \theta \quad 265 \text{ pounds}$$

$$F_g = (9.81) (12.02 \text{ kg})$$

$$\approx 117.92 \text{ N}$$

* Assumption - Cigarette lighter lead for power

Specifications given for:

High Torque Turbo Geared Box Motor DC 12V Reduction Motor 15/20/50/100/200RPM (12V, 200RPM); Amazon.ca, Tools & Home Improvement

No. Leads	Wiring	Rotation	Current	Reaction Torque	Over Size Length (mm)
2V	2W	0.5	1.1	0.01	20.0
10	10W	0.5	2.0	0.02	20.0
15	15W	0.5	3.0	0.03	20.0
20	20W	0.5	4.0	0.04	20.0
50	50W	0.5	10.0	0.10	20.0
100	100W	0.5	20.0	0.20	20.0
200	200W	0.5	40.0	0.40	20.0

* We require motor capable of lifting 12.02 kg of weights.

→ Torque is given in units of kg.Cm, where 1 kg.Cm = 0.0981 Nm. This means that a motor with 1 kg.Cm of torque is capable of holding a 1 kg weight at a radial distance of 1cm.

→ So, the same weight at twice the distance requires twice the force (to maintain the same speed).

→ We are required to lift 117.9 N, thus the torque required at 1cm radius is $\tau = Fr \rightarrow \tau = (117.9)(0.01) = 1.179 \text{ Nm}$, surpassing that of the torque for a single motor at 8.1 kg.Cm $\rightarrow \tau = 0.7946 \text{ Nm}$

→ The 30 RPM motor outputs 8.1 kg.Cm \rightarrow

→ This gives an RPM of 30, which equates to:

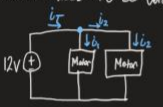
$$f = \frac{\text{RPM}}{60} = \frac{1}{2} \rightarrow \omega = 2\pi \cdot \frac{1}{2} = \pi \text{ rad/s}$$

$$\rightarrow v = r\omega = (0.01\text{m})(\pi) \approx 0.0314 \text{ m/s}$$

↑ kind of slow
↳ ≈ 32 seconds/meter

→ Assuming we use a cigarette lighter for power, the max output 12V or 10.2V at max 10 amps, requiring power from 120 watts to 240 watts when the car's engine is on.

→ Given each motor requires 12V and 0.68A (seems low...), the motors need to be wired in parallel:



* In parallel, Voltage remains the same, but current gets divided

→ Not a viable option as the car outlets will not provide sustainable power, nor is a motor of greater strength in our budget.



↑ video goes over how to wire/configure Arduino