SWARM

STREET WASTE AND RECYCLE MAINTENANCE

BACHELOR OF INDUSTRIAL DESIGN THESIS REPORT

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Optimising Urban Litter Collection

by

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2022

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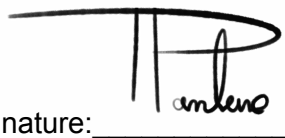
Student Signature: 

Abstract

Along city streets, specifically Toronto and surrounding cities, the formulation of trash has become an increasingly major and problematic issue. This is due to the fact that there is such a high volume of residents that live in and around the area. As more residents move to dense urban areas, the environment continually becomes negatively impacted by the amount of litter that is being produced by its inhabitants. The surrounding area around cities, where wildlife resides, becomes affected by the number of microplastics that leach off of degrading litter and into their water and food supplies. The accumulation of litter has been seen to also affect the drainage systems leading to the creation of floods and other environmental impacts. The rate at which litter is being collected is overshadowed by the catastrophic amount of litter that is being spread within cities.

It is estimated that Toronto has contributed $27 million dollars each year in order to clean up and tidy its streets of the litter that has been left behind by its residents (*Litter – City of Toronto*,). Unfortunately, the amount of money that is used to clean up the streets is not enough to contribute to improving this problem. Thus, it is important to create and implement a plan that is cost-effective, efficient, and sustainable in which we can enhance this problem.

The purpose of this thesis project is to complete an in-depth study on the daily process of how waste management workers handle litter, and also the process of how the litter is being addressed by the city. The data will be collected from observation, surveys, and one-to-one interviews. The data will be targeted both toward the residents who live within a city and the workers who maintain it. Results from this data analysis will be turned into an in-depth design solution to better help enhance cities' protocols in gathering problematic litter.

Acknowledgments

This Thesis project would not be possible without the help, guidance, and support from the professors of industrial designs at Humber College.

I would like to start by thanking Cathrine Chong and Sandro Zaccolo for helping me throughout the whole design process and supplying me with feedback. I would also like to thank all previous professors that taught me through my Industrial design journey at Humber College. Without the perspective and knowledge of my professor, I would not be able to achieve the final design solution.

I would also like to thank my Advisor for their vast comprehension of the problem area. They volunteered their time to answer any questions I had to aid me in my design. This information is crucial to the design process.

A Special thank you to my fellow classmates. My Classmates helped me achieve greatness by guiding me with their unique design thinking.

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CHAPTER 1- Problem Definition

1.1 Problem Definition

Litter within Toronto and surrounding cities have become an emerging issue as cities continue to grow. This has been affecting residents' quality of life and the environment of the surrounding areas in which they live. A large amount of litter that is not managed can lead to undesirable and unkempt living conditions and can lead to detrimental health concerns in residents. The degrading litter and trash can emit harmful chemicals and microparticles in the air that not only affects the environment but the health of its inhabitants as well. If Toronto wants to continue to protect its citizens and wildlife from the harmful effects of degrading trash, an effective and sustainable litter collection solution is needed. This solution would need to address the physical needs of the primary, secondary, or tertiary users in order to preserve the environment.

1.2 Rationale and Significance

1.2.1 Key Information to be Determined

To better understand the job of a litter collector's experience, as well as gain insight into the waste management industry, several research methods will be used to analyse the needs and wants of a litter collector. Research questions have been created using scholarly papers and research to guide the design process. These research questions will aid in understanding the process of a litter collector.

In order to design an effective product that will improve this litter issue, there is key information that will need to be sought after. The key information that will need to be determined

are: current methods of litter collection, ergonomics of current products, inauguration of new technology, and current process of litter collection.

1.2.2 Key Questions to be Answered

Currently, waste collection branches have been attempting to solve the city's litter issue for many years. Some current ways they have been attempting to solve this issue is by utilising volunteers, city workers, and encouraging their citizens to help tackle this problem. Many waste collectors are seen to be eager to solve this issue and are willing to help in many ways. Questions that will need to be answered in order to tackle this issue are: how might we improve litter collection? What are the current efforts that are being made to stop littering? What is the most difficult aspect of collecting litter? What would you do to reduce litter in high-volume areas?

1.3 Background / History / Social Context

1.3.1 Background

As cities, like Toronto, grow in popularity and infrastructure, it attracts large amounts of individuals who come to visit for tourism purposes and/or live within this city. With the influx of individuals enjoying the city, it brings along with them a trail of litter which can become a detriment to the city. Oftentimes, when people litter, they may believe that one piece of litter will not affect the environment. But, from constant littering, the accumulation can build up and affect the wildlife and surrounding areas. Current efforts to collect litter are often slow and can become time-consuming due to the task primarily being an individual job.

1.3.2 Media trends

The awareness of the littering problem has grown exponentially throughout recent years. The impact that littering has on the environment has been broadcasted through media outlets in order to inform and make the general public aware of its effects. Activists, such as Greta

Thunberg, have continuously vocalised our ongoing issue with plastic pollution/litter and how it has been affecting our world. As litter degrades, it turns itself into microplastics and harmful particles. These microplastics leach chemicals such as arsenic and formaldehyde into soil and freshwater which affects both the surrounding wildlife and humans. (*Littering Facts: How Littering Really Affects the Environment* | *TDS*, 2020)

1.3.3 Product Trends

Many products within the waste collection industry are used to pick up small pieces of litter or larger pieces of garbage. Currently, the main tool litter collectors have been using is a garbage picker. The garbage picker is a simple and easy-to-use product that can be utilised by any person from a volunteer to a city worker. A more specific and larger tool that is used on city streets is a Vacuum Sweeper. Vacuum Sweepers are only used by city workers and need specific training to use. With current products, the lack of speed and mobility limits the amount of litter that can be collected in a given workday.

CHAPTER 2 - Research

2.1 User Research

The goal of user research is to better understand who the target audience is for the proposed design. This research entails identifying the primary, secondary and tertiary users, as well as creating a user profile and analysing their tasks.

2.1.1 User Profile – Persona

2.1.1.1 Primary, Secondary, Tertiary Users

When looking at litter collection, there are three types of users we should consider. This would include primary, secondary and tertiary users. Firstly, the primary users would be the individual who is actively picking up the litter. Specifically, these individuals would include waste collectors. The primary user would be interacting the most with the product as this level of the user profile is directly involved with operating the proposed design. The secondary users would be the individuals who indirectly communicate with the litter, such as city planners/government waste managers, service tool maintenance workers, and litter organisers. The secondary user group only interacts with the product by way of organising facilities for the city. Lastly, the tertiary users would include individuals that would directly contribute to the overall amount of litter in high populated cities. These users would include residents, tourists, and wildlife.

2.1.1.2 Demographic

When considering what users would primarily work within the litter collection field, the demographics of the user should be analysed. The demographics were broken down into eight subsections. These subsections include age, gender, ethnicity, income, education, location, working section, and working hours. This section will allow for a baseline to understand who a product is being designed for.

Demographic of an Average Waste Collector

Age	40
Gender	Male
Ethnicity	Caucasian/ Canadian
Income	$40,000/yr
Education	High school diploma and General Workplace training
Location	Toronto
Working sector	Parks, beaches, and sidewalks
Working hours	7am - 5pm

Figure 1 (Persona)

2.1.2 User Behaviour

When further online research was performed, it brought attention to the fact that waste collectors demonstrate many challenges when working for long hours. The challenges that need to be solved can be categorised into two groups; issues with **mobility** and issues with **comfort.**

Mobility – When a waste collector is working, they either spend long hours on their feet walking around collecting litter or sitting in large bulky machinery that is less manoeuvrable**.** As the waste collector walks around collecting litter, this leads them to becoming tired and less efficient

at work. This may in turn sway users in wanting to pick better solutions such as ride-on vacuums. Ride-on vacuums come with their own issues. The mobility lacks in these machines as they are less manoeuvrable and harder to steer.

Comfort – Comfort plays a big role in a user's experience when collecting litter and in all physical labour jobs. If the worker becomes uncomfortable during work, it becomes evident based on the work that is completed. Users may try to perform work faster and with less efficiency if they feel uncomfortable. This is why it is extremely important to create a solution that is comfortable for all workers to use for long periods of time.

2.1.3 User Observation – Current User Practice

Stage	Description
 Figure 2 (User Observation)	The workers start their day by scouting out the surrounding areas.
	They next gather all the larger objects into their truck for transportation. The two workers help each other lift the heavy objects into the rear part of their vehicle.

	After that, they gather all of the small debris left behind. They gather glass, plastic, and other small objects. They will pick up the small objects with their hand, shovels, brooms, and garbage pickers
	They continue their journey on their normal route for garbage collection when they spot roadkill that needs to be picked up. They may use a broom, shovel, and garbage bag to pick up the roadkill.
	They bring the roadkill to a freezer where it will remain up to 7 days before they incinerate it.
	They then begin their regular rounds cleaning up the sidewalks using litter pickers and garbage bags.

Figure 2 (User Observation)

2.1.4 User Observation – Human Factors of Existing Products

The existing products that are currently being utilised have been shown to be problematic for the user. One of the issues is that litter collectors might suffer from body pains when operating poorly designed products. Due to constant repetition of collecting litter and poor body mechanics from the products they currently use, they become more susceptible to body pains and injuries. There are some current products that solve this problem but these products

also create their own issues by doing so. Products that solve this repetitive movement problem in their users have been seen as becoming less manoeuvrable and decreasing the speed at which the user can collect litter. Current products also lack comfortability for the user. This in turn decreases enjoyment in the user's work experience as well as reduces their productivity. According to WebMD, sitting for long periods of time can tighten muscles in the low back and cause pain, especially if you continue to have bad posture.

2.1.5 User Observation – Safety and Health of Existing Products

The health and safety of current products have been a concern. Due to the limited available working areas that litter collectors have access to, users become more susceptible to harsher land environments. Some litter collectors ride on vehicles that are heavy and can become trapped within muddy climates or snow. When these vehicles become trapped, it decreases user productivity at the task at hand. This is due to the fact that the litter collector will need to dismount the vehicle and release it from being stuck. Also when working, litter collectors may collect a large array of litter which can include dangerous sharp objects like glass or needles. With current products when workers empty collected litter these sharp objects can become hazardous and may even injure the user; this is why it is important to incorporate hands free emptying devices.

2.2 Product Research

Litter collecting products were researched in order to determine trends within the area of interest. The products that were investigated were from a wide range of areas that pertain to litter collection. The selection of products that were looked at were chosen in order to better understand every aspect of litter collection. The products that were researched range from manual garbage grabbers to city street cleaners. The major features of focus that were looked

at for current product trends were their efficiency and effectiveness when the user is collecting/cleaning.

2.2.1 Benchmarking Benefits and Features of Existing Products

Below is a chart of products that a waste collector uses and their pros and cons.

Product - Name	Pros	Cons
Garbo Grabber 	- Reduces the users' need to bend over and pick up trash. - Comes with a handle on the garbage bag to hold easier. - Garbage lid holds it open. - Trigger to help open and close the hand at the end.	- Trigger can wear the user's hand out. - When garbage is full it becomes heavy and hard to carry .
Hand Foldable Pick Up Grabber 	- Wide garbage hand to collect more garbage. - Foldable. - 4 finger trigger.	- Hinges can fail when picking up garbage. - Only has one length to pick up garbage. - Does not come with an additional garbage compartment. - User’s grip strength might fail when used for long hours.

All–Terrain Ride on Vacuum 	- Do not need to carry anything/no user strength needed - Vacuum reduces the motion of the user. - Does not tire out the user from walking. - The internal storage of litter.	- User's need to be trained. - The driver needs to drive over the litter. - Larger litter can be stuck or trapped in a vacuum. - Needs to empty the litter storage once the job is complete.
The WheelieVac 	- More dexterity when collecting litter. - Very mobile. - Requires one person to operate. - Internal litter storage. - Arm brace to reduce pressure of carrying vacuum. - Vacuum allows for pinpoint precision. - Garbage bin does not need to be empty by the user.	- Users need to carry a heavy garbage can. - Walking can make the user tired after working long shifts. - Constant use can create pain in both the user's shoulders/back (dragging garbage can and holding vacuum hose).
Electric Backpack 	- Does not need to carry an eternal garbage bin behind the user. - Back storage for garbage. - The vacuum allows for point accuracy.	- Backpacks might lead to back pain. - Small carrying capacity. - Shoulder pain from constant use. - Could become heavy from litter.
Street Sweeper	- Able to clean up city streets at night. - Very Mobile. - The user does not need to carry or lift anything.	- Might spread more litter into the sidewalk/ drains. - Needs one or more users to operate. - Can only clean one side of the road at a time.

Figure 3 (Product Benchmarking)

2.2.1.1 Features and Benefits of Existing Products

The features and benefits were identified through analysis. Each product is examined to show what the most common features and benefits are:

Product Name	Garbo grabber	Hand Foldable Pick up grabber	All-Terrain Ride on Vacuum	The WheelieVac	Electric Backpack	Street Sweeper
Benefits	- Effective - Compact	- Easy to use - Compact - Durable material	- Easy to use - Reaches hard areas - Comfortable	- Effective - Quiet	- Light - Environmentally friendly - Easy to use	- Quiet - Environmentally friendly - Comfortable - Easy to use
Features	- Handle - Garbage storage - Longarm - Picks up small objects - Collapsible	- Handle - Picks up small objects - Collapsible - Large grabber	- Ride on - Garbage storage - Vacuum - Mechanical - Manoeuvrable - Picks up small objects	- Vacuum - Mechanical - Garbage Storage - Picks up small objects	- Garbage storage - Mechanical	- Mechanical - Ride on - Manoeuvrable

Figure 4 (Product Benefits and Features)

Benefits

The majority of products that were researched incorporate strong user-centred design. The benefits put emphasis on the ease of use, comfort, and how compact the product is. Ease

of use is a very prominent benefit because the user must be able to use the product with minimal training. Comfort is also a common benefit amongst the majority of current products because productivity is increased if the user is comfortable. Lastly, compatibility is a shared benefit that current products share. Users prefer to have products that can be stored easily to maximise their working space

Features

Some key features amongst the current products that were analysed were having an internal storage for garbage and mechanical aspects. Having internal garbage storage is key to maximising efficiency. Products that use this feature have improved efficiency because it removes a step for the user to interact with the product. The user no longer has to manually put litter into a garbage storage area because it is internal. Having a mechanical aspect to a product can also improve efficiency. If the product has a vacuum feature it reduces the steps it takes in order to pick up litter. Meanwhile, if it is a ride-on device, it improves the speed at which the product can clean and collect litter.

2.2.2 Benchmarking – Functionality of Existing Products

Although all products serve similar purposes, they go about it in very different ways. There are different types of products that were analysed which are either manual or mechanical. This was done in order to get a greater scope of products that a litter collector uses.

Product	Functionality	Usability
Garbo Grabber	- Basic litter picker - Manual picker	- Has a trigger for picking up one piece at a time - Two components (picker and garbage bag holder)
Hand Foldable Pick up Grabber	- Manual picker - Foldable to become compact - Has a large gripping mouth for litter	- Can reach further distances - Can pick up small to medium-sized litter
All–Terrain Ride on Vacuum	- Can go on all terrain - Has a vacuum hose - Comfortable seating	- Vacuum suction allows for quicker work time
Electric Backpack	- Can become more mobile	- The medium-sized vacuum hose can suck up medium to small-sized litter

Figure 5 (Product Functionality and Usability)

After examining the functionality and usability, the products that are deemed most effective are those that have integrated vacuum hoses, comfortable seating arrangements, far-reaching litter collection hoses, and a device that can pick up all sizes of litter. These functionality and usability features improve the overall work experience a litter collector has by improving the enjoyment the worker has completing tasks. The improved hose allows the worker to become less strained when working, mitigating long-lasting pains from using alternative

methods. Improved comfortable seating arrangements allow the user to also improve efficiency by allowing the user to focus more on the task at hand and not the discomfort they are experiencing. The far-reaching litter collection hose allows the user to easily grab litter that is farther away from them. Lastly, a device that can pick up any size of litter enhances the user's abilities and effectiveness at completing their duties.

2.2.3 Benchmarking – Aesthetics and Semantic Profile of Existing Products

2.2.3.1 Aesthetics

Majority of products that were analysed used a similar design language. The design language that is currently used gives off an industrial feeling with softer edges and chamfers. The forms that were used for the shape of the products were usually dictated by the garbage storage unit which took up the majority of the product. The garbage storage unit must be at the forefront of the design because it is one of the main features of the product. The garbage storage is large and bulbous because it needs to house all litter that is collected within a singular day of work.

The products also use a combination of dark ridged colours with an accent of various colours. The dark colour ensures that the product does not become affected by outside elements such as mud and dirt. The dark colour shades the discolouring from the elements by blending in with its surroundings. The bright accent colour allows the product to be noticeable if lost and makes the product become less blan. The colour also breaks up the dark dreary colour and adds life to the product. The overall design appearance is that of industrial work equipment.

2.2.3.2 Semantics

The design semantics on existing solutions are driven by the user's touchpoints and are created to be user-centred. The products all have clear touch points which aids in the user's

operations. The touchpoints often resemble one another and are shaped as various handles. Also, the design of the products all follows a similar formula which puts the user at the centre of the design. Because the user is the sole operator of the product, it is key that the design utilises the user in all forms. By designing around the user's interactions, it improves the experience the user can have with the products.

2.2.4 Benchmarking – Materials and Manufacturing of Existing Products

Within this section, products with similar features are analysed and compared in order to support the design. Below is a chart of the products that were analysed.

X8 Scooter	Emmo Ado	Electric Litter vacuum LR50	Dodge Promaster
			
$699	$1799	$30,000	$37,640
Figure 14 (X8 Scooter) https://epiccycles.ca/product/electric-scooter/x8-electric-scooter/	Figure 15 (Emmo Ado) https://emmo.ca/emmo-ado	Figure 16 (Electric Litter Vacuum) https://madvac.com/electric/all-terrain-litter-vacuum-lr50/	Figure 17 (Dodge Promaster) https://www.ramtruck.ca/en/promaster

2.2.4.1 Materials

The primary material that is currently used in the automotive industry is aluminium and steel Aluminium is used to create the outer protective shell of each vehicle. Aluminium is a great material to use because it is lightweight and adds structure to the overall vehicle. The reason designers tend to use aluminium on the outer shell of their vehicles is because of their energy-absorbing properties. Since aluminium is one-third as dense as steel, it means that it can be three times the thickness before you have the same weight as steel. The 1xxx series of

aluminium is the most pure aluminium available. At 99% pure, 1100 aluminium sheet is extremely malleable. It also demonstrates excellent corrosion resistance. (Stanley, 2021) Aluminium is also a great material to use because it enhances safety without increasing weight (MetalSupermarket). Due to the lightweight of the aluminium, it allows the vehicle to stop quicker thus reducing the impact it can cause. Since aluminium is easily dentable, it acts as a cushion for the user if impacted by a great force. This, in turn, supports the user by creating less impact and minimal damage to the user. Steel is one of the strongest yet flexible metals and makes up the majority of the frame of most vehicles. Steel has a unique ability to bend on impact instead of breaking like other alternative materials. The steel also shares some similar features like the aluminium in which it acts as a cushion for the user. This increases the safety for the user when they are utilising the products.

2.2.4.2 Manufacturing

Within the automotive industry stamping is primarily used for the majority of the vehicle manufacturing process. The steel starts out as cold-rolled steel then pressed into the desired shape with a 5,000-ton press. Both the frame and outer shell are stamped, assembled and the spot welded together. Typically the outer shell which is made up of various aluminium panels are 18-gauge, which is 48 thousandths of an inch thick (actually 0.0478 inch). (Joseph, 2019) The electronics for each product are also assembled on an assembly line then implemented into the frame to create the final end product. In recent years most Car manufacturing has become more streamlined by having robotic arms assemble the vehicles to reduce margin of errors. (The History of Robotics in the Automotive Industry, 2017)

2.2.5 Benchmarking – Sustainability of Existing Products

During research, it was found that vehicles that use both aluminium and steel are more inclined to become recycled. Aluminium and steel are extremely recyclable, in which can both

be recycled indefinitely. At the end of a vehicle's life cycle, each can be taken apart and resold back to its manufacturers to create a circular economy. Also, vehicles that use lithium batteries are seen to have an increase in sustainability. The batteries can be recharged thus mitigating the use of gas to operate the vehicles. Gas-powered products emit hazardous air pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and sulphur oxides(SOx) that aid the process of climate change. (Air Pollution From Cars, Trucks, Vans and SUVs, 2017). Products that use rechargeable batteries create zero emissions thus making it an extremely efficient alternative to methods. As Electric vehicles become more popular, many charging options have become more prominent in the design world. Most parklots have now implemented electric car parking zones, which allow the user to charge their car. Within recent years vehicles have become more sustainable by implementing solar panels into the cars design. These solar panels allow the car to recharge its internal battery thus making itself sustainable.

2.3 Summary

The research that was conducted gave further insight into the current products and user interactions that litter collectors have. The main demographic showed to be middle-aged males with medium income.

Researching current products leads to investigating problem areas and how they can become strong points within new designs. Analysing aesthetics and semantics provided an understanding of how each product can be unique yet still follow a similar design language. Conducting research into manufacturing and sustainable methods allowed for greater insight into how products can be produced to mitigate harm to the environment. Going forward, all research from this section will be used as a benchmark for the following sections in order to understand the user and what they need for a proposed design solution.

CHAPTER 3 - Needs

In this section, an in-depth analysis will be looked at. This will include the user's needs, wants, experiences and journey when working as a litter collector. This analysis will aid in the designing phase in order to ensure that all aspects of the user's experience are met. The research that was completed in the last section will be analysed to uncover possible design opportunities for the completed design solution.

3.1 Analysis – Needs

In order to create a well-established product, the needs of the user will be analysed to uncover the problematic areas. Once the problem areas are identified, a proposed design will be developed that will enhance these areas of weaknesses. Current products, latent requirements, and categorization of needs are examined in order to develop an idea of what a user would want in a litter collection product.

3.1.1 Needs/Benefits Not Met by Current Products

The products that will be analysed to create the needs/benefits list are those that serve the potential user. The products that are analysed were: All-Terrain Ride-on Vacuum, Garbo Grabber, The WheelieVac, and Electric Backpack Vacuum. The diagram below is sectioned off into the 3 main components of the products that were looked at. These 3 categories are all-terrain, cleanliness, and speed.

Figure 6 (Need/benefits diagram)

The diagram above shows the four products that are broken into three sections of user needs/benefits. These sections include All-Terrain, Cleanliness, and Speed. All-Terrain describes whether a product is able to travel on all types of ground matter. Cleanliness is in regards to how effective the product is at staying free of dirt, stains, and debris. Lastly, Speed refers to the rate at which the product is able to operate.

These three sections overlap to demonstrate the different criteria that the current products meet. As it is seen in the diagram, there is not a single product that hits all three categories within the middle section. This presents evidence that all the products analysed have areas of improvement. The All-Terrain Ride-on Vacuum is the product that is closest to having all three aspects as efficient as possible. This product can be used on all-terrain but is lacking in the overall speed and cleanliness that could be potentially achieved.

3.1.2 Latent Needs

Current research was conducted on the needs of a litter collector in order to understand the areas that need improvements. The latent needs were analysed and recorded below:

- Users need to see how much litter was collected to ensure effectiveness levels.
- Users need to be comfortable using equipment because it will improve their work ethic.
- Users need to have knowledge on how to operate a vehicle because not understanding this may lead to improper work.
- Users need to know how much litter they collected because it is a sign of accomplishing their job.
- Users need to understand the type of litter that is being collected in order to improve the job speed.

3.1.3 Categorization of Needs

Within this section, the needs of the user are plotted based on their wishes, wants, latent needs, and immediate needs.

Wishes	Wants	Latent Needs	Immediate needs
Fun to use	Easy to use	Visual representation of litter that has been collected	An easier way to collect litter
Comfort	Light equipment	Vehicle to drive and protect the user	Durable and weather-resistant
Fast	Easy to see litter		

The majority of the categorization of the needs are user-centred putting most of the emphasis on the accessibility of how the user interacts with the products. Some outlying areas include durability and weather resistance. These areas are an immediate need so that the user does not spend extra time maintaining the product and continues to have unnecessary job disruptions.

3.2 Analysis – Usability

This section is based on the information gathered within 2.1.4 User Observation in order to acknowledge the potential improvement areas. The journey of the user was recorded to understand the goals, actions, and thoughts that a user may have during their job to find problem areas that can become improved.

3.2.1 Journey Mapping

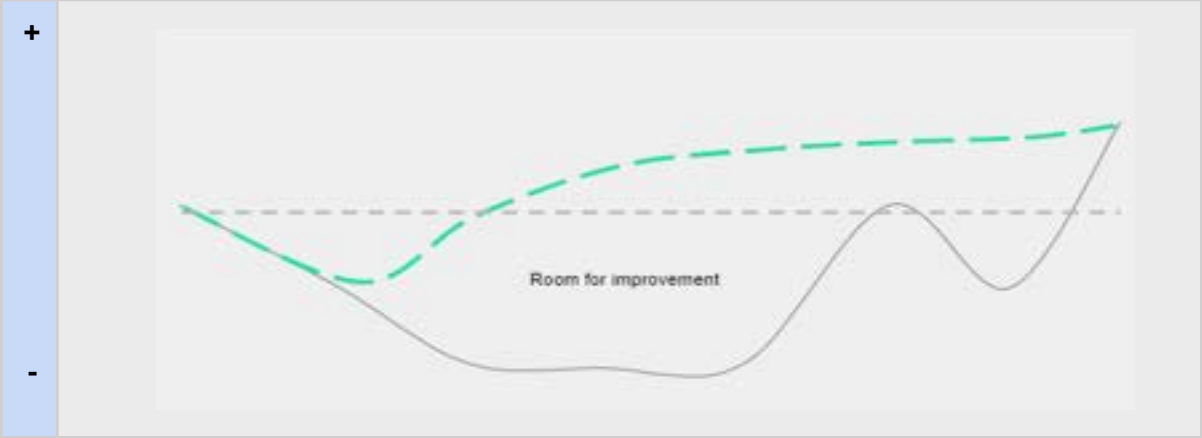
The figure below provides information on a litter collector's daily tasks and the thought process behind it. This data is used to gather greater information on the user in order to develop an enhanced product. The takeaways from figure 7 are that the user usually gets body pains from long hours and the work that is completed is "mind numbing" because of the lack of fun with their job. These takeaways will be used when gathering ideas to create new and unique concepts.

	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Task 5	Completion
User Goals	Wakes up and drives to work	Gathers all equipment and puts it in their truck	Starts the day off by collecting larger roadside litter	Loads large objects into the truck	Starts to clean litter on sidewalks	Cleans parks	Loads all garbage bags onto the vehicle	Completes daily tasks and work shift
User Actions	Gets dressed and puts high vis and gloves on, then drives to work	Gets garbage pickers, shovels, brooms, and garbage bags and puts them in vehicle	Finds larger pieces of litter Discusses how they will load their truck	Both workers get on either side of the large piece of litter and lift it They make sure that the item is secure	Drives to their designated cleaning sector with their vehicle and begin collecting	They use garbage bags and garbage pickers to collect garbage in the parks while talking to residents.	Gather numerous bags and load it into the back of the vehicle	Drives home
User Thoughts	"I hope today is warm so I don't get cold while at work"	"I hope these tools don't break while I'm working"	"Will this fit in the back of my truck?"	"How am I going to lift this and get it in my truck?"	"I hope there isn't hard to pick up litter on the sidewalks"	"I hope these people in the park notice my hard work and stop littering"	"My back hurts from picking up litter all day"	"I feel exhausted from all the work I have done today and my body feels sore"

Figure 7 (Journey Map)

3.2.2 User Experience

In the study below, the users' experience completing tasks were gathered in order to have an in-depth analysis of each task. The user experience chart corresponds with the user's journey map in order to identify the problem areas and key takeaways. The user describes their experience collecting litter and provides what areas they see as more challenging and what they believe needs to be improved.



	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Task 5	Completion
User Goal	Wakes up and drives to work	Gathers all equipment and puts it in their truck	Starts the day off by collecting larger roadside litter	Loads large objects into the truck	Starts to clean litter on sidewalks	Cleans parks	Loads all garbage bags onto the vehicle	Completes daily tasks and work shift
Problems/ Challenges	Tired from waking up early Needs to be alert	Organising tools take too much time	Hard to scout out larger objects	Can be strenuous from doing it every day	Pain from constant walking	Has to hold a garbage bag that has litter from a whole day of work	Has to load having garbage into the truck	
Ideas / Takeaways	Improve alertness	Designated spots for tools	An easier way to call high volume areas	Improve loading truck with heavy objects	Improve the mobility of the worker	The better way to hold heavy bags	Improve loading truck for garbage bags	

Figure 8 (User Experience)

The user's main ideas and takeaways from their experience at a day's work are that they want to improve mobility and comfort and decrease strain on the body. These ideas can become

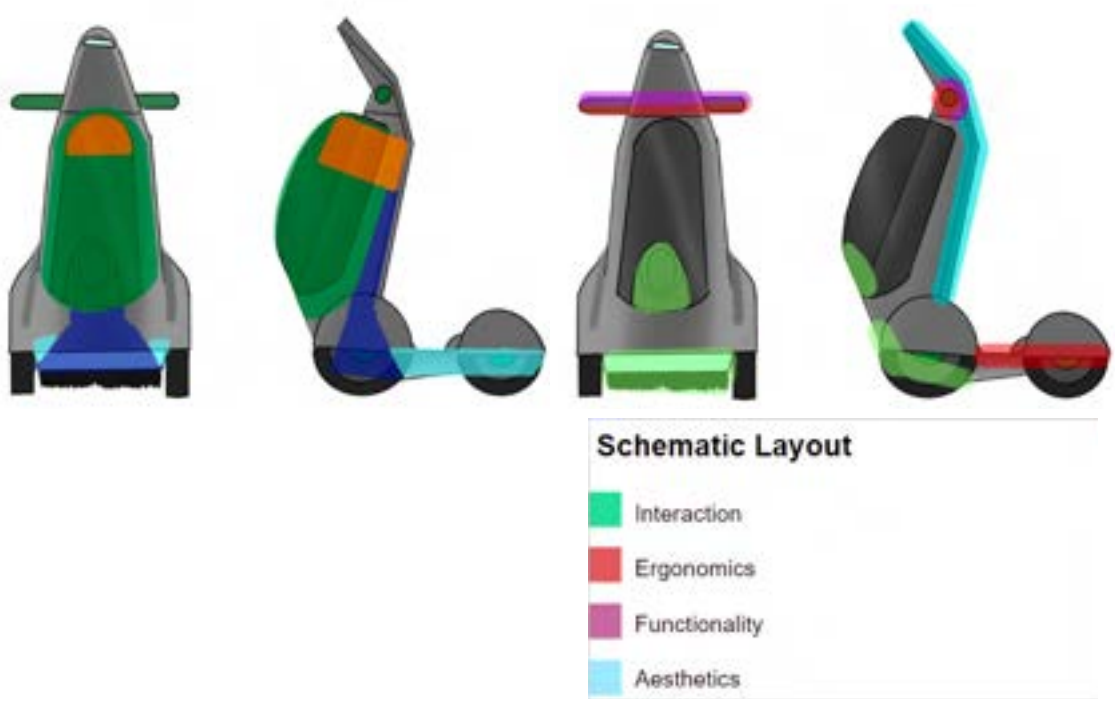
elaborated on within the design phase to ensure that these problem areas are solved appropriately.

3.3 Analysis – Human Factors

Human factors investigation seeks to evaluate how the user interacts with the product, the ergonomics, and the usability of the potential end design. This section will include a full-bodied human interaction as well as a configuration diagram. These two diagrams will aid the design process by categorising and dimensioning the primary features.

3.3.1 Product Schematic – Configuration Diagram

The configuration diagram below includes two design concepts. It includes a primary design as well as a secondary design. Each configuration diagram illustrates both the components diagram and schematics layout. The component diagram highlights the key elements and how they would lay within the proposed design. The schematic layout highlights the interaction, ergonomics, functionality, and aesthetics of the suggested design. The areas in which are highlighted will provide a greater understanding of the thought process of the design. The main components of the design are Garbage storage, Vacuum, and Battery. Both of the primary and secondary proposed designs work cohesively thus they are analysed together.



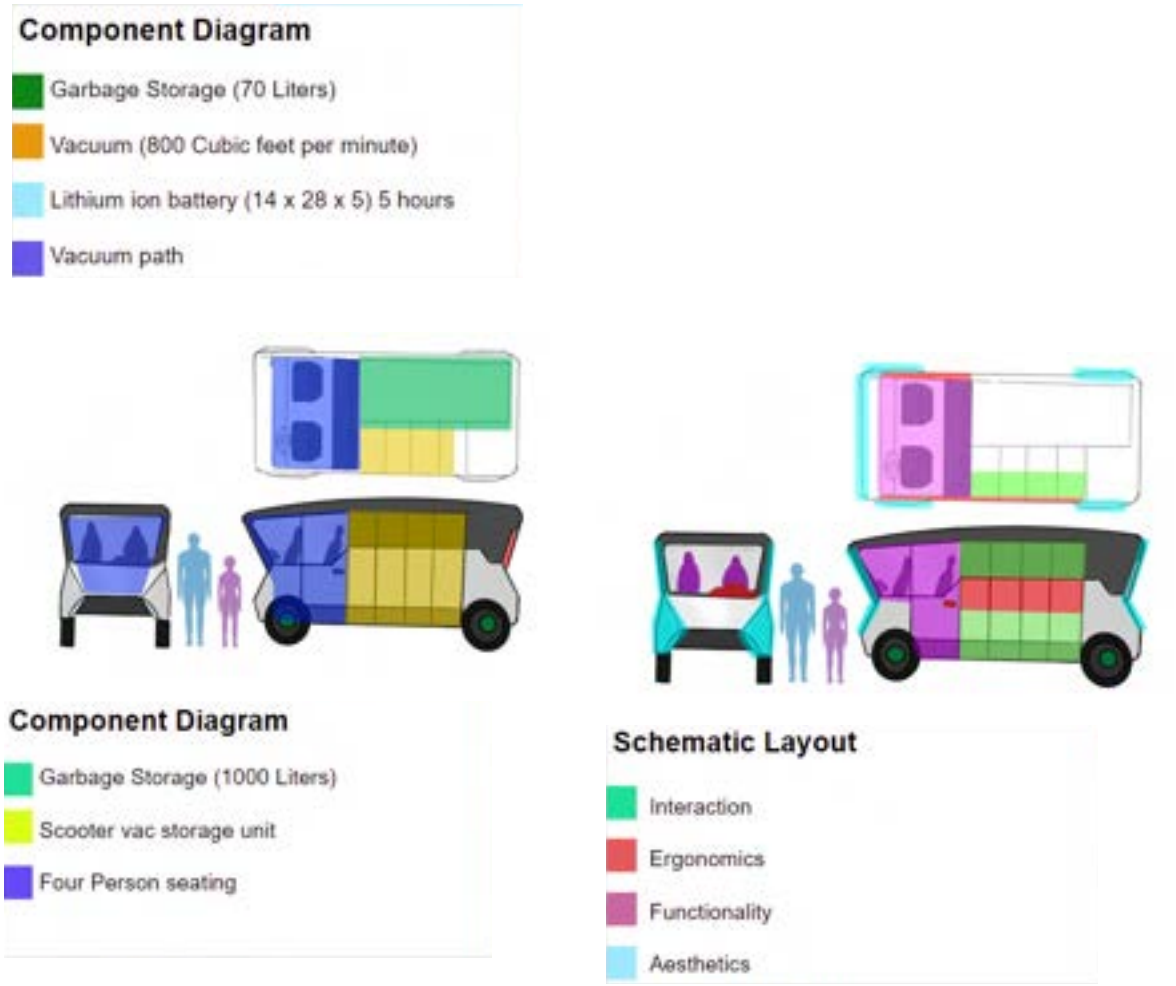


Figure 9 (Configuration Diagram)

3.3.2 Ergonomic – 1:1 Human Scale Study

3.3.2.1 Introduction

Litter collectors without vehicles are susceptible to back and leg fatigue from constant bending to pick up litter. Workers also report that repetitive motions can also produce minor pains in the upper arms and back.

Workers who are fortunate enough to have ride-on vehicles complain about the lack of stability the vehicle has. When going over rough terrain, the vehicle will occasionally shake the user thus making them uncomfortable within their seat. To better understand how to mitigate these problems the user has, an ergonomic study was conducted to determine these areas of weakness. If the study is completed properly, the issues the workers have should become

minimised.

3.3.2.2 Literature review

During the ergonomic study, a conducted literature was reviewed to understand the human body. The literature review provided information on human measurements, ergonomics, human interaction, and full-body interactions with products. The main source of information on the human body was **“The Measure of Man and Woman”** (Dreyfuss,2016) to determine the 90th percentile male and the 5th percentile female. The measurements of the 90th percentile male and the 5th percentile female were used because of their contrasting dimensions. All human measurements that fall between the 5th and 90th percentiles will accurately be accounted for within the ergonomic study.

3.3.2.3 Methodology

Objective

This investigation seeks to evaluate the human interaction, ergonomics, usability, and functionality of the proposed design. This includes the evaluation of “full-bodied human interaction design”. The evaluation will result in identifying the areas within the design that need improvements.

Decisions to be Made

The interactions with the major body parts were investigated to better understand how the touchpoints can be improved. The touchpoints included:

<u>Primary product</u>

- Foot positioning
- Vacuum length and handle
- Handlebars
- Touch screen

Secondary product

- Seating positions
- Steering wheel height
- Storage compartment

Description of Users Targeted by Product

The targeted user is male, aged between 25-40 with an average income of $40,000 a year.

Evaluation Process

The evaluation was completed by first constructing a full-scale model made from cardboard and wood. Comparing the models to a 5th and 90th percentile human figures, the following was observed:

Primary product

- How the user interacts with the handle
- How the user interacts with the hose
- How the user can comfortably stand on the vehicle

Secondary product

- How the user interacts with the steering wheel
- How the user interacts with the seat

3.3.2.4 Results

Ergonomic 1:1 Drawings

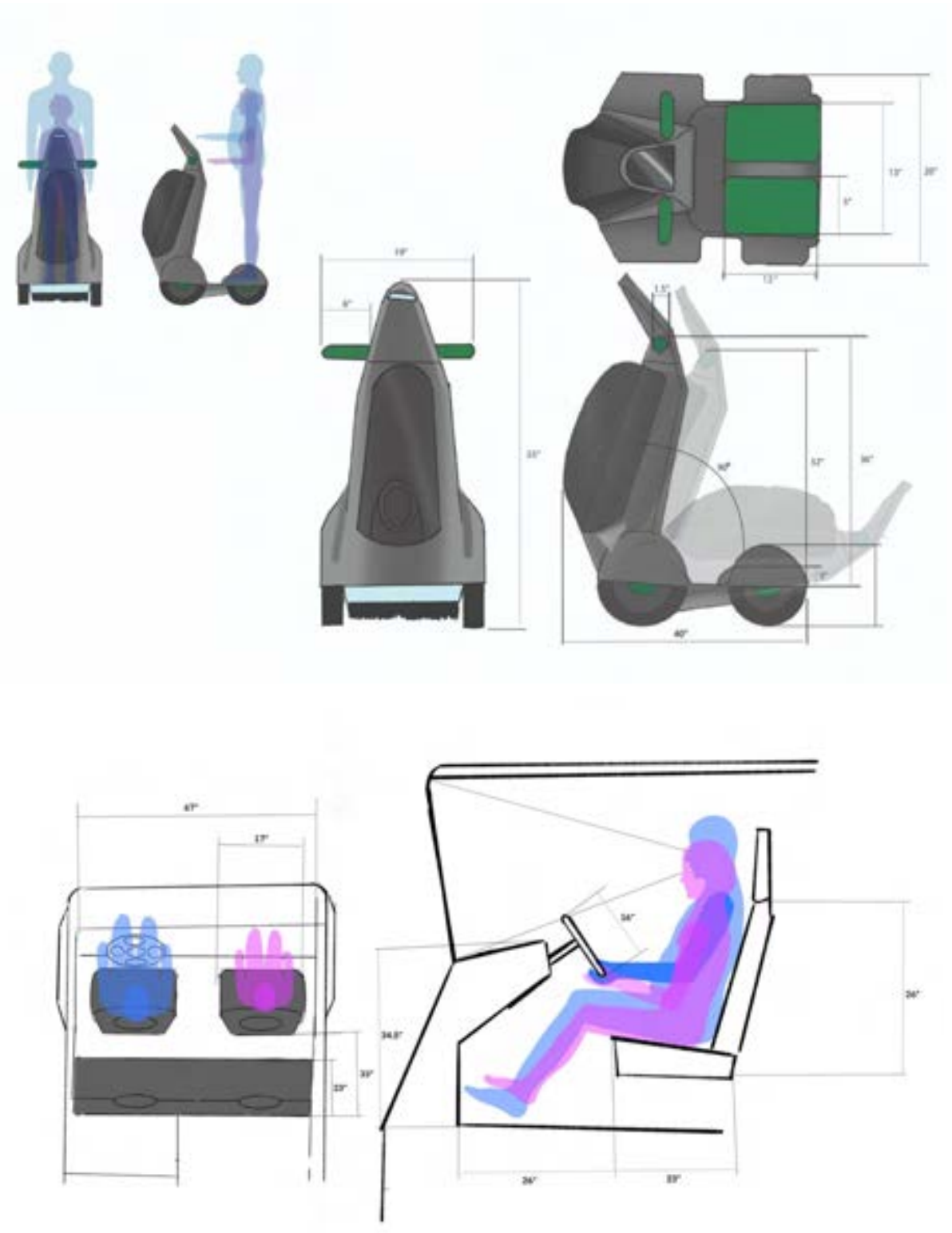


Figure 10 (Ergonomic Drawings)

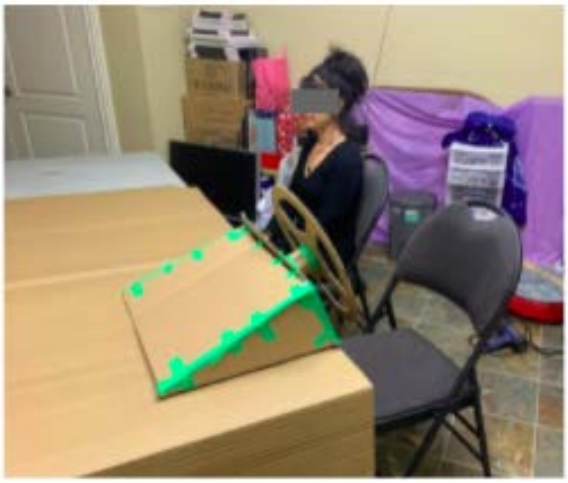
Before construction 1:1 scale models for ergonomics, in-depth dimensioning of both the primary and secondary designs were created. The dimensioning was needed to ensure that all sizes of operators can use both devices. The drawings were used to create templates for the 1:1 scale models.

1:1 Primary scale model: 5th Percentile Female

Model Images	Description
	This image provides information on a 5th percentile female operating the primary design. The image provides a view of the adjustable handlebar height to ensure the user is comfortable while operating.
	This image showcases a 5th percentile female interacting with the handlebars. Because the user has smaller hands, it gives them more room along the handle to find where the most comfortable area is to hold.
	This image indicates the standing platform and how the user interacts with it. The user has smaller feet so there is ample amount of room for the user to stand.

This image demonstrates how a 5th percentile female would interact with the vacuum hose. The hose has an extended reach allowing the user to grab far away objects.

1:1 Secondary Scale Model: 5th Percentile Female

Model Images	Description
	This image demonstrates a 5th percentile user interacting with the transport vehicle. Due to the adjustable seat, it allows users within the lower percentiles to comfortably reach the steering wheel.
	This image showcases a 5th percentile female sitting in the passenger seat. This view shows the amount of room they have while being a passenger.
	This image shows a 5th percentile female interacting with the steering wheel. Because of the adjustable height of the wheel, the driver can operate the vehicle comfortably.

1:1 Primary Scale Model: 90th Percentile Male

Model Images	Description
	This image demonstrates a 90th percentile male operating the primary design. The image provides a view of the adjustable handlebar height to ensure the user is comfortable while operating.
	This image showcases a 90th percentile male interacting with the handlebars. Because the user has larger hands, the surface area of the handle can be gripped more comfortably.
	This image shows the standing platform and how the user interacts with it. The user's feet fit snugly between the wheels. The wheels also act as protection for the user's feet

1:1 Secondary scale model: 90th Percentile Male

Model Images	Description
	In this image, a 90th percentile user interacts with the transport vehicle. Due to the adjustable seat, it allows users within the higher percentile to adjust giving them more room to reach the steering wheel.
	This image showcases a 90th percentile male setting in the passenger seat. TThis view shows the amount of room they have while being a passenger.

	This image shows a 90th percentile male interacting with the steering wheel. Because of the adjustable height of the wheel, the driver can operate the vehicle comfortably.

3.3.2.5 Analysis

Observation One - Hands

The hand ergonomics can be seen in figures 22 and 29. These figures display the users (5th percentile female and 90th percentile male) interacting with the handlebars. The handlebars are 1.5 inches in thinness which will accommodate all percentile users. The width of the handlebars is 13 inches across thus allowing all users to position their hands along the handles to best fit their comfort. Figures 27 and 33 demonstrate the user operating the transport vehicle. The steering wheel can be seen as being 1.5 inches thus will better accommodate all percentile users.

Observation Two - Feet

Within figures 23 and 30 the feet ergonomics can be seen. These figures display the standing platform for the users. The width of the standing platform is 14 inches across, allowing for an ample amount of room for both the 5th percentile female and 90th percentile male. The height of the wheels also acts as a protective barrier for the user’s feet.

Observation Three - Arms

Within figures 21 and 28, the arm length ergonomics can be seen. The stem of the handlebars is adjustable for the user's comfort. The stem can pivot in the Y-axis of the vehicle to accommodate all users' arm lengths. In figures 25 and 31, it demonstrates the user interacting with the transport vehicle. Due to the adjustable seat, it allows both larger and smaller users to remain comfortable when operating.

3.3.2.6 Limitations

After analysing the designs, some limitations arose. An area that is problematic is the handlebar height. If the user is taller than a 95th percentile male, they may run into issues with the height of the handlebars. The comfortability of using the primary design may be affected and the user may begin to hunch their back after operating for long hours.

3.3.2.7 Conclusion

This study revealed some ergonomic challenges that needed to be overcome. The 1:1 scale model aided in the overall design solution to ensure that all users from various percentiles are accommodated for. Within the ergonomic study, many dimensions were changed from the initial two-dimensioned drawings when making the 1:1 scale model. The final 1:1 scale model has all resolved dimensions correctly accounted for.

3.4 Aesthetics & Semantic Profile

To better understand the semantic and aesthetic profiles of the proposed design, three areas of interest are used. These areas include inspiration, influence, and aspirations. When all three areas of interest are brought together and implemented to the proposed design, it has the potential of creating a cohesive product. Each area of interest brings unique data along with it, thus allowing a greater understanding of similar products and how their aesthetics will improve

their overall design. The aesthetic and semantic profile is important to the proposed design because it influences how the potential user will feel about the product. It is important to create a cohesive design because it impacts the user's first impression of the product, making it a make or break moment. (*Design Principle: Aesthetics. The Power of Beauty in Design | by Anton Nikolov*,.) The semantic profile is also the building block of the design. Without it, there is no structure to the design of the aesthetics. (Fredrick,)

3.4.1 Inspiration

The proposed design takes inspiration from products within its area of work. It also takes inspiration from current design trends. When looking at a similar product, they tend to use dark colouring around the wheel as well as the bottom portion of the vehicle (Hitti et al.,). The reason for the dark colouring is because of the various surfaces the vehicle goes over. Due to the all-terrain feature on similar products, the vehicle is more likely to attract various forms of mud and dirt. The dark colouring aids in hiding most outdoor elements left on the vehicle.

When looking at the configuration of similar products, a slender sleek form will be used. This form factor is incorporated into the proposed design based on the interaction the potential user has with this product. When using similar products, users want more ease of use. This

means that they will need the most important features to be in reachable lengths to enhance their comfort when operating.

3.4.2 Influence

To gather influence, current design trends were looked at. Smart devices are a big part of the evolving design landscape and have been incorporated into the proposed design. (Kimbarovsky, 2021). Within the dash, there is a touchscreen that operates as a smart device. The smart device will allow for the users to improve the customizability of the vehicle to improve the overall safety and comfort. The smart screen will also provide the user with essential information. The information that will be displayed is: speed, storage capacity, battery life, GPS, and adjustable ergonomics.

When looking at the form factor of the vehicle, influence from existing products was used. Current products use smooth faces and soft edges to provide a user-centred design. The soft and smooth faces invoke a sense of safety to the user, which is key to providing a safe journey for the operator. The softer edges provide a more inviting feel for the user and pedestrians, making the user's journey more appealing and comfortable. These examples will be integrated during the design process of the proposed design.

3.4.3 Aspirations

Within this section, the aspiration of what the proposed design strives to achieve based on its functionality and usability. The proposed design aims to be aesthetically pleasing while remaining as functional as possible. The design needs to allow the user to feel comfortable while operating but still needs the user to remain focused when doing their daily tasks. Also, the design should be robust enough to be all-terrain as well as still maintain its inviting feel for the user. It should aim to minimise the amount of environmental elements that the vehicle comes in contact with so that it will reduce the quantity of required maintenance that it may need. The

product should aspire to achieve a design that mimics current and future trends that are similar to the proposed outline.

All three of these sections must be incorporated into the final proposed design to ensure that the concept is cohesive. All sections have unique values due to their differing data points. This will allow for an effective design that has a well-thought-through aesthetic and semantics profile.

3.5 Sustainability – Safety, Health, and Environment

3.5.1 Environmental safety

When designing a litter collecting concept, environmental safety must be considered. Sustainability is a key aspect of the design due to the fact that its main purpose is collecting litter. During manufacturing processes, there are many byproducts that are produced and thrown away causing a snowball effect and piling up litter. To ensure sustainability is being considered, the manufacturing process should become minimal in order to reduce the byproducts.

With the evolving landscape of sustainable vehicles, current trends must be looked at. Currently, in Canada, 2.2% of vehicles are electric, thus being an increase of 125% from 2017 to 2018. (*Electric Vehicle Sales in Canada in 2018*,) Switching over to electric-powered vehicles decreases the overall planetary pollutants that are caused by gas-powered vehicles that produce carbon emissions.

3.5.2 Health and Safety

Health and safety is seen to be a high priority within the proposed design. Because the vehicle will be exposed to all terrains, the vehicle must ensure the user remains safe at all times. Looking at all of the adjustable ergonomic features of the design, the majority of user body pain (legs, arms, and back) are mitigated and provide an improved comfort level when working. The wheels of the primary vehicle serve two main features. The first beneficial feature is to propel

the vehicle forward when driving. The second is that the rear wheels protect the user's feet from external harmful objects. The rear wheels act as a shield and allow the user's feet to be safeguarded when operating the vehicle. Also, the design's handlebars allow the user to remain balanced while using the vehicle. This will help prevent the user from falling off the vehicle and potentially hurting themselves.

3.6 Innovation Opportunity

3.6.1 Needs Analysis Diagram

The diagram below provides information on where innovation can arise. The needs analysis diagram is broken into three sections and four sub-sections. The main sections include business (viability), technology (feasibility), and people (desirability). The four subsections are seen to be where the innovation can arise. These sections include process innovation, emotional innovation, functional innovation, and experience innovation.

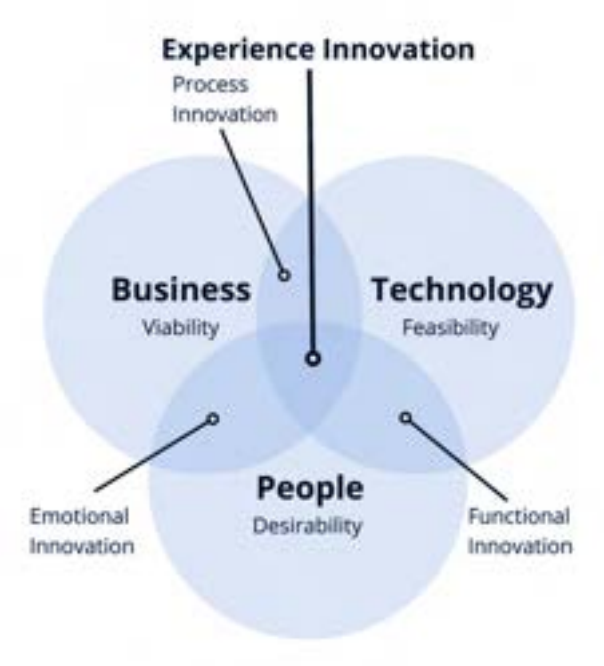


Figure 11 (Innovation Diagram)

3.6.2 Desirability, Feasibility & Viability

Desirability

Desirability is based on why someone would be attracted to a certain product. Currently, there are methods to clean dense urban areas but these products lack efficiency. Developing an efficient vehicle for collecting litter will create a more desirable product that more cities will want to implement.

Feasibility

Feasibility is based on how easy it is to create or operate a product. In terms of manufacturing, similar products demonstrate that the cost of manufacturing is low. The technology that is being used, although new, is completely achievable during manufacturing. In terms of operating the product, the user can easily learn how to use the vehicle. The vehicle does not need intense training in order to understand how to operate it.

Viability

Viability is based upon how easily the product can become integrated into current processes. Creating a clean environment is necessary to maintain the ever-growing landscape of consumerism, therefore the market for products that aid in this process will never become obsolete.

3.7 Summary of Chapter 3 – Defining Design Brief

3.7.1 Design Brief

The following provides information on the various criteria that the proposed design must meet in order for it to be effective:

1. **Design for the User -** The proposed design should aim to create a versatile litter collecting vehicle for the user. It should have all-terrain features to minimise the amount of physical labour the user goes through.
2. **Easily Customizable -** The design should allow the user to be able to customise their

vehicle to improve their individual experience. They should be able to mix and match what features work for them to improve their experience.

3. **Simple to Use -** The design should be able to be used with minimal knowledge of how to operate. This is so that a wide variety of user backgrounds will be able to utilise the vehicle.
4. **Easily Adjustable -** The user should be able to adjust the vehicle with ease to improve comfort. The handlebars and hose in the primary design and the steering wheel and seat in the secondary design are easily adjustable.
5. **Improved User Ergonomics -** The design should be all-inclusive for all heights of users. This will decrease the user's chances of becoming uncomfortable or injured.
6. **Versatile -** The design should be effective and mobile to ensure that the job at hand is completed in a fashionable manner. The vehicle should be able to adapt to any terrain it may come in contact with.
7. **Sustainable Materials Used -** The design should aim to use sustainable materials to minimise the number of byproducts that will be created during manufacturing. This is also important when determining how the vehicle will run. In this case, lithium batteries will be the most sustainable route that should be used.
8. **Easy to Maintain -** The conditions with which the design may come in contact with, it should be able to be easily cleaned and maintained. This is important so that users spend less time cleaning and maintaining the vehicle instead of collecting litter.
9. **Durable -** The design should be able to withstand harsh environmental conditions to minimise vehicle damage. This is so that continuous maintenance is not needed for the vehicle.
10. **Integration of New Technology -** The proposed design should incorporate new technology to ensure a long-lasting design. This will allow the product to continue to stay up to date with current design trends.

CHAPTER 4 – Design Development

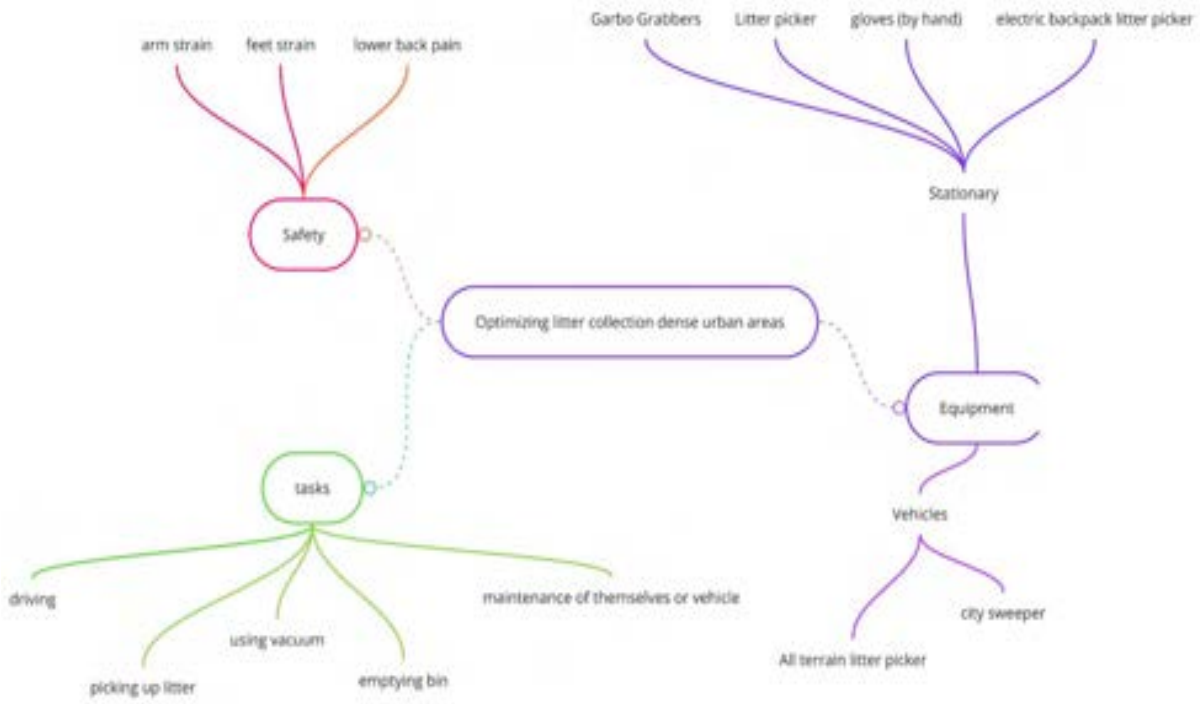
Within this chapter, ideas and concepts were developed in order to optimise litter collection in dense areas. A range of different design opportunities were used in creating concepts to gather a wider array of ideas. In this section, brainstorming sketches are shown as well as developmental sketches to convey the functionality of the proposed design.

4.1 Initial Idea Generation

4.1.1 Aesthetics Approach & Semantic Profile

Before the start of concept creation, inspiration on current and future designs were completed. The inspirations aided in the designing of the aesthetics and semantics of each proposed design to ensure all concepts can become unique. The concepts were heavily influenced from designs that rely on futuristic aesthetics, mainly focused on the sleek straight edges with a monochromatic colour scheme. Each image provides differing elements that are unique and have been incorporated to inspire each proposed design that was created.

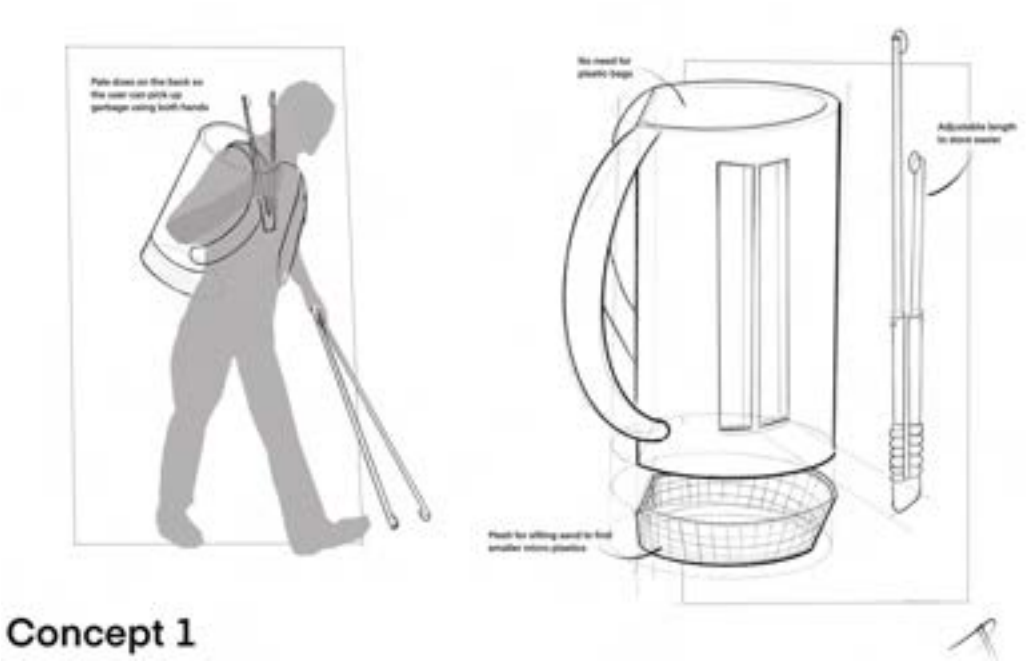
4.1.2 Mind Mapping



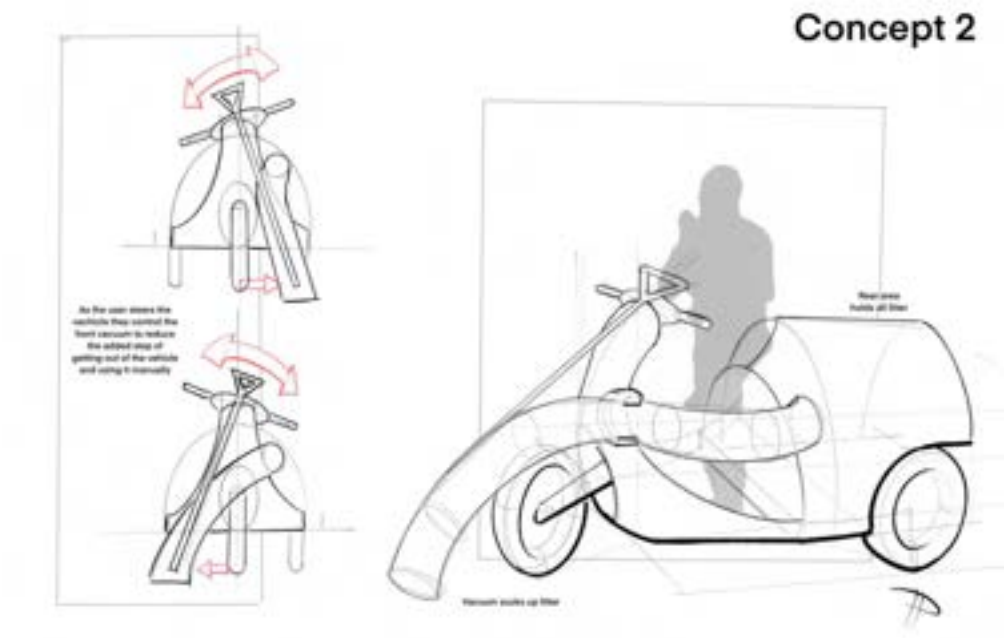
Before the designing and ideation phase began, a mind map was created. This map aids in the thought process to narrow down the problem areas of litter collection that must become solved. This was done by analysing products that are currently in use and determining their functionality as well as their areas of improvement. Some elements that were analysed were safety, task and equipment. These elements were elaborated into sub sections that were used to help discover areas of interest to create various new concepts.

4.1.3 Ideation Sketches

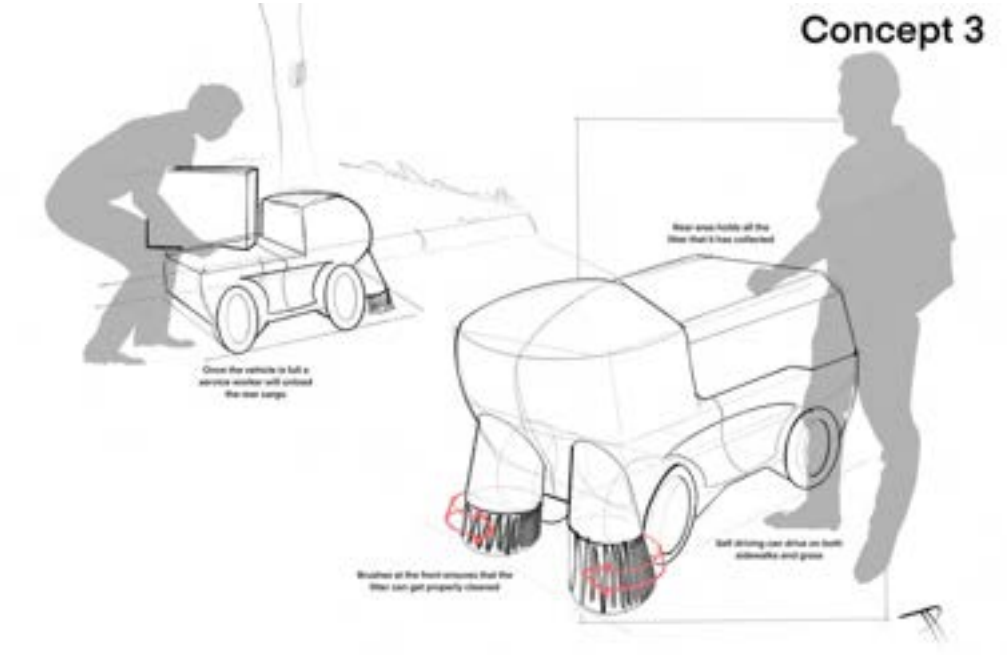
During the initial ideation phase, a wide range of products were created from wearable tech to ride-on vehicles. During this phase, multiple problem areas were designed in order to ensure a unique design solution was created. The initial ideation sketches focus more on the functionality of each product rather than the form factors of each design.



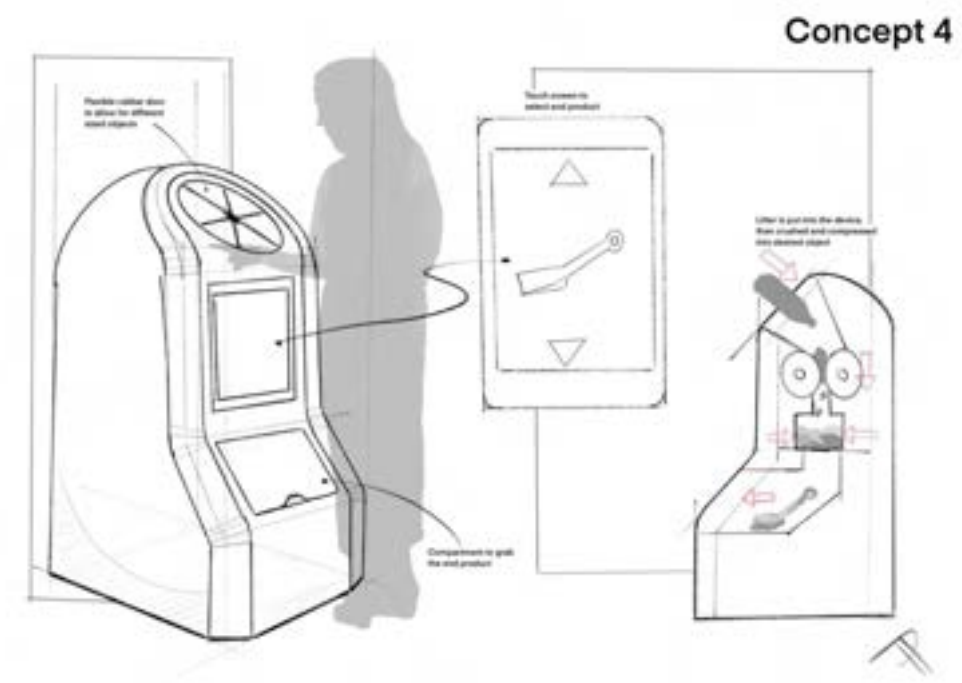
Concept 1 focuses on optimising litter collection for an individual worker. This concept utilises wearable technology to aid the worker in efficiently collecting litter. It is made up of four parts, the backpack, sift, and litter stick.



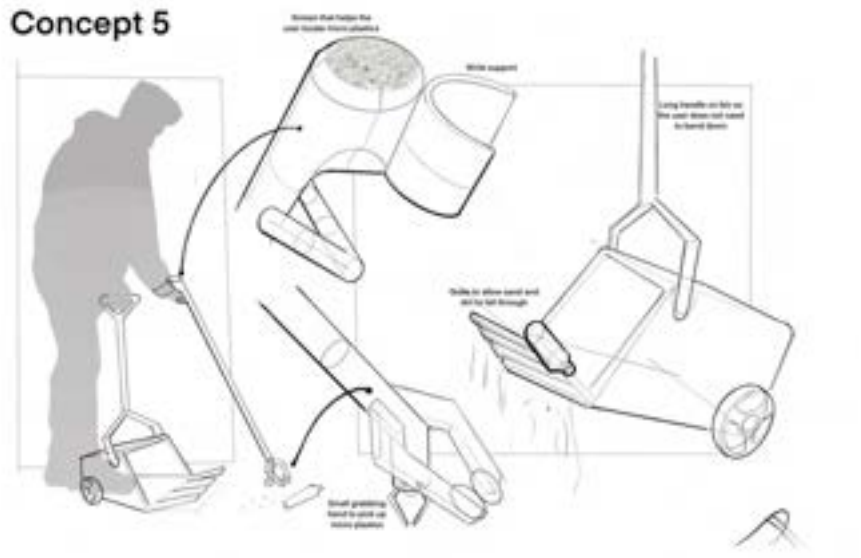
Concept 2 is a unique take on a litter collecting vehicle. This concept focuses on manoeuvrability for the user when operating. The concept utilises a vacuum hose to maintain a more precise collection.



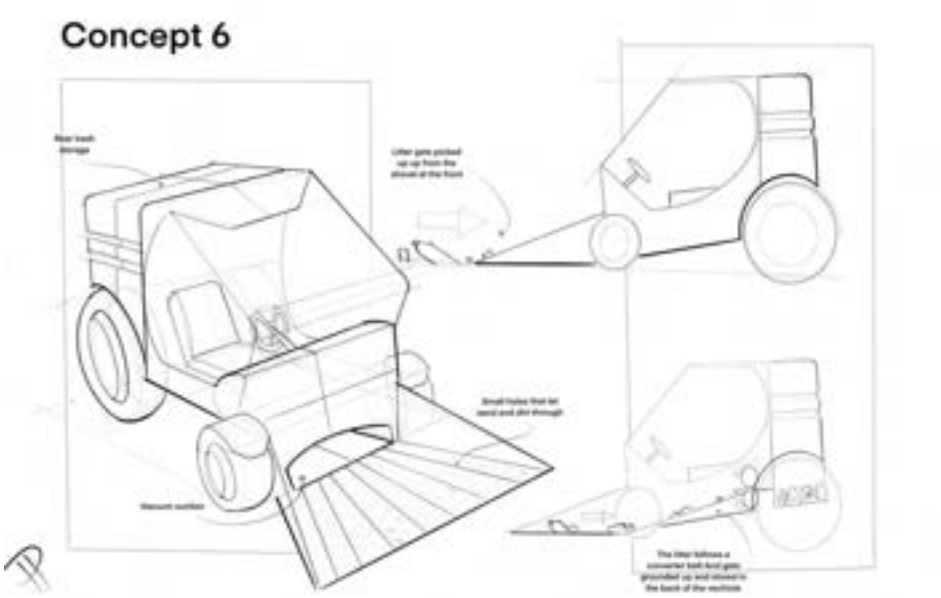
Concept 3 was developed to be an automated litter collector. This device would operate autonomously through all hours of the day collecting litter.



Concept 4 is a stationary device that turns litter into unique objects/toys. This design would utilise the public to pick up litter and operate the device.



Concept 5 is similar to concept 1 but utilises more technology. This concept uses a small camera to pinpoint smaller pieces of litter that can not be seen from far away.



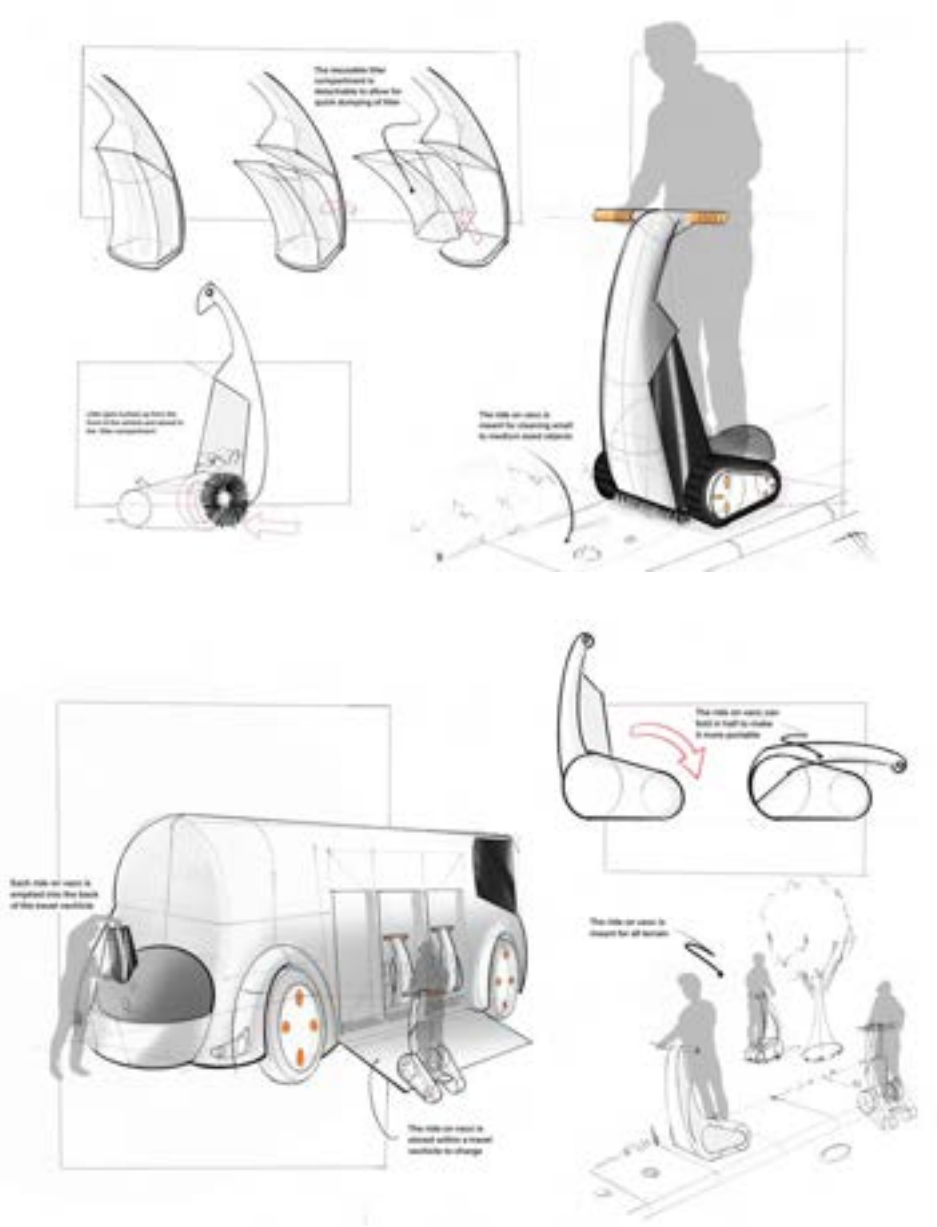
Concept 6 is a ride-on litter collector with a shovel filter at the front of the vehicle. The shovel has perforations at the front to allow sand or dirt to fall through the vehicle and not end up within the vacuum.

4.2 Concepts Exploration

Concept exploration uses the previous sketches/ideas to develop further into realistic ideas. Three of the initial sketches were brought over into this phase and were developed further into unique ideas. At this point, the design criteria were created to ensure that all concepts were solving a similar problem.

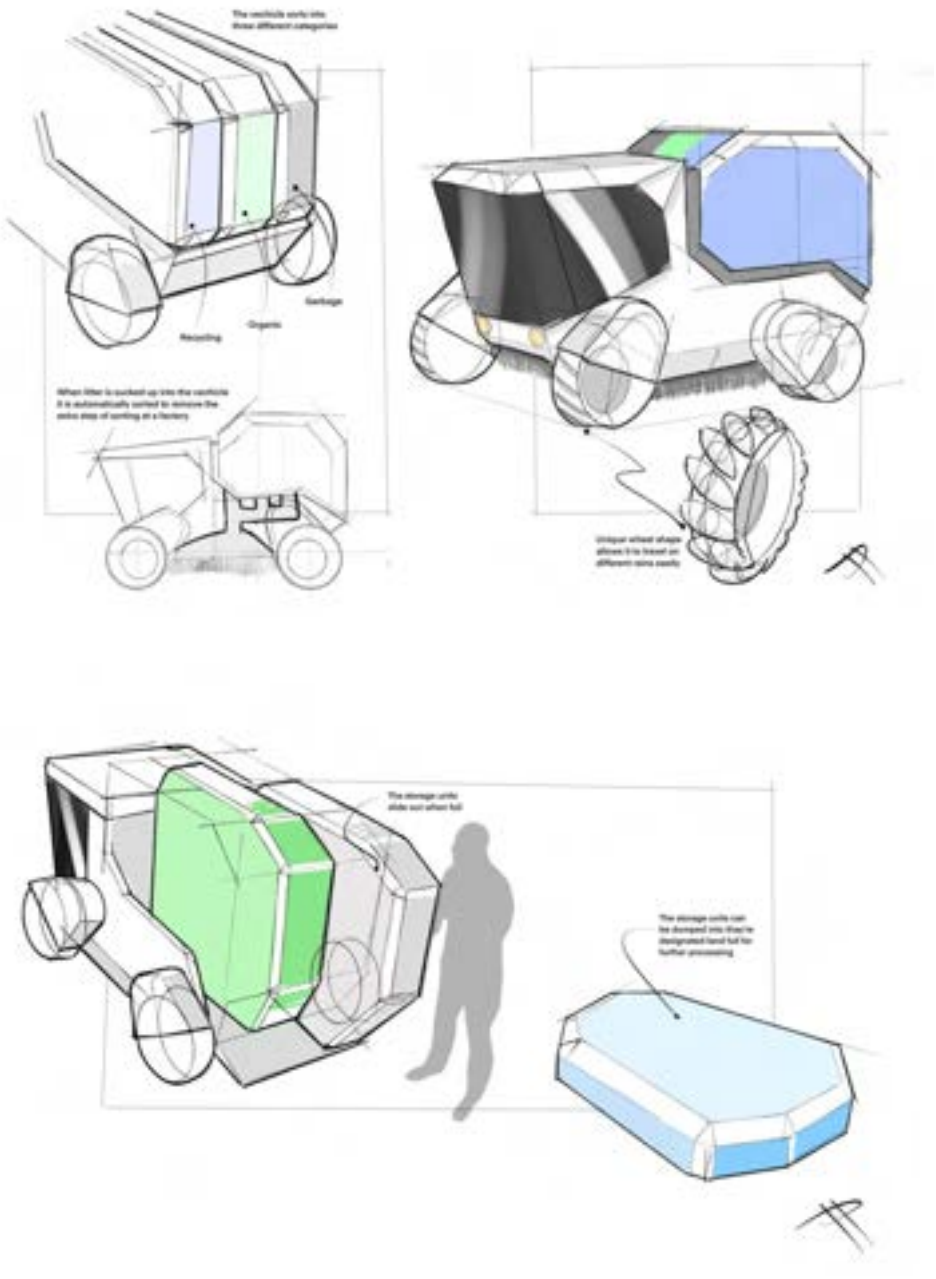
4.2.1 Concept 1

The first concept within Concept Exploration is The Ride on Vac. This vehicle would be used in city areas and is highly manoeuvrable. The scooter is transported within a bigger vehicle that empties and charges each scooter. Within the transport vehicle, four scooters are housed.



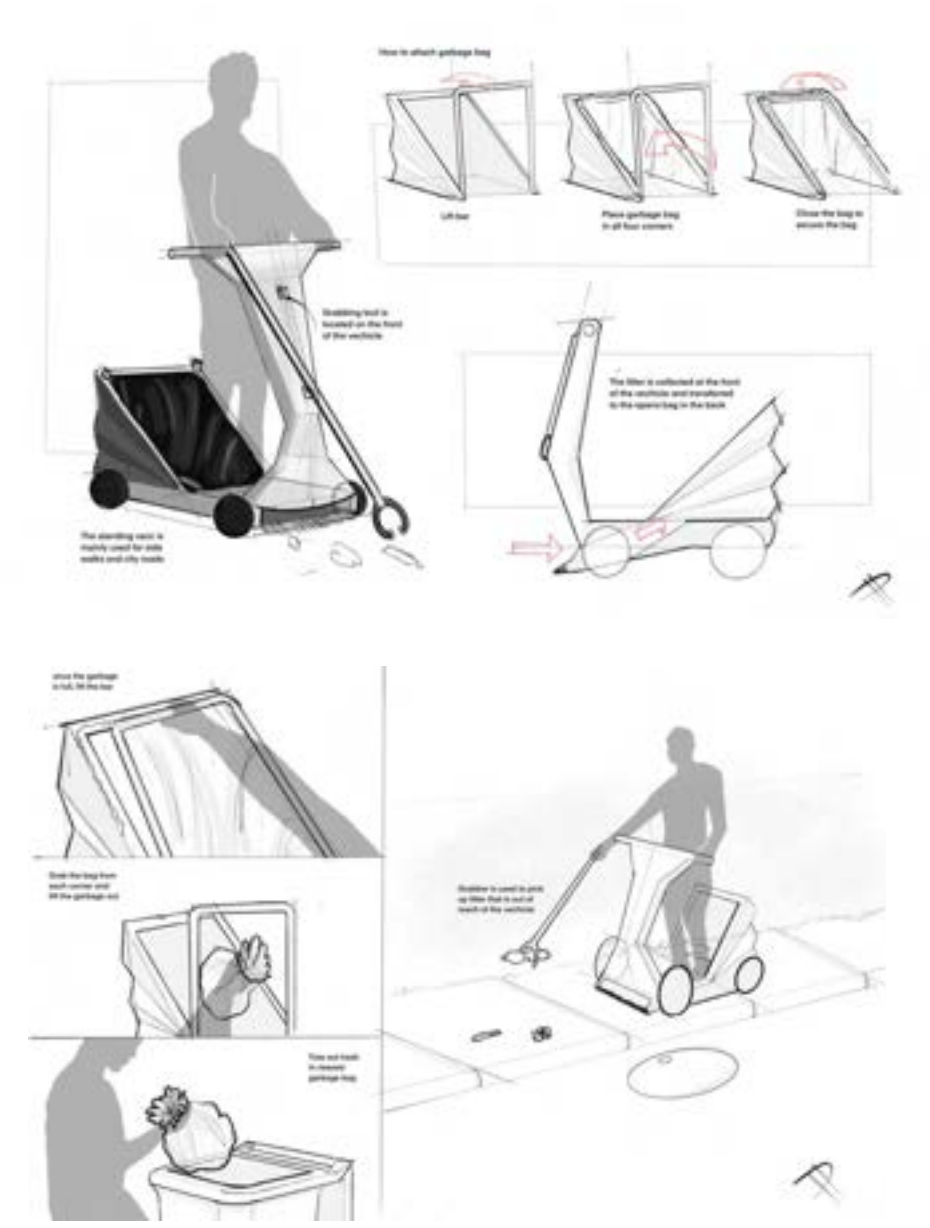
4.2.2 Concept 2

The second concept is an auto sorting litter collector. This vehicle separates organic, recycled and metals within its storage unit. The vehicle's main purpose is to reduce the amount of post processing of litter.



4.2.3 Concept 3

The third concept is a litter collector that utilises garbage bags to quickly empty the litter within it. This negates the need of going to post processing due to being able to put the garbage bag directly into the trash.

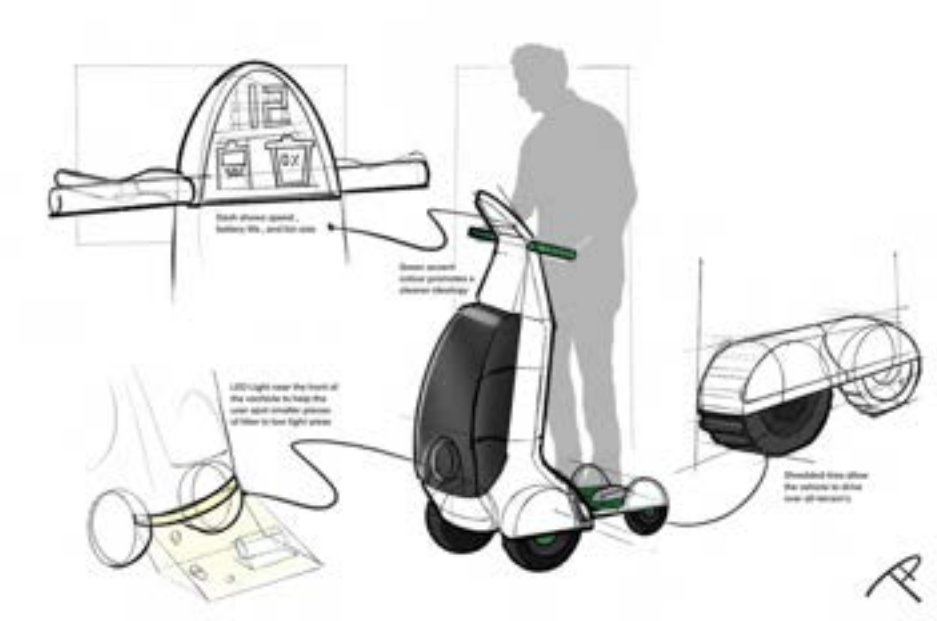


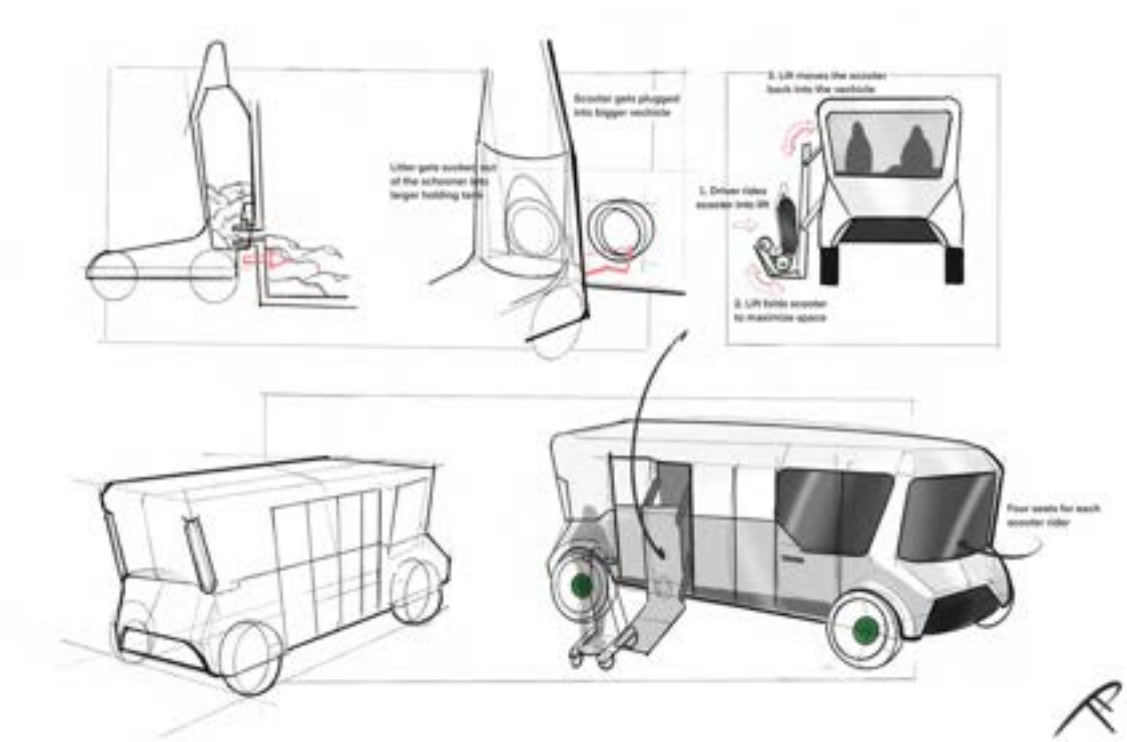
4.3 Concept Strategy

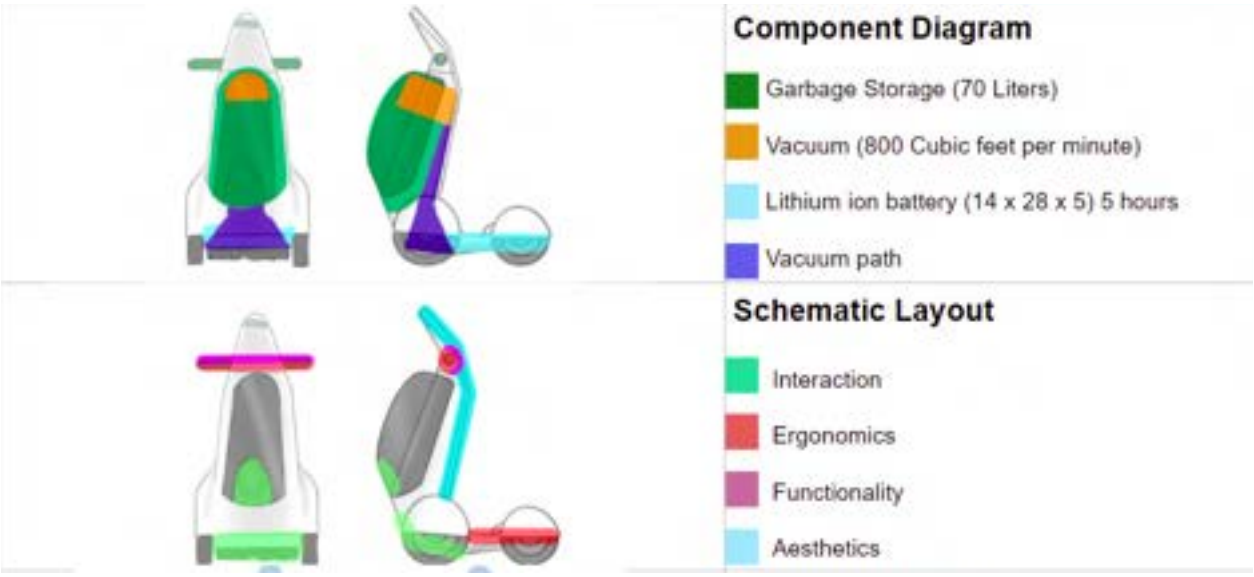
The concept strategy phase uses the two most promising ideas and further analyses their features. The concepts were further refined to hone in on each concept. Both concepts were laid out into product schematics to gather a greater understanding of how the concepts would operate.

4.3.1 Concept Direction & Product Schematic 1

This concept was chosen to develop further based on its unique effectiveness when collecting litter. The design is manoeuvrable and easily transported. This concept is twice as effective as standard litter collectors and could reduce the amount of litter that remains in city streets.






Component Diagram
Garbage Storage (70 Liters)
Vacuum (800 Cubic feet per minute)
Lithium ion battery (14 x 28 x 5) 5 hours
Vacuum path
Schematic Layout
Interaction
Ergonomics
Functionality
Aesthetics

4.3.2 Concept Direction & Product Schematic 2

This concept was chosen to be developed further because of its internal sorting system. This vehicle negates the use of post processing making the start to finish job of collecting litter shorter.

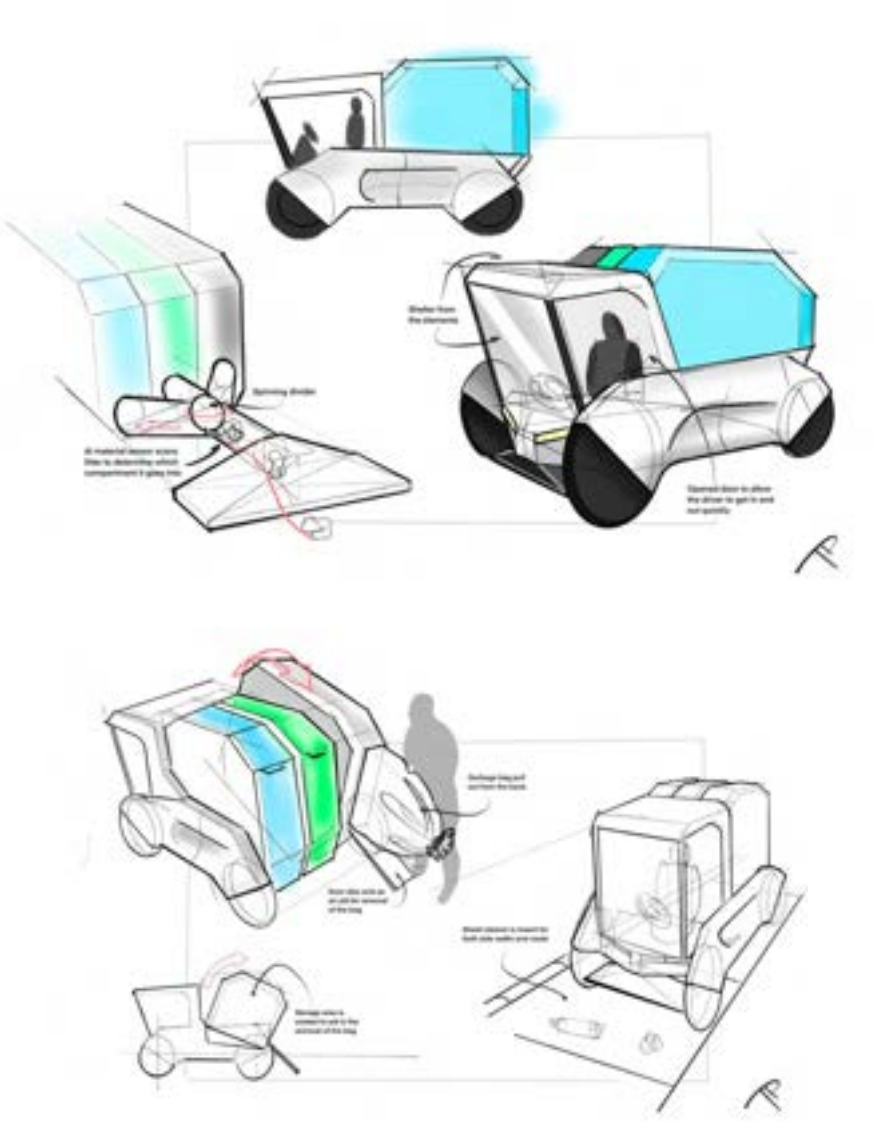


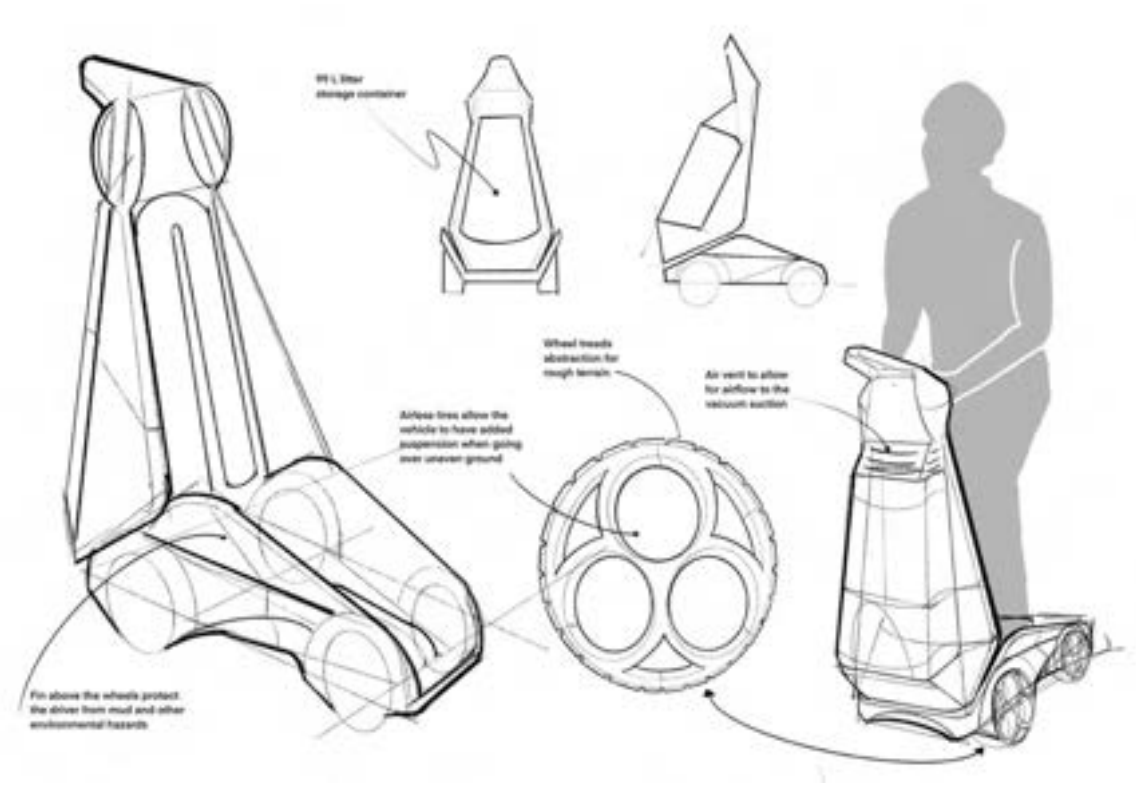
Figure 52 (Concept 2.2 refinement)

4.4 Concept Refinement & Validation

One concept was chosen to move forward with and to create further detailing. This concept underwent form revisions to create a more pleasing aesthetic, but also to serve functionality. Further refinement on both vehicles from this concept was done along with creating detailed drawings of the various features the concept has. To better understand the concepts, a refined schematic drawing was done. This aids in understanding in-depth features the product will have.

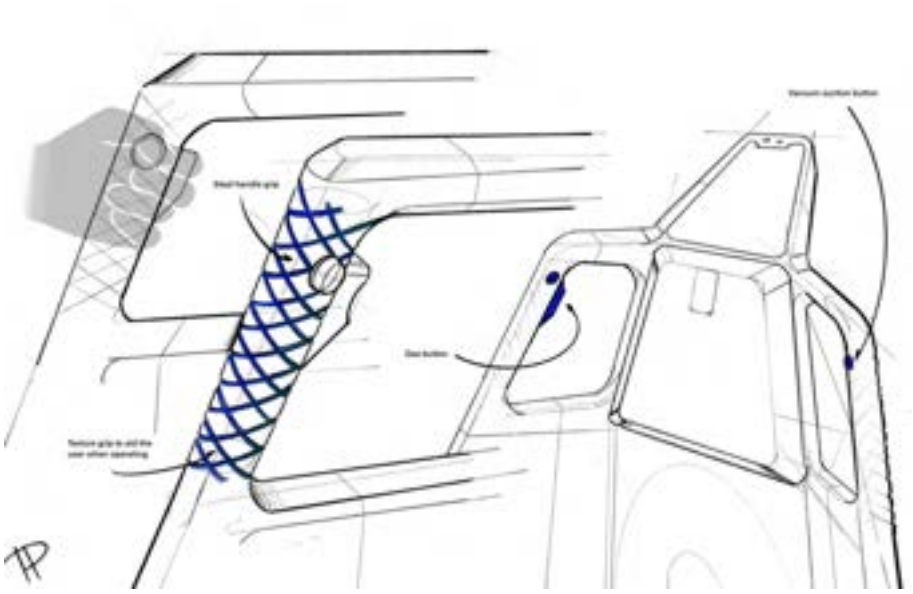
4.4.1 Design Refinement

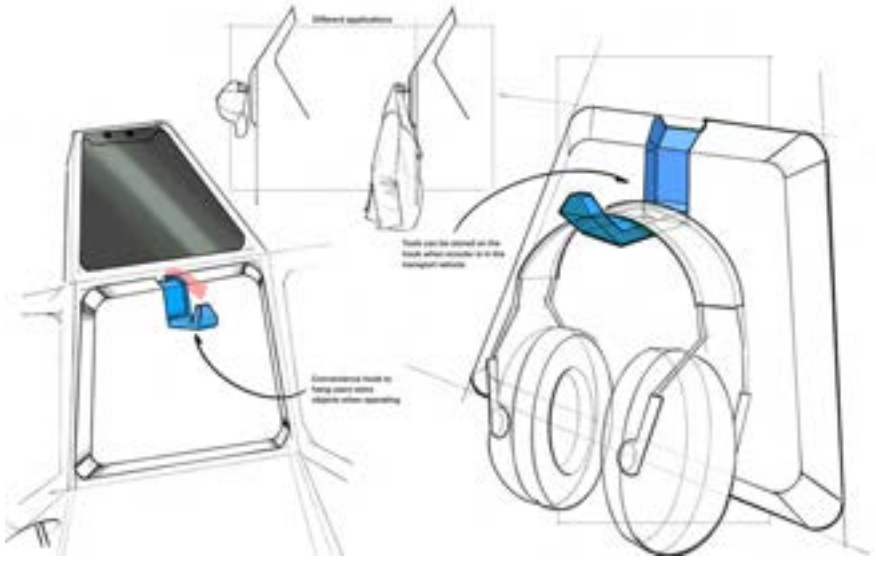
Below is the concept refinement of concept 1. The design follows more closely to the aesthetic inspiration from Chapter 4.1. The design focuses on the sleekness of the product. The design needs to be highly manoeuvrable that is why most design elements of the product are close to the user promoting an arrow dynamic form.

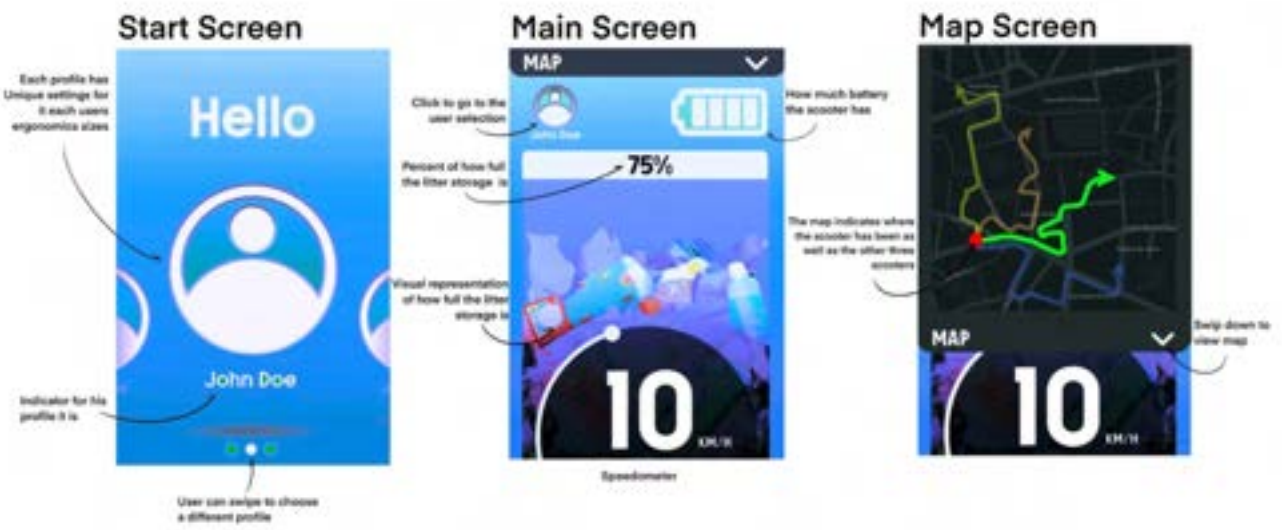


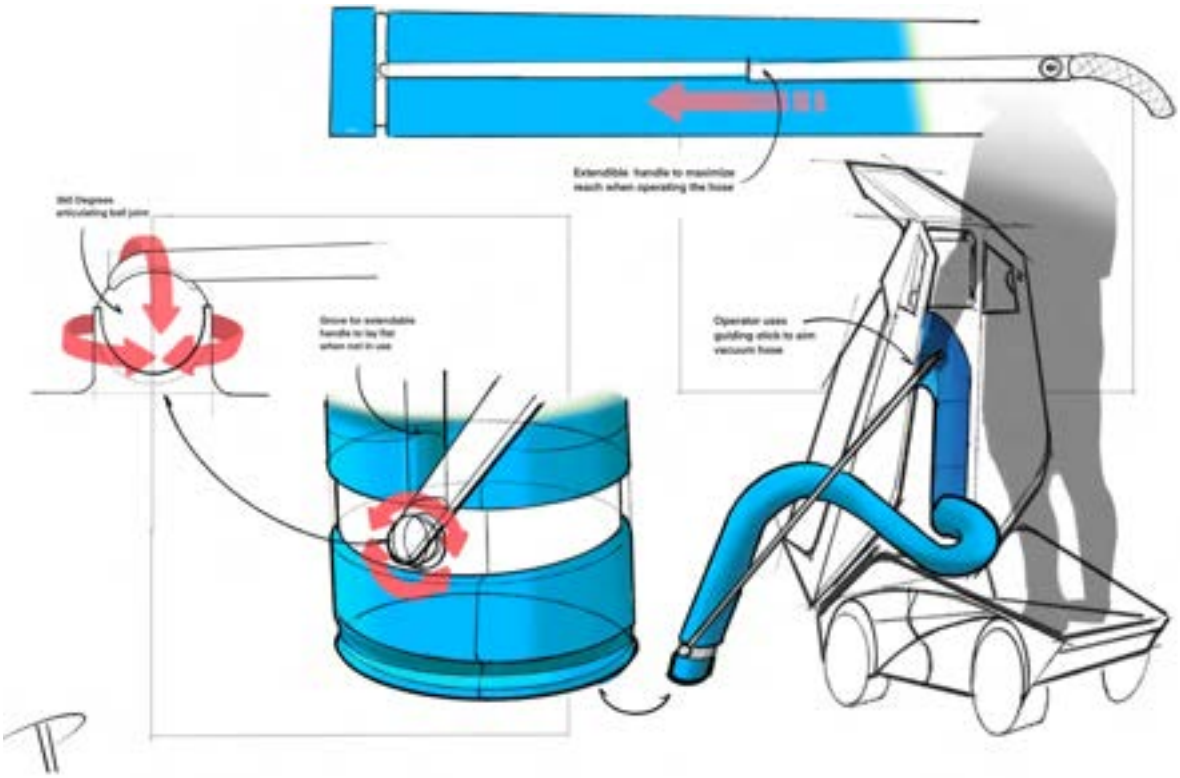
4.4.2 Detail Development

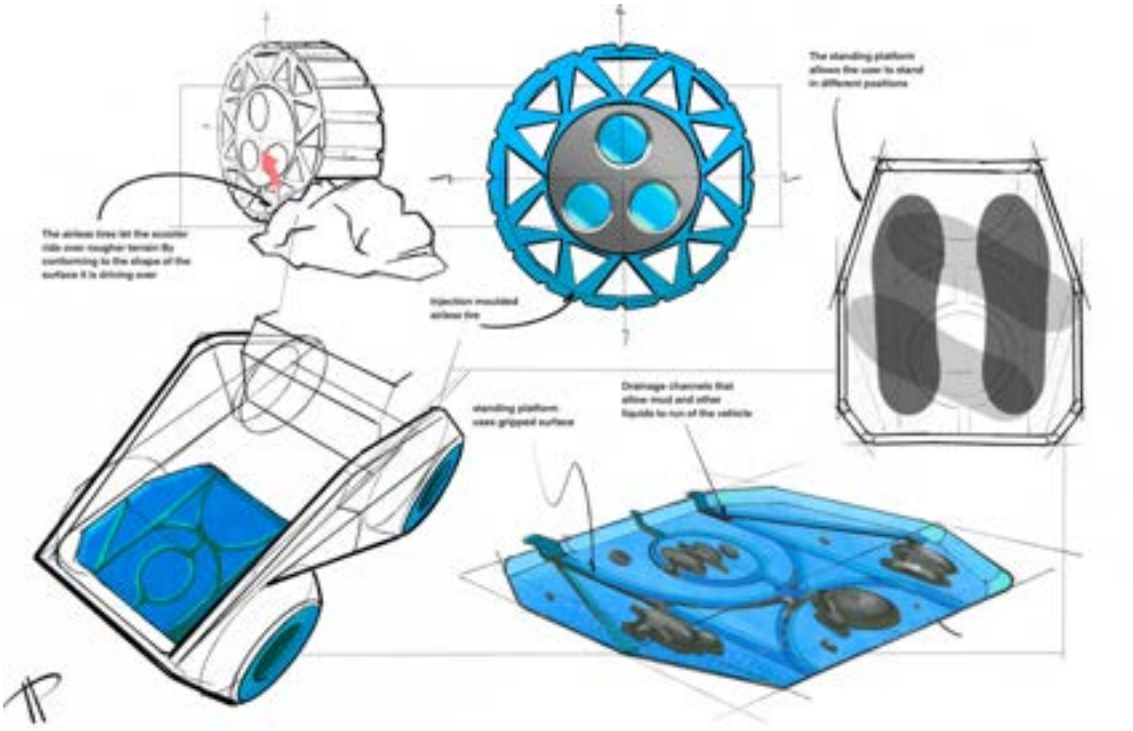
After the overall form of the proposed design was completed, design detailing was done. The purpose of this phase of concept creation is to narrow down the details to truly make the design unique. This phase also aids in the CAD development, by honing in every feature. Each image below provides an in depth analysis of micro features the proposed design has.

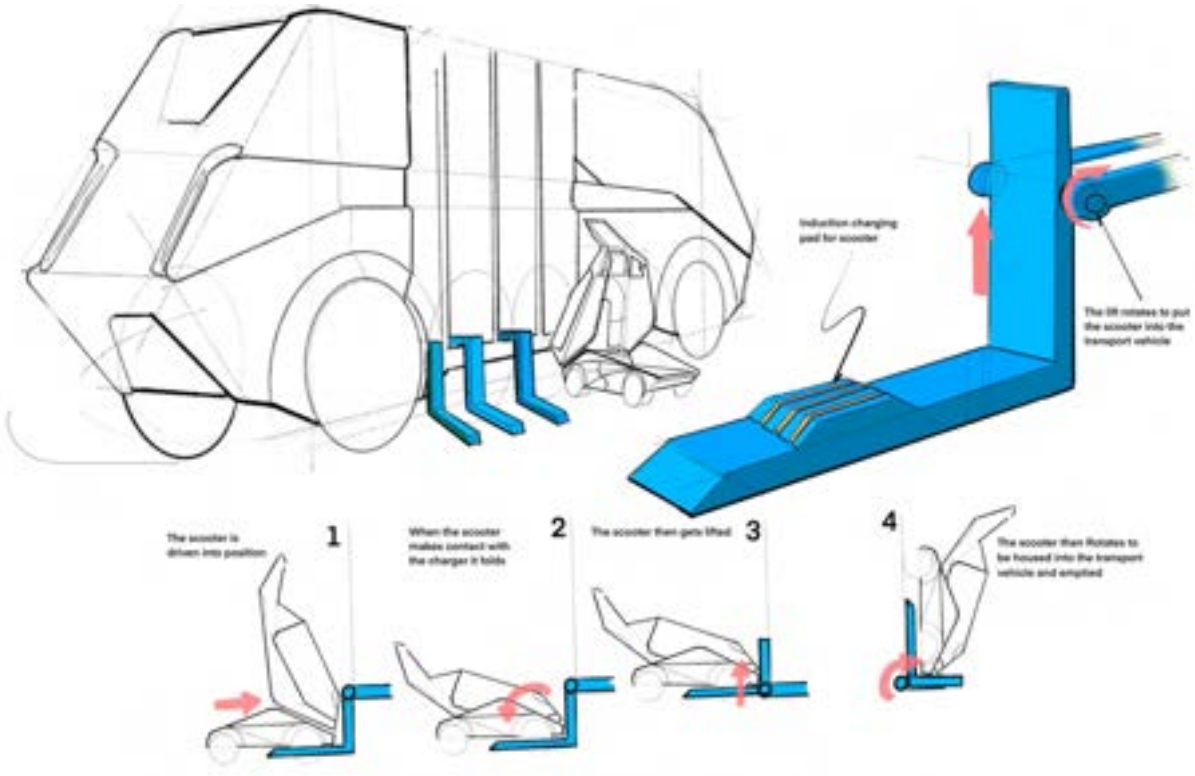





Start Screen
Hello
John Doe
Each profile has Unique settings for it each users ergonomics sizes
Indicator for his profile it is
User can swipe to choose a different profile
Main Screen
MAP
Click to go to the user selection
How much battery the scooter has
Percent of how full the litter storage is
75%
Visual representation of how full the litter storage is
10
KM/H
Speedometer
Map Screen
The map indicates where the scooter has been as well as the other three scooters
MAP
Swip down to view map
10
KM/H


Extendible handle to maximize reach when operating the hose
360 Degrees articulating ball joint
Groove for extendable handle to lay flat when not in use
Operator uses guiding stick to aim vacuum hose


The airless tires let the scooter ride over rougher terrain By conforming to the shape of the surface it is driving over
Injection moulded airless tire
The standing platform allows the user to stand in different positions
standing platform uses gripped surface
Drainage channels that allow mud and other liquids to run of the vehicle


Induction charging pad for scooter
The lift rotates to put the scooter into the transport vehicle
The scooter is driven into position
1
When the scooter makes contact with the charger it folds
2
The scooter then gets lifted
3
4
The scooter then Rotates to be housed into the transport vehicle and emptied

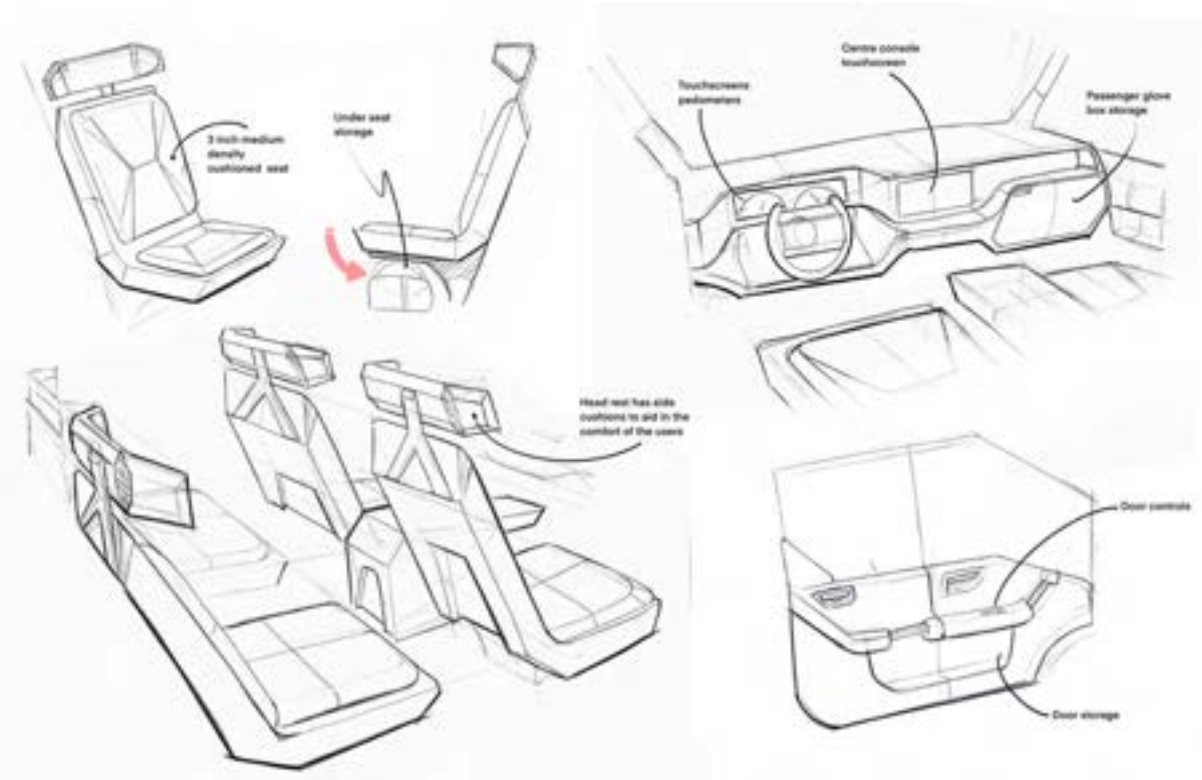
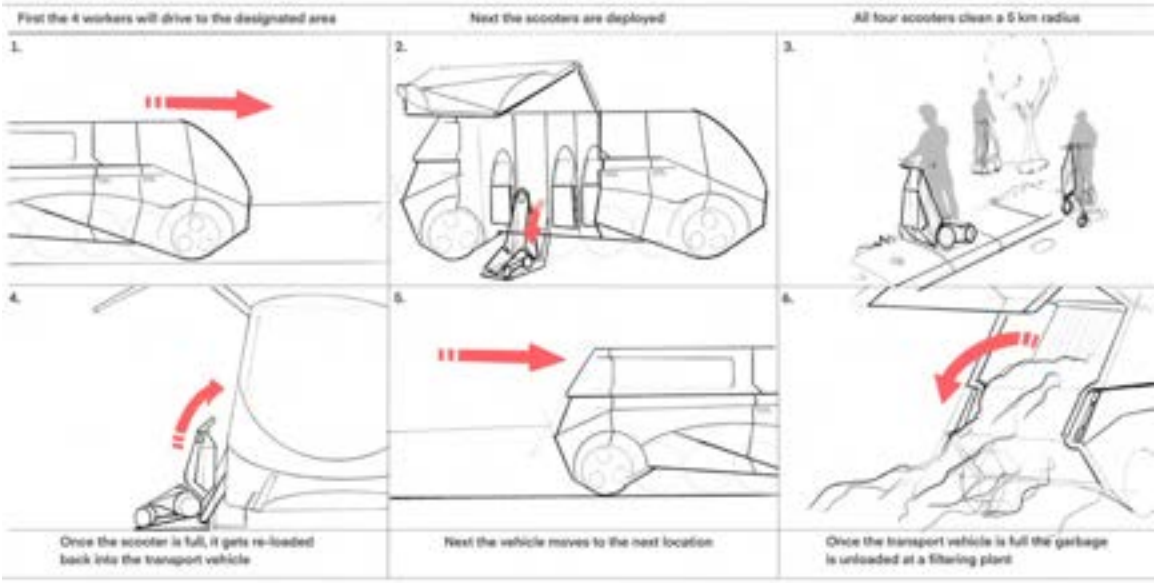


Figure 59 (Detail development 5)



4.4.3 Refined Product Schematic & Key Ergonomic

To understand the full scope of the product a refined product schematic was created. This schematic diagram illustrates the internal components of the proposed design. The diagram provides in depth information on speed, battery capacity, cleaning power and litter housing size. This additional information is key to understanding the mechanism that allows the design to operate successfully.

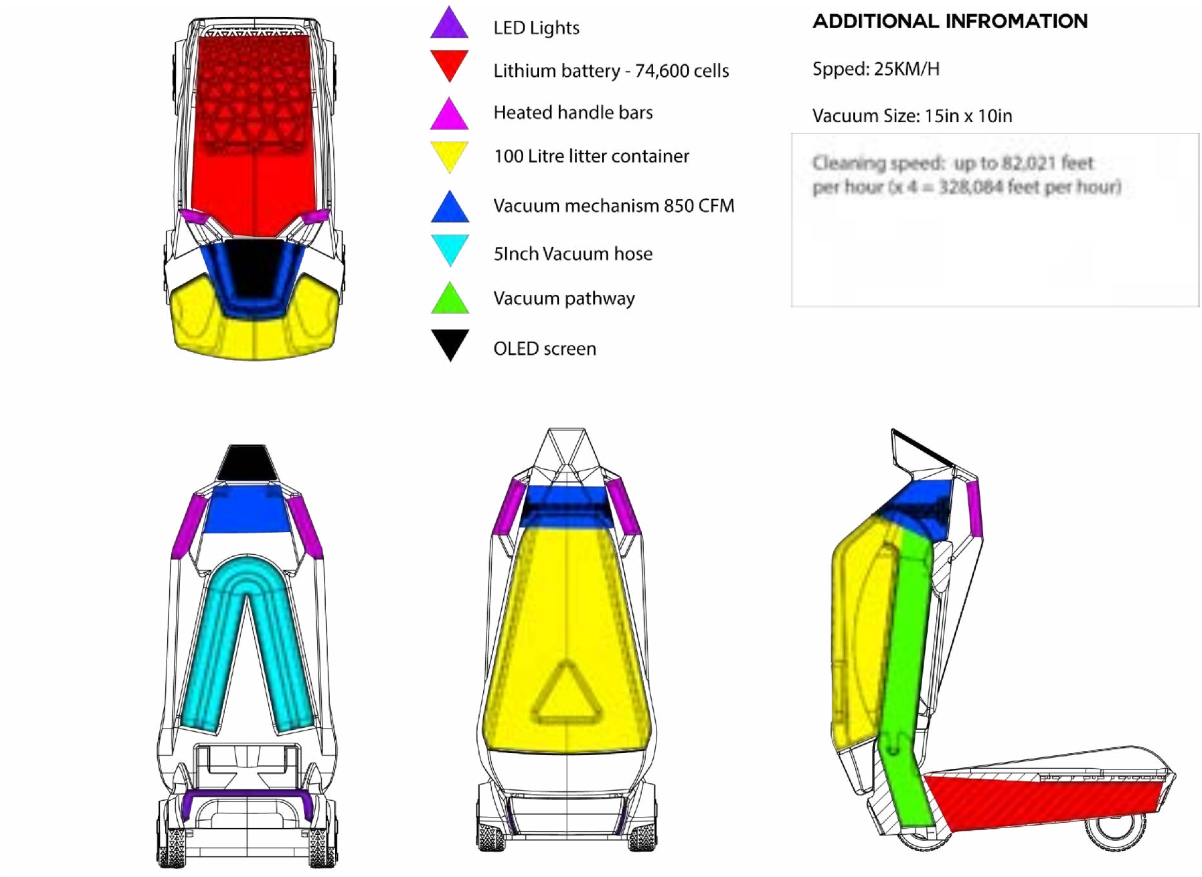


Figure 12 (Product schematic 1)

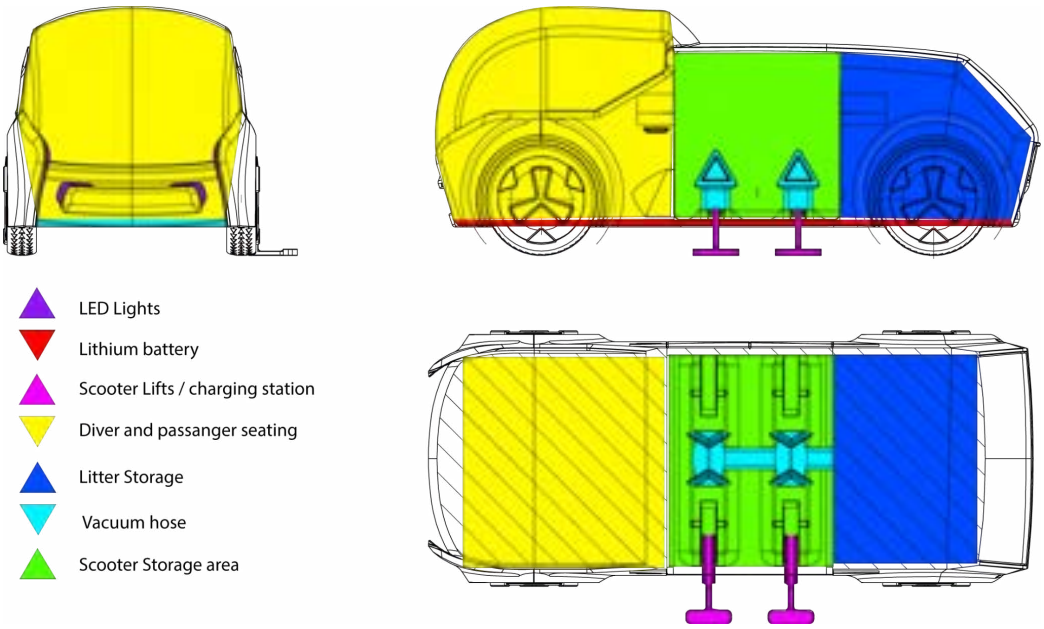


Figure13 (Product schematic 2)

4.5 Concept Realisation

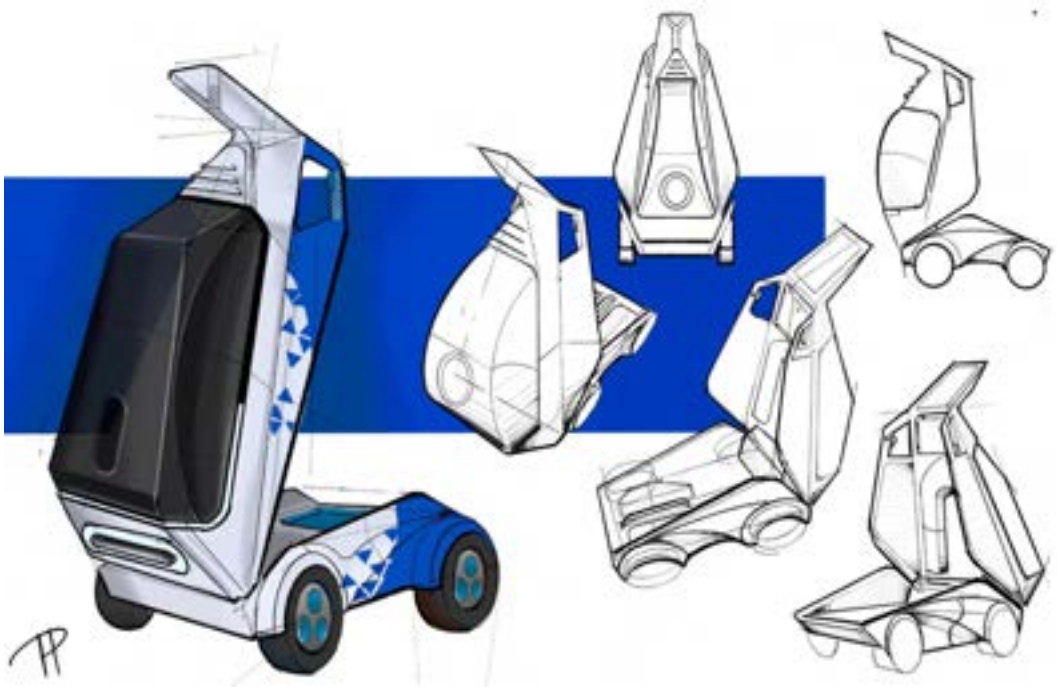
4.5.1 Design Finalisation

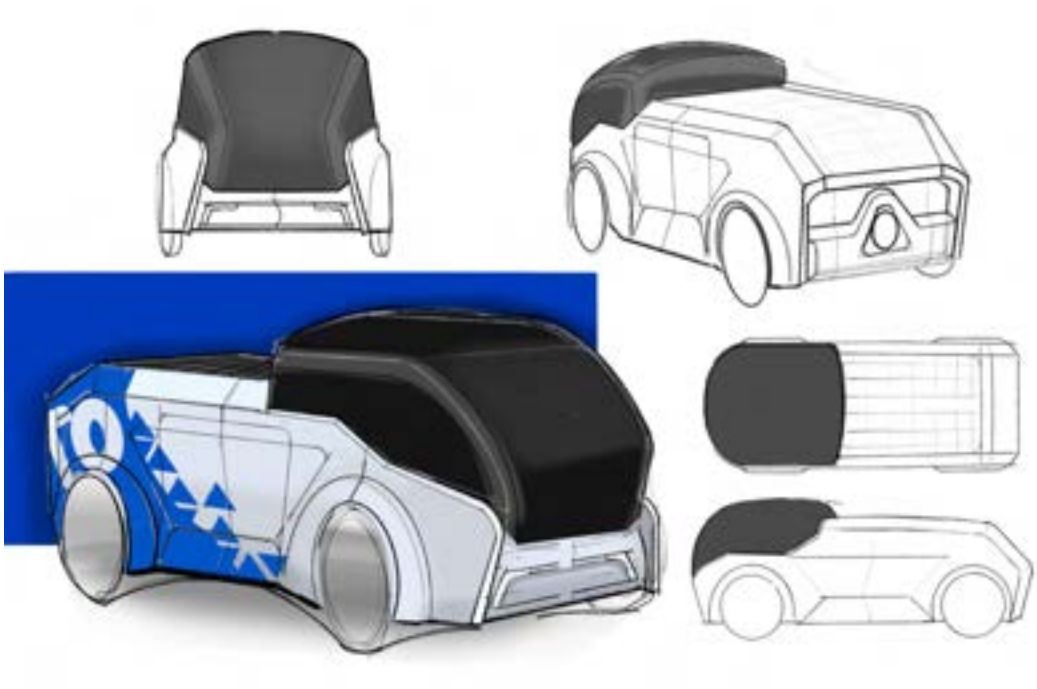
The images below demonstrate the finalised design. These images are crucial in aiding in the CAD process. All images provide various views of the vehicles and are used to gather greater Information on the form of both the Scooter and Truck before CAD.

The form of both the scooter and truck use a majority of sharp angles and flat surfaces to indicate the use of the design. The rigidity of the design provides an outside observer with the perspective that the product is robust and reliable. The design needs to indicate that it can complete the job at hand without interruptions. The front compartment is semi transparent to allow the operator to have a visual representation of the work that has been completed, in addition to the transparent window a LED trim also indicates the same visual representation. To create a cohesive product, the truck takes

influence from the design of the scooter. Both the scooter and truck utilise the same chamfered edges and form factors to ensure a holistic design.

The decals on the side of both of the scooter and truck serve two purposes; the first purpose is to provide an indication of what the product actually does (ie, collect litter) and the second purpose is to provide a location of what city owns the vehicle. The triangular design of the decals are positioned to resemble litter being sucked into the vehicle. The colouration of the decale indicates the location/city that owns the SWARM unit. The colour that corresponds to the desired city is also used as an accent colour for various parts on each vehicle. For the scooter, the colour is used for hubcaps, standing platform and hose, and for the truck it is used for the hubcaps. The accent colour also adds to the overall holistic approach to the design.

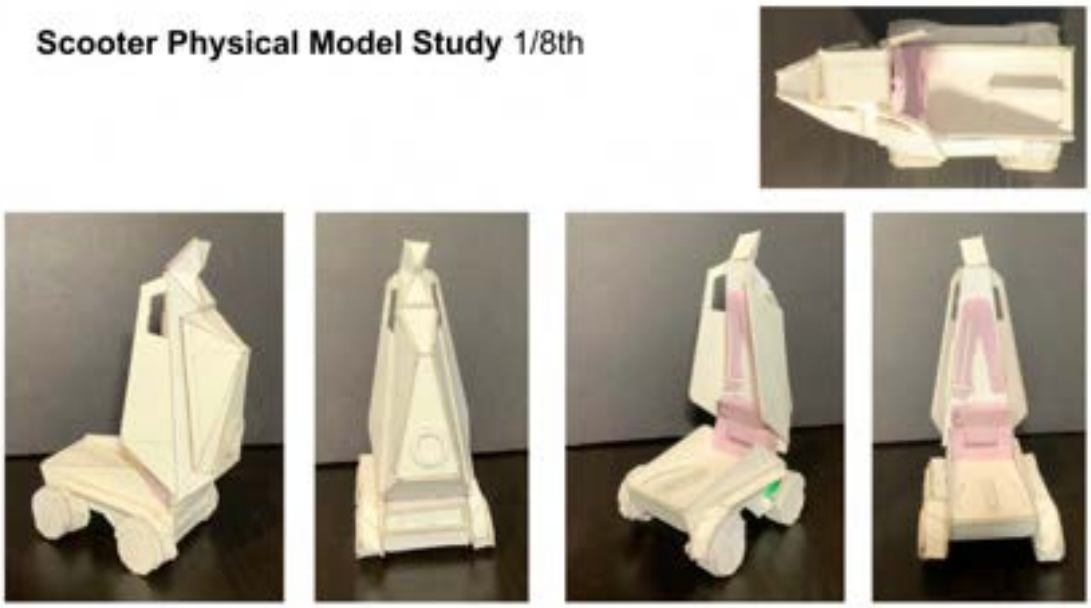




4.5.2 Physical Study Models

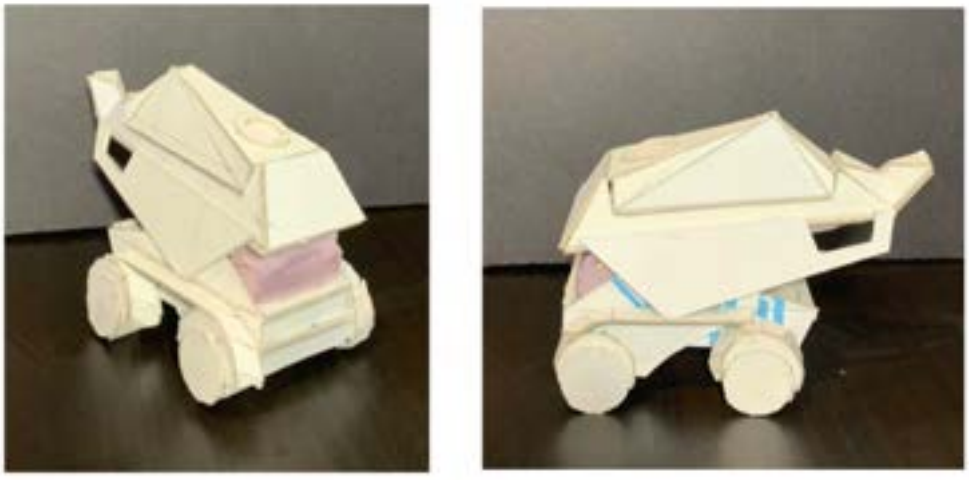
When conducting the physical model study, a sketch model was created. The sketch model uses a 1:8th scale dimension. When dimensioning both the scooter and transport vehicle, the ergonomic study was used to create accurate measurements. Thoroughly dimensioning each measurement was needed because of the mating of both vehicles. The models were made from both foam core and illustration board. The physical model study brought greater insight to the exterior surfaces of both vehicles which will eventually aid in the creation of CAD.

Scooter Physical Model Study 1/8th

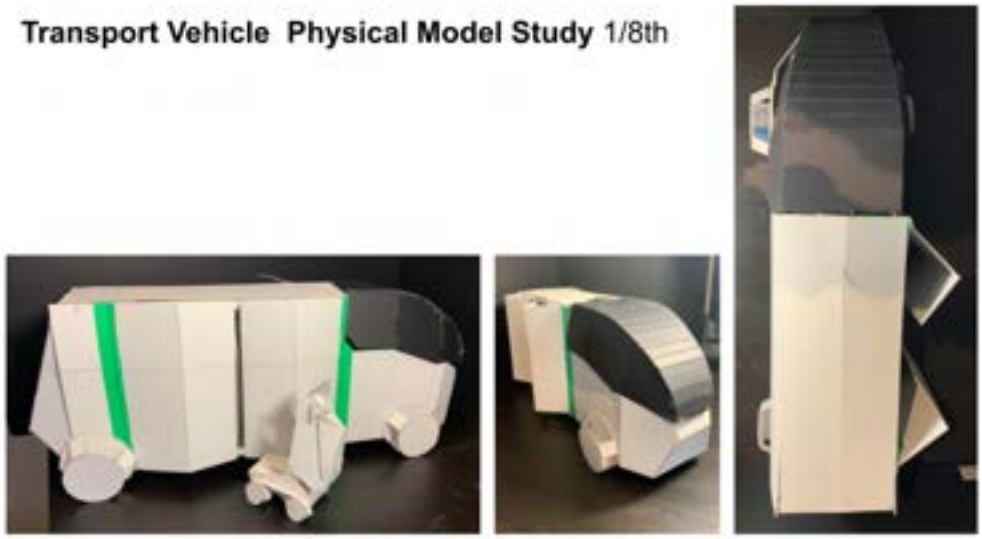


This image provides 3/4, front, back and top views of the scooter to better understand its form.

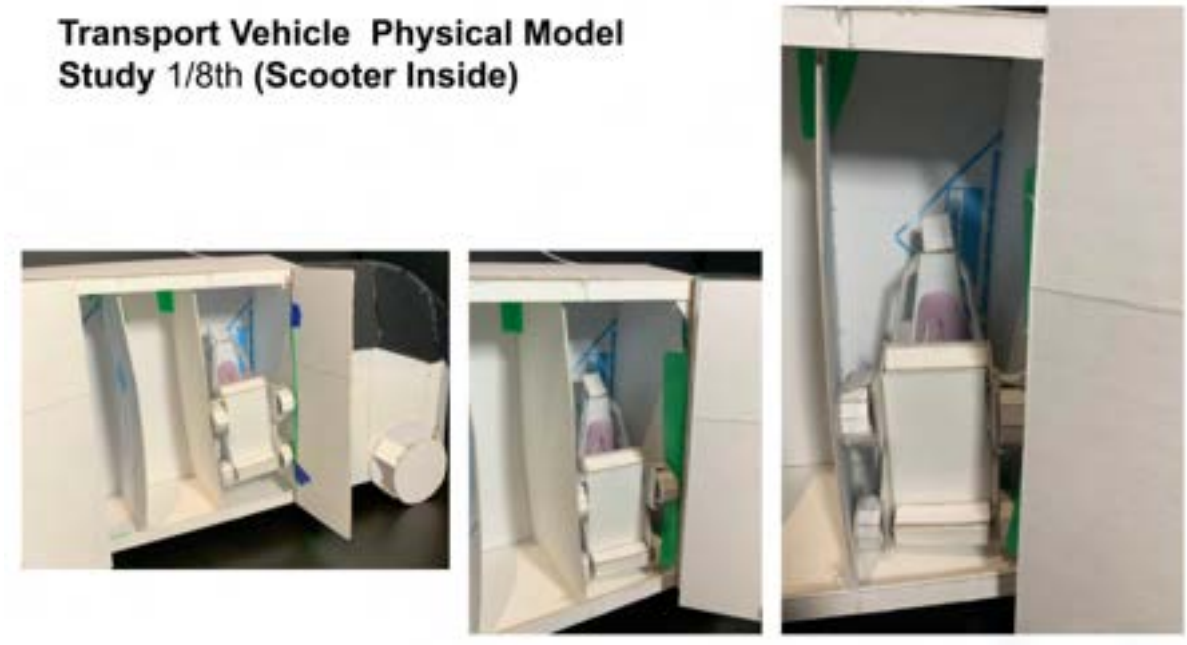
Scooter Physical Model Study 1/8th **(folded)**



This image demonstrates the folding mechanism of the scooter.



This image provides a side, ¾ and top view of the transport vehicle.



The final image provides the mating between both the scooter and transport vehicle.

4.6 Design Resolution

The final design was created through various sketches, prototypes and computer aided design. This section indicates the finalised resolved design which includes ergonomic factors and considerations to focus on the operator's needs. The resolved design takes inspiration for other competitive products as well as current and future design trends. The resolved concept was a design created with the intent of manufacturing. All parts of the design utilise high quality materials and technology to ensure that the design will last the test of time. The resolved design takes into consideration that the users operating the scooter will come in various heights and sizes, so thus the scooter is completely customizable and adjustable for the users needs.

4.7 CAD Development

Computer aid design was used to develop the design of SWARM. The program that was used to create the visual design was Solidworks. A combination of surface and solid modelling were used to create the complex faces of the design. Once the design was completed, Keyshot was used to create high definition renders. The following CAD below shows a guide of how both of the vehicles were designed.

Scooter

To begin, the computer aid design of the scooter model's basic surfacing was done. Surfacing was used to create complex faces, and to create the overall form of the scooter. Next, it was turned into a solid to complete finner detailed components. Finally the design was mirrored once all features were designed.

Truck

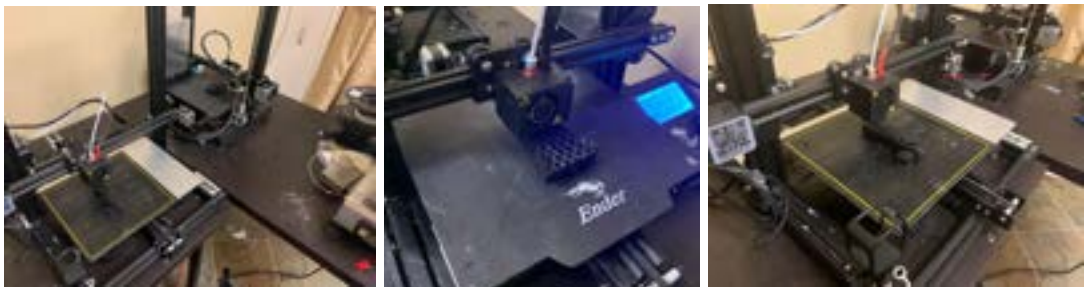
To start creating the shape of the truck, basic surfacing was done. These surfaces act as the base form of the truck. The model was then turned into a solid so that more detail can be added. Once the interior was completed, the model was then shelled and mirrored to complete the model.

4.8 Physical Model Fabrication

Below are pictures of the process of the fabrication of a 1/8th scale model of the SWARM concept.

Printing

To begin the model fabrication process, the model was first printed using PLA plastic extruded from an additive Edner 3 3D printer. The printing process took one week to complete.



Assembly

After the 3D printers were complete, the parts were glued together using super glue. To create a seamless transition of parts automotive gap filler was used. All parts were sanded using 80, 150, 200, and 400 grit sandpaper before painting.

Painting

To start painting the model, two coats of spray paint primer were used on each part and sanded between each layer. Next, the final colour was applied over the course of two coats.



Prepping

Finally, decals were applied to the outside of the model and the final glueing process was done. During the process of completing the final details, the base for the model was also being created. The base is made from high density insulation foam and carved to the desired shape, then painted.



CHAPTER 5 – Summary

This chapter showcases the finalised design of SWARM. This chapter will also go in depth of the design criteria that has been met, full bodied interaction, materials and technology, design, CAD and Physical model.

5.1 Summary

Description:

SWARM is a litter collection solution for the urban environment. SWARM allows the operator to manoeuvre in small areas to collect litter at an increased rate. Each scooter is deployed from the transport truck and designated to a zone within a 10 km radius to increase productivity. The scooter can clean at a rate of 133 feet per minute.

Explanation:

Litter is not only destructive to the environment but also the residents within the area, that is why it is crucial for the excessive amount of litter to be properly managed. Current solutions lack accuracy and speed when completing the task of maintaining the litter within cities. Many solutions are large and not meant for the fast paced lifestyle of urban cities. The lack of efficiency almost negates the effects of the collection that the vehicle has done. Although current models are making a push towards EV technology, the majority of current litter collective vehicles still use gas power to operate.

Benefit Statement:

SWARM is an efficient solution for the fast paced lifestyle of urban cities. SWARM uses EV technology to create structured vehicles that are highly manoeuvrable and are perfectly suitable for all operators. The SWARM design is like no other waste collecting vehicle on the market. The way SWARM is superior to its competitors is by having multiple units that can cover a larger area in a more efficient manner. The mobile charging station deploys four scooters which each have their own designated 10km radius to collect litter as quickly as possible.

5.2 Design Criteria Met

To reduce overall litter production, products must be designed to withstand the test of time. This means that products and vehicles must be made from material that can both be used to promote longevity and to be able to be recycled. Products and vehicles that can be recycled create a circular economy which reduces the overall production of litter by not creating extra waste.

Another factor that aids in sustainability are electric vehicles. Electric vehicles have become more popular in recent years due to their ability to reduce overall carbon emissions that are produced by a vehicle. Electric vehicles do not rely on gas consumption but rather battery charging.

5.2.1 Full Bodied Interaction Design

The SWARM scooter accommodates all users because of its adjustability. The front portion, where the handle bars are located, is completely adjustable and can become set to a desired height. Each operator who uses the scooter has their own user profile within the scooter. Once a profile is selected the scooter will automatically adjust to the desired height. Full body interaction was also considered in the overall position for the user. Additionally, the scooter has a large standing platform that allows the user to stand in various positions to maximise their efficiency. The standing platform allows the user to turn/spin around while using the hose attachment when cleaning to increase productivity.

5.2.2. Materials, Processes and Technology

Materials:

Various materials were considered when designing SWARM. The scooter and truck will both be made from aluminium to ensure that they are lightweight and durable. The front litter compartment of the scooter is made of translucent acrylic to allow the operator to see how much

litter they have collected. All wheels are standard issued, meaning they are made from a rubber material to aid in gripping the outdoor environment.

Process:

To begin the manufacturing of both SWARM's scooter and truck, it would start with aluminium that is pressed into the desired shape with a 5,000-ton press. Both the frame and outer shell are stamped, assembled and the spot welded together. The outer shell, which is made up of various aluminium panels, is 18-gauge aluminium, which is 48 thousandths of an inch thick (0.0478 inch). (Joseph, 2019). The aluminium shells are powder coated with acrylic polyurethane paint. The front portion of the scooter is made from translucent acrylic sheet which is vacuum formed to the desired shape. Lastly, the electronics are implemented into the shell of both the scooter and truck. They are then all fastened together on an assembly line.

Technology:

To create the litter collection system a 850 CFM suction motor is used. This motor is housed in the top portion of the scooter and is surrounded by a perforated aluminium housing. The perforations are key to allow maximum air flow into the motor.

To control and navigate the scooter an OLED screen is used. The OLED screen provides the operator with more vivid colours that aids in navigation.

To ensure that SWARM is environmentally friendly, both the truck and scooter rely on lithium batteries that can be recharged. Because the truck is stationary the majority of the day, a solar panel was implemented on the top portion of the vehicle. The solar panel is used to recharge the internal lithium batteries in addition to the four scooters.

5.2.3 Design Implementation

The bill of materials was created to indicate the total cost of materials and manufacturing. The price points below are based on competitors within the waste management industries. Additionally, a cost and rental fee for a city to obtain a SWARM unit is also provided.

Bill Of Materials			
Scooter			
Component	Material	Description	Cost
Chassis	Carbon Steel	Structural frame for the vehicle	$2,000
Body panel	Aluminium	Panelling on the exterior of the vehicle	$800
vacuum motors	Various materials	Attaches to the internal structure	$975
batteries	Lithium battery	Powers the vehicle	$1,000
Rims	Aluminium alloy	Attaches to the vehicles axel	$300 x 4
Tires	rubber	Provides traction	$ 80 x 4
OLED Display	Various Materials	Used to provide the user with current location	$600
Litter Compartment	Acrylic	Provides a viewing area into the litter compartment	$10
Standing Mat	Synthetic rubber	Adds grip for the user	$5
Hose	Rubber	For the user to get 360 degrees of cleaning	$10
Total:			$6,800

Figure14 (Scooter Bill of Materials)

Bill Of Materials			
Truck			
Component	Material	Description	Cost
Chassis	Carbon Steel	Structural frame for the vehicle	$15,000
Body panel	Aluminium	Panelling on the exterior of the vehicle	$8,000
vacuum motors	Various materials	Attaches to the internal structure	$2,000
batteries	Lithium battery	Powers the vehicle	$8,000
Rims	Aluminium alloy	Attaches to the vehicles axel	$800 x 4
Tires	rubber	Provides traction	$100 x 4
Solar Panel	Various materials	Charges internal lithium battery	$2,000
Total:			$38,600

Figure 15 (Truck Bill of Materials)

Implementation for Cities		
	Buy	Rent
Scooter	$15,000 per scooter	$200/per day
Truck	$55,000	$800/per day
Truck and Scooter	$80,000	

Figure 16 (Cost Analysis)

The business model that is implemented means that a city has two choices when obtaining SWARM devices. The city can either buy a complete unit (one truck and four scooters) or rent individually. The city has the opportunity to rent the appropriate amount of scooter for their desired job.

5.3 Final CAD Rendering

Below are computer generated renders of SWARM and all of its features. The images provide an in depth and closer look at SWARM.

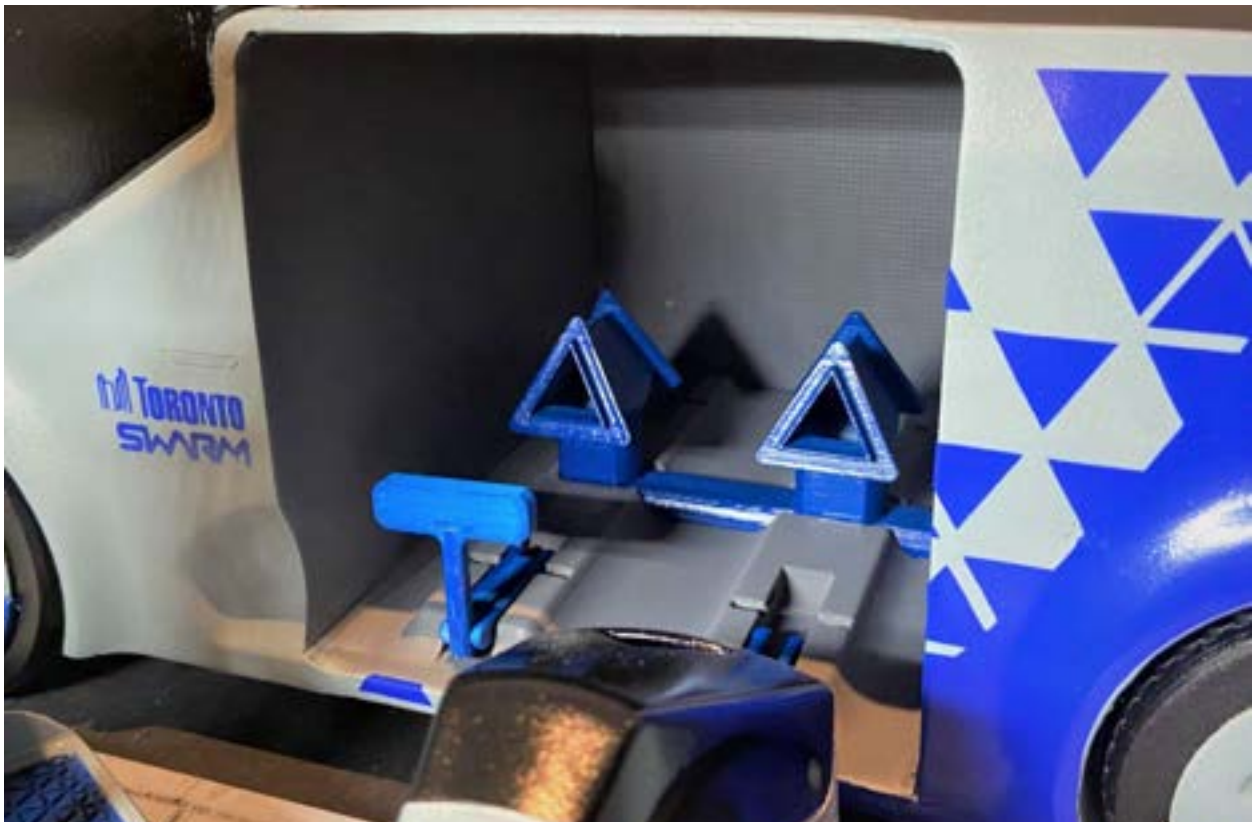

USER
INTERFACE
10


ADJUSTS FOR
HEIGHT
THE USER


CHARGERS USING
SOLAR POWER

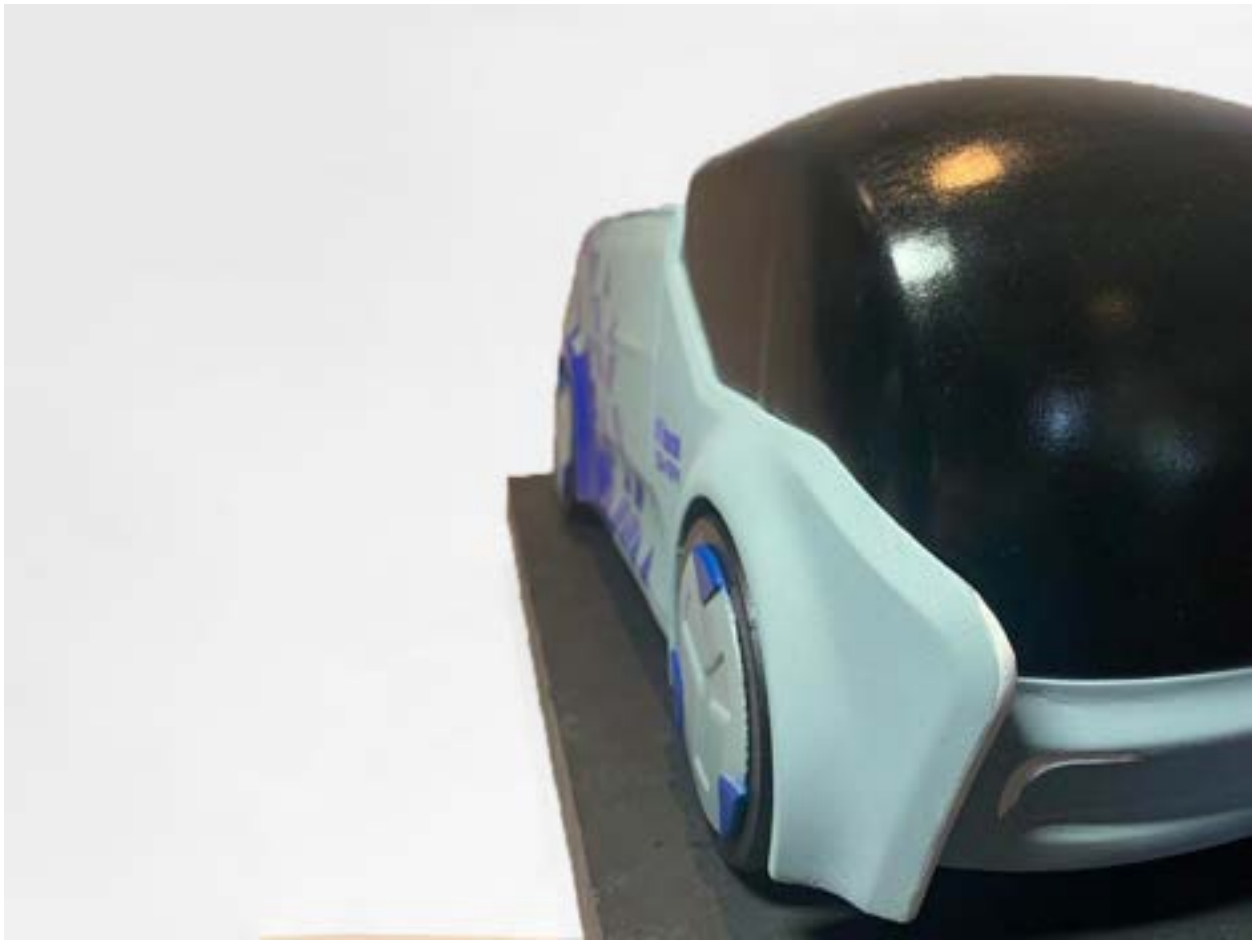
5.4 Physical Model

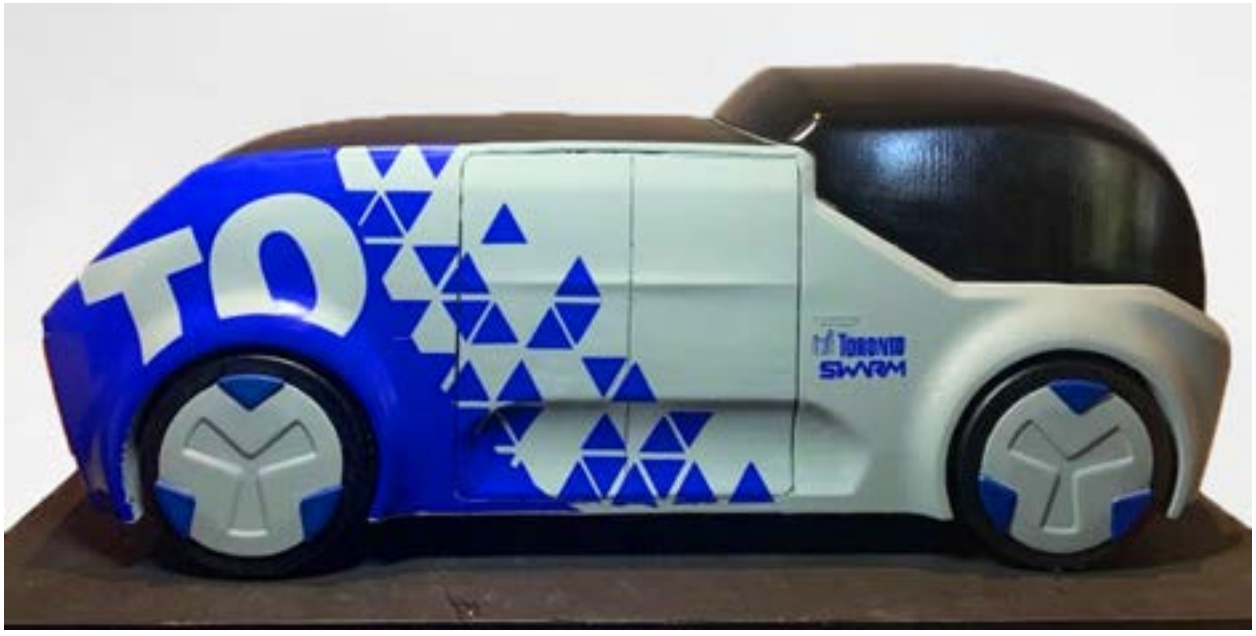
The physical model was created using PLA 3D printing filament. The model was then glued together, gap filled and then sanded. Once the surface was smooth, spray paint was applied to create the final model. The base of the model was created using high density foam to create depth. The base was then painted and the finer details such as grass and litter was then applied. Below are photos that were taken of the final complete model.


TORONTO
SWARM


TORONTO
SWARM


RONTO
ARM




TO
SWARM

5.5 Technical Drawings

Below are the overall dimensions of both the scooter and the mobile charging station. These images provide proper scaling of the vehicle to understand how large each component is. All dimensions below are in centimetres.

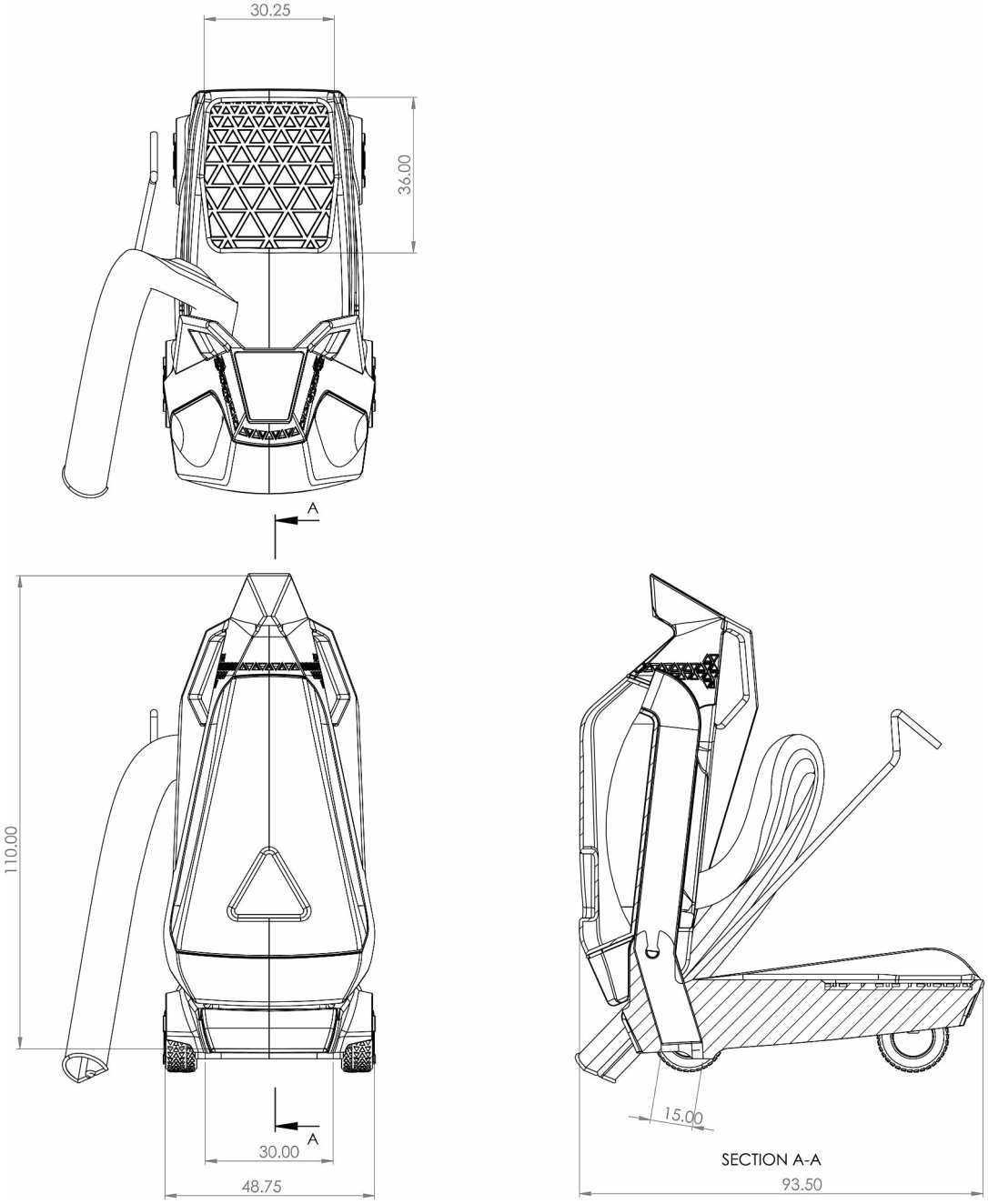


Figure 17 (Technical drawing 1)

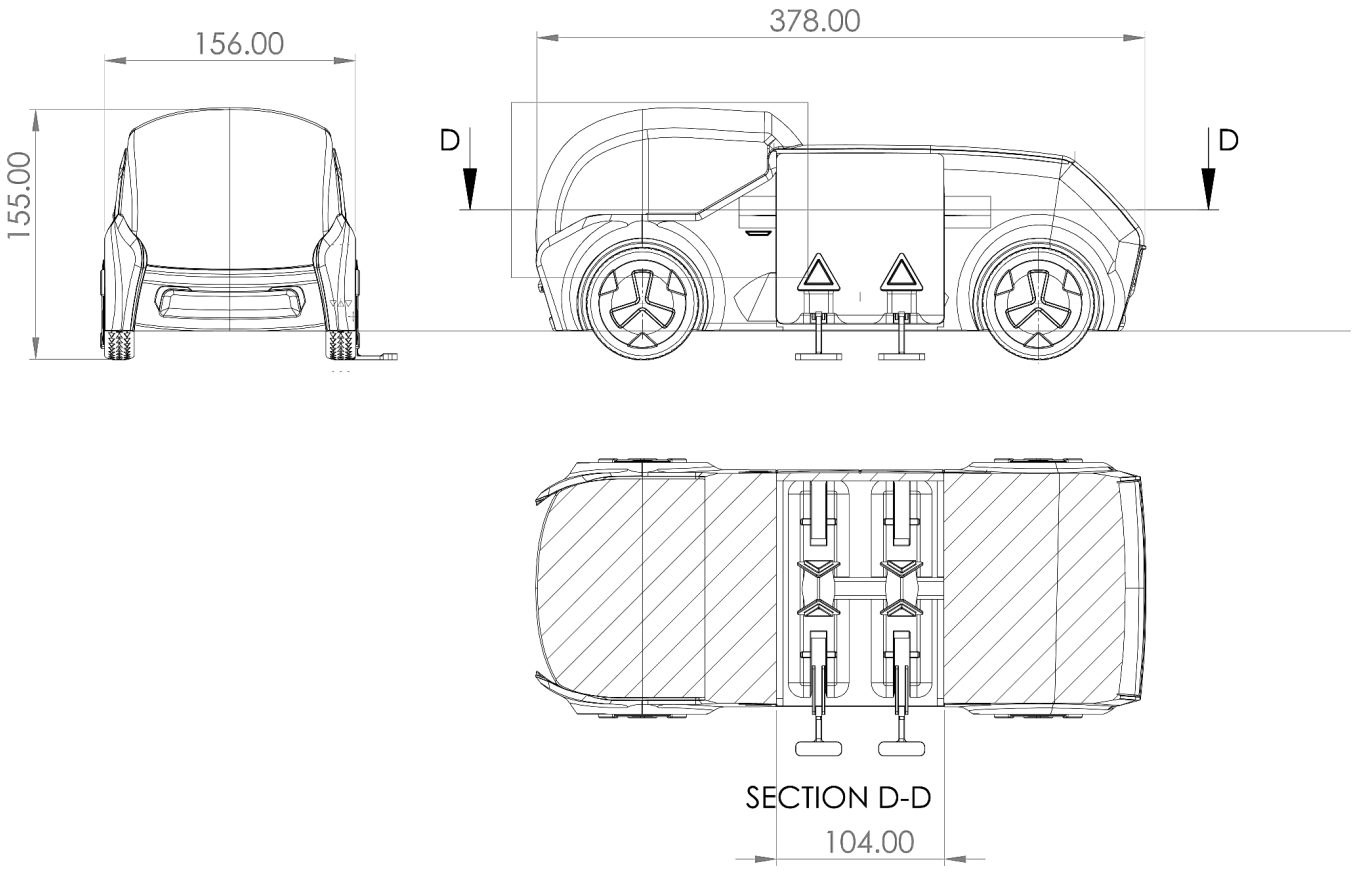


Figure 18 (Technical drawing 2)

5.6 Sustainability

During research, it was found that vehicles that use aluminium are more inclined to become recycled. Aluminium is extremely recyclable, and can be recycled indefinitely. At the end of a vehicle's life cycle, each can be taken apart and resold back to its manufacturers to create a circular economy. The main body of both vehicles will be aluminium to reduce the overall weight. Reducing the weight is key because of the heavy lithium batteries within the vehicles. The aluminium also aids in reducing the force of impact the scooter might have due to the various terrains it must overcome.

SWARM utilises lithium batteries, which are seen to have an increase in sustainability. The batteries can be recharged thus mitigating the use of gas to operate the vehicles. Gas-powered products emit hazardous air pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and sulphur oxides(SOx) that aid the process of climate change. (*Air Pollution From Cars, Trucks, Vans and SUVs*, 2017). Products that use rechargeable batteries create zero emissions thus making it an extremely efficient alternative method.

As electric vehicles become more popular, many charging options have become more prominent in the design world. Most parklots have now implemented electric car parking zones, which allow the user to charge their car. Within recent years vehicles have become more sustainable by implementing solar panels into the cars design. SWARM utilises 1.12 meter by 2.60 meter solar panels on the top of the truck. These solar panels allow the car to recharge its internal battery thus making itself sustainable.

Vehicle emissions have a direct impact on the health and safety of the operator. If the vehicle emissions become too much it can lead to having aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses, including pneumonia and bronchitis. (*Cleaner Air | US Department of Transportation*)

CHAPTER 6 – Conclusion

Within city streets, the abundance of trash has become an emerging issue among its residents. This is because of the increasing population of residents that live within the surrounding areas. When individuals enjoy outdoor areas they tend to leave behind trash and other garbage that they have accumulated, or brought with them. This becomes extremely problematic and contributes to the city looking unkempt and negatively impacts the environment. Thus, it is crucial for these urban cities to implement a plan that is cost-effective, efficient, and sustainable in which we can tackle this problem.

SWARM is an innovative solution for urban litter collection. The mobility design is based on Electric Vehicle systems platform (EV). This improves mobility efficiency and reduces environmental harm while providing an ergonomic focused platform. SWARM's design intent is to offer a highly mobile litter collecting vehicle that can manage cluttered high paced urban environments like downtown cores and city streets. When cities begin to implement SWARM, there will be clear evidence of cleanliness through a highly efficient and manoeuvrable device.

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APPENDIX

A - Discovery

Report 1

The Purpose of this section is to conduct preliminary research on trash collection/ management in Toronto. The preliminary research is collected by using both scholarly and consumer/popular search tools.

Search topic

Scope: Trash/Litter has become more and more of an issue due to the high volume of residents that live in the surrounding areas. This affects the environment in a negative way, creating a downward spiral that may not be reversible.

Background: most current trash collection solutions are time-consuming and take multiple operators to use.

Need statement: Toronto needs a more effective way to clean up trash from its city's streets.

How is this problem currently being solved?

There are approximately 10,000 street litter/recycling bins across the city and 10,000 garbage and recycling bins in City parks.

B - Contextual Research

Primary User Interview

can you like, tell me a little bit about you and a greener future.

Yeah, so a greener future is an environmental nonprofit that I started back in 2014. The reason I started it was because I went to my did a litter cleanup and I realized that one litter cleanup, really wasn't going to solve anything so I wanted to come up with something that was community-based and more frequent, to get people kind of out. A lot of people want to participate in literacy notes but they don't necessarily want to host one and get it all organized and find supplies and all of that stuff so I was completely fine with doing that part on my side. And what I found over time was that obviously litter isn't just a problem in the town where I started out, it's a problem everywhere. So I ended up applying for grants and funding so that we could expand our program, and we ended up doing 100 litter cleanups along the shores of Lake Ontario each year since 2016 and expanding in other ways to looking at the data we're collecting through our litter cleanups to figure out what the problem items are where the problem areas are and, and then kind of moving forward with that data to come up with better solutions and ways that we can tackle certain types of litter or certain issues.

Okay. What areas do you primarily do these like cleanups

Unknown 2:08
yeah so most of our cleanups are shoreline because that's where a lot of waste accumulates, whenever it rains a lot of waste goes downstream and ends up in the lakes, and a lot of the spaces along the lakes are public spaces which means that there's a lot more people, which means more litter, so we do try and focus on public areas, but we do have a program called the buck blitz which is focused on cigarette litter because that's the number one littered item in the world. And for that one. A lot of our volunteers pick up, you know like, around, community centers, you know like, around, baseball diamonds in parking lots of grocery stores because that's where there is a lot of cigarette litter so I'd say for general litter, it is more focused on public parks and shorelines. But when it comes to cigarette litter the places to find it is a little bit different.

Do you do you do a just clean up around like GTA area or do you go outside.

Unknown 3:17

No, it's so across Canada. Our cigarette campaign is across Canada. Most of our cleanups are along Lake Ontario but we do go outside of that as well we've, we've gone up towards tilba Mori, we've gone along Lake Erie as well. So I'd say mostly Southern Ontario but when it comes to our buckless program that is Canada wide.

Could you give me like a breakdown of what you would do on a day of cleaning letter, like from organizing it to. How many people are there and like how long you're doing it for.

Unknown 4:00
Yeah. So generally when we host a public cleanup we'll advertise it on our website on our social media, gather volunteers we do have a volunteer database so a lot of our volunteers come back again and again. We also put it in our monthly newsletter which a lot of our volunteers receive. So, once we have everyone kind of organized, we'll send out an email that has information on where to me and what where we're close toed shoes, dress for the weather. Bring a reusable water bottle that kind of thing. Depending on what program it is sometimes we send virtual training beforehand. And it's usually just a series of videos about 10 minutes long that goes over the process of collecting data. And, you know like how we stay safe and that kind of thing. If we don't do the virtual training beforehand, we give all of that information on site, but usually we collect the data with our staff and Corps volunteers that have experience. So for instance we just did a cleanup with Volvo Canada, and they didn't do virtual training but when they came on site. We told them all the safety rules like don't go in the water. stay with a buddy if you find syringes, let us know we'll pick them up because we're trying to do that. And just making sure everybody knows to stay within a certain, certain area. And when we're meeting back on location, and when we do our cleanups we try and reduce waste by as much as possible so we don't give everyone a plastic bag we give out buckets or a canvas bags, and our volunteers will fill those they've dumped them in a central area, and then we sort it all out so that way we can recycle what needs to be recycled including cigarette butts and textiles, and then we can put the waste where it needs to go so we usually work with whatever city or municipality to ensure that the waste that is collected will be removed right after, so that it's not sitting out there and get scattered around again by animals or anything like that so we do have partnerships with a lot of municipalities and cities and just like local like TRCA and, and those type of groups so that we can make sure that they know what we're doing and they support us in that. And then after we collect the data. We put that into our database which, right now we have over 3 million pieces of litter collected in our database, and we create infographics and trying to analyze the litter data to find different trends or interesting information that our supporters our followers our donors would like to hear about and then we post that on our website and on social media.

Okay, sounds good, you're talking about. You were sorting the the recycled or the letter on do you do that on site,

Unknown 7:15
Generally we do and unless the weather's bad if it's really windy then sometimes I will bring it home and we'll sort it like in my garage, but for the most part we generally try and do that on site. If there are no recycling bins on site I will bring the recycling home and just put it in my normal blue bin. So we do try and make sure that we put everything where it's supposed to go.

And on a day of like doing the volunteer litter collection. What time would you guys start and what time would you finish

Unknown 7:52
our cleanups are usually around two hours long, so we would do 10 to 12, or 123. It just depends on what group we're working with. Some of them go a little longer and we have kind of like a lunch break in between and talk about different environmental topics. Sometimes our volunteers go out on their own and do cleanups if they're trained to do that on their own so they might go for, for 15 minutes or they might go for three hours so it is very flexible but I'd say for a public event, usually training for around two hours,

how many people would you normally have helping.

Unknown 8:51
So we try and aim for around 20, the pandemic has changed a lot of things for us. In the past we had sometimes like 60 or so people come join us. But we really had to cut back once there were restrictions in place so I find 20 is a good number, it's not overwhelming. People can distance themselves, and we still have a pretty big impact with 20 people participating. So I'd say that's like our average number right now, and it also comes down to Equipment because we want to make sure that everybody has a litter picker and gloves and, and that we can make sure that everybody's staying safe so even going forward I think we'll probably try and stick to Around 20 people but you know it could go, go up a little bit, as the pandemic relaxes.

Do you use other tools other than just litter litter pickers.

Unknown 9:52
not usually it is usually just gloves litter pickers and buckets and bags for the most part, when we're so we've started doing nurdle hunts which are, we look for like plastic pellets that are along the shore and we do have little glass vials that we put those in. Just so that they don't get lost because they are so small. But yeah, I mean, it's pretty basic, not, not a whole lot of equipment.

Do you ever do you ever work with the city and use like city. Tools like as in like they have those vacuums that they, that they use.

Unknown 10:32
No, no, we haven't done that. Really the city when we work with them it's more just for promotion to get people to come to the event, and for the waste to be hauled away after.

Okay. What do you find most difficult about cleaning letter.

Unknown 10:57

Um, I think the biggest hurdle is that it's, it's a problem that is so complex, and it just, you know, doing one cleanup doesn't do a lot you can go back to the same location, time and time again and it's, there's more litter there. So I think for a lot of people that can be very discouraging to like work really hard and then go back and it's a mess again. So I think that's probably the biggest hurdle, but it is one that can kind of be overcome, like it doesn't bother me anymore because when I see all of these people come out and, you know, they know they're making an impact, and they're learning, and they're just out there in the environment and building an appreciation for their surroundings and and building like pride for their community. I think that overcomes all of it because at the end of the day that the biggest takeaway is that everybody's kind of learning and working together to solve this problem. So, although it is hard to see like how much pollution is actually out there. I think we are on the right track to finding the right solutions and working together to solve it.

That's good. Do you guys do this all year round. Or is it just in the warmer months, season.

Unknown 12:21
so we do slow down a lot in the winter. We have cleanup scheduled, up until November 25 this year. But, I mean we still go out from time to time in the winter, just to see what's out there, but we really do focus more on relaunching in the spring and getting people inside as the snow starts to melt,

Unknown 12:44
that's good. And you said you primarily just do like beaches and parks right you don't you don't do any like City Cleaning, or like, go into neighborhoods and, and try

Unknown 12:57
not often. If we do, it's more of our core volunteers so the ones that are trained by us, they might clean up around their neighborhood and they collect the data on that. Even for me, I go around my own neighborhood and clean up. But it's not usually an event, it's just kind of Corps volunteers here and there that do clean up within their communities.

Unknown 13:23
Okay. And how many events would you guys have a year.

Unknown 13:29
I'm probably so at least 100 Because we generally do 100 cleanups on Lake Ontario. And then it's a little bit flexible with the pandemic. It's changed a lot. But next year we'll probably have about 200 that we

Unknown 13:46
want. That's good. And just in Ontario are all across Canada.

Unknown 13:55
Dots mainly Ontario, we will be running our booklets program and with that one. Volunteers participate for the whole month. So it will be running again in April and just this past September we ran about blitz event we had 189 volunteers, and they put in over 1000 hours and picked up over 550,000 Cigarette butts.

Unknown 14:22
That's good. I, and you said, the cigarette butts are like the top piece of litter, is there any, any items that are like bigger that you'd say, are at are not as common but are pretty common.

Unknown 14:40
Um, so, plastic pieces is our second biggest thing and it can mean a lot of things a lot of it is kind of stuff that's been in the lake that breaks down over time and you don't really know what it is anymore. A lot of plastic bottles and plastic bottle caps. We used to find a lot of straws, but I am finding less now that a lot of restaurants are switching either to paper straws or don't have them altogether. So I think that's that's good news. But yeah, a lot of food and beverage type stuff, granola bar wrappers and that kind of thing. And a lot of construction wastes so like pieces of snow fence or, you know like nails and wood and shingles and things that get kind of blown around from construction sites. And then we are finding a lot more vape cartridges as well, because I think there's a lot of people that are switching from smoking to vaping, so we did find a lot of those.

Unknown 15:42
Okay. What would you do to reduce litter. Like how would you go about saying this is we need to stop doing this or stop doing this to reduce the overall amount of litter, that's attached. Yeah, I have to ask the tricky questions.

Unknown 16:06
Yeah, it's, it's hard because it is a very complex problem. There are some people that throw litter on the ground, and just don't realize what the consequences are. But a lot of the waste that we find isn't necessarily from people throwing stuff on the ground, there's a lot that that does come from storms when things get thrown around. There's animals that dig into the garbage cans and drag stuff all over. There's, you know, things like nurdles that are spilt from industrial type settings, so a lot of shipping going on in the lakes and there's a lot of things that kind of fall off boats all the time. And there's sewage bypasses and combined sewage sewage overflows which means when we have high water levels. A lot of times raw sewage gets dumped into the lake. And anything that's flushed down the toilet goes along with it so we find things like condoms and tampon applicators and cue tips and bags of drugs and stuff that people have flushed down the toilets. So it's not there isn't just one thing that we can say like, if we stop this. Yeah, then there won't be any more litter. It's a lot of education, and a lot of awareness, a lot of people don't even know what a nurdle is.
Unknown 17:35
Yeah, so that's one of the biggest problems like if, if people don't know about it, then how can they care about it or try and stop it, so I think it comes down to education and just understanding that Lake Ontario is drinking water for us, and we don't want it polluted and by throwing things on the ground or you know just in the end like buying things you don't need that are gonna end up in the garbage or in the environment. You know it all plays a role. So I think for me the biggest message is just be a very conscious consumer, do all those little things like bringing your own bag and saying no to straws and, you know like, do you really need to buy that new thing, Or is it just gonna end up in the garbage eventually so I think it comes down to consumers

being cautious about what what they purchase and speaking up for what they want, like, we want to be able to buy food with no package. And, you know, just using our voices to tell like industry and corporations, what we really want.

Secondary User interview

Are you okay if I record this conversation please note that this is for research purposes and your personal information will not be used outside of this research, you can end this interview at any time and withdraw your consent?

Okay.

What is your name,

Rachel Pantano

What is your gender identity?
Female.

How old are you
26

Where do you live,
I live in Caledon east.

How often do you traveled to downtown Toronto?
And I travel, maybe once every couple weeks.
Why only a couple of weeks, every couple of weeks,
because that's when I go and hang out with my friends.

Do you visit any fast food or restaurants when going downtown?
not so much fast food but more restaurants.
Why?
Because I am a big foodie and I love food so I always, every time I go downtown, it's probably to go eat at a restaurant..

Okay, so say you will do get fast food, how do you dispose of the bag?
I'm usually, it usually stays in my car until I come home, and then I throw it out when I get home.
Why do you wait too long to throw it out?
I just find that there's not a lot of places to dispose of the garbage. So, I kind of just wait until I get home.

Do you ever use reusable items?
reusable containers mostly in water bottles.
I just find it's easier to have those containers and then I just wash it when I get home.
Why is it easier to use them?
readily available.

Do you ever chew gum?
Well, When walking downtown. Yes, I do.
What do you how do you dispose of the gum?
I usually put it in my pocket. In its wrapper, because there's not a lot of garbage is around. And then, what do you, and then once I find a garbage then I just throw it out into the garbage,
if I'm walking and I see your garbage then I'll throw it out. If not, it stays in my pocket until I go.

Do you ever bring anything with you, downtown?
no I usually, I usually, I usually bring my purse. My wallet sunglasses, and like a granola bar in case I get hungry.
What do you do with the granola bar wrapper when you're done?
put it in my purse until I find a garbage if I don't find garbage, then it becomes homeless.

Do you ever use the street garbage bins when you're downtown?
It's kind of rare because there's not a lot I feel like there's not a lot unless you like go into like parks. If I'm going into a store there's usually garbage. So I usually probably throw it out there but like on the streets, there's not that many fine.

So do you feel like the current garbage bins downtown are adequate enough?
No, I don't think so.

How would you improve?
I think, by adding more to like street side instead of just in parks, because I find that the majority of the garbages and recycling is in parks.

what are your feelings about the amount of litter that is in Toronto?
there's a lot of litter. How do you feel about it, it sucks, because who wants to be walking around downtown and seeing plastic bags and cardboard and crap everywhere.

How would you reduce the amount of litter?
Probably should be picking it up and throwing it out but I don't really feel comfortable picking up nasty garbage off the ground.

Have you ever witnessed an animal interact with litter?
Yeah, probably like a pigeon nibbling on a bag or something.

how do you ensure that you are reducing clutter?
by throwing stuff in the garbage and we're waiting until it like if a garbage is not readily available then waiting until I get home to throw it out and making sure like no garbage has fallen out of my pocket or anything like that.

when shopping, how do you dispose of your bags?
usually wait until I get home because I have to carry the, the bags around

Do you ever transfer your items into one bag and then only have one or do you?
know, usually, like if I go shopping, I usually like put more things in, like, I instead of getting more bags, I put them in the same bag, just so I don't have so many things to carry too.

Do You ever bring a reusable bag with you. To reduce on litter,?
um, I do but it's not like it's it's kind of rare that I do it. But I have.

Okay, do you have anything in your vehicle that helps you reduce litter?
Yeah, I do have reusable bags.
I like canvas bags,
big.
I have like a big one and a small one,

how big and how small?
like a small one like probably like the size of my like laptop. And then like a bigger one, like, like you know those like big shopping bag kind of ones

you find these are easy to bring around with you. Yeah. Why?
just because they're light, and you can just like, you can like, fold them really tiny and put them in your bags and stuff, and also to like if they get dirty, they're really easy to clean, you just like throw them in the washing machine and they get clean.

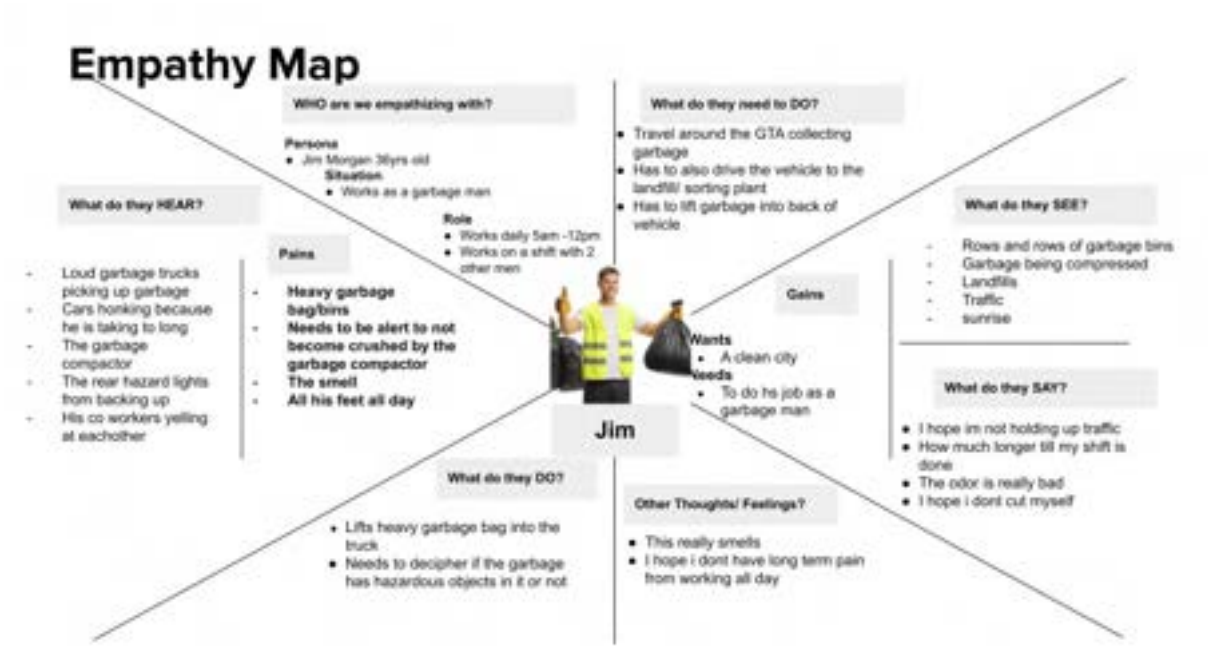
Interview analysis

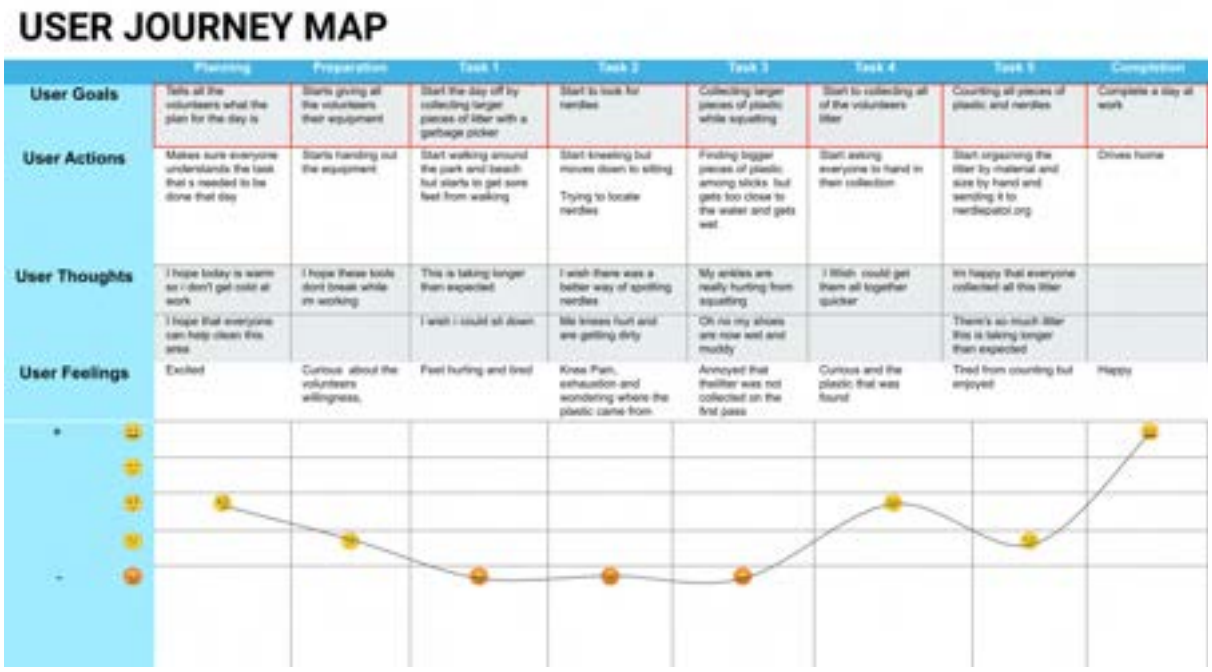
C - Field Research

How might we:	How may we improve litter collection in cityscape areas?			
User	Product Image	Product: Pros and Cons	Environment: Pictures	Environment: Challenges
PRIMARY USER: Garbage collection workers picking up litter along city streets and surrounding area		Grabo Grabber PRIMARY Pros: reduces the users need to .bend over and pick up trash. -comes with a handle on the garbage bag to hold easier -garbage lid holds it opened. -trigger to help open and close the hand at the end Cons: trigger can wear the users hand out. -when garbage is full it becomes heavy and hard to carry .		Side Walks PRIMARY/SECONDARY People walking along side walk throw trash or garbage's that might over flow and create more litter. If not enough garbage bins user might lose litter along the side walk
PRIMARY USER: Community Service Worker: Picks up litter within the city to improve the environmental impact		hand Foldable Pick Up Grabber Gripper PRIMARY Pros: wide garbage hand to -collect more garbage -foldable. -4 finger trigger. Cons: hinge can fail when picking up garbage. -only has one length to pick up garbage. -doesn't come with an additional garbage compartment. -grip strength might fail when using for long hours. -cant pick up bigger items due to the limited hand size.		Roads PRIMARY/SECONDARY users driving vehicles throw litter out of their vehicles because of no internal garbage bins
PRIMARY USER: Urban planner: Develops and determines when and how the litter is cleared		Litter Picker Grabber Tool PRIMARY Pros: no trigger metal spikes make it easier to collect garbage thumb button to collect/push off garbage Cons: harder to collect garbage litter might fall off the metal spikes needs force to collect the litter only one length thumb might get tired from constant use needs to b paralled with trash to be able to collect		Parks PRIMARY/SECONDARY parks are enjoyed by many residents and tourist but lack the facilities of garbage removes because the area needs to preserve the natural environment thus promoting people to bring their own food which leads to more litter.
SECONDARY USER Toronto Residents: Living in unsanitary conditions, contributes to over all litter. Worried about the environment		Terrain Ride-On Vacuum Sweeper PRIMARY/TERTIARY Pros: do not need to carry anything -vacuum reduces motion of the user -does not tire out the user from walking. -internal storage of litter Cons: not all trained. -the driver needs to drive over the litter . -larger litter can be stuck or trapped in the vacuum. -needs to empty the litter storage once job is complete.		Public Transit Stops SECONDARY when waiting at public transit stops people might be in a hurry and not wanting to bring garbage with them on their journey
SECONDARY USER Wildlife (animals/environment): litter ruins the existing habitat, animals can die from eating plastics from litter		The WheelieVAC PRIMARY/TERTIARY Pros: more dexterity when collecting litter -mobile -needs one person to operate. -internal litter storage. -arm brace to reduce pressure of carrying vacuum. -vacuum allows for pinpoint precision. -Garbage bin can does not need to be empty by the user. Cons: needs to carry a heavy garbage can behind the user. -walking can make the user tire after working long stints. -constant use can create pain in both the user shoulder (dragging garbage can and holding vacuum hose).		Businesses SECONDARY/ TERTIARY businesses are high stress areas, blue collar workers tend to smoke cigarettes/ and drink coffees which can contribute to the overall garbage accumulation
SECONDARY USER Bikers: can become injured from riding over litter that is put on the streets or on bike paths		Electric BackPack Vacuum PRIMARY/TERTIARY Pros: does not need to carry an eternal garbage bin behind user -back storage for garbage -vacuum allows for point accuracy. Cons:back pack might lead to back pain. -small carrying capacity -shoulder pain from constant use. -could become heavy from litter .		Shopping Centers SECONDARY shopping centers use a lot of one time use shopping bags that can easily be taken by the wind and get stuck in areas that are hard to get

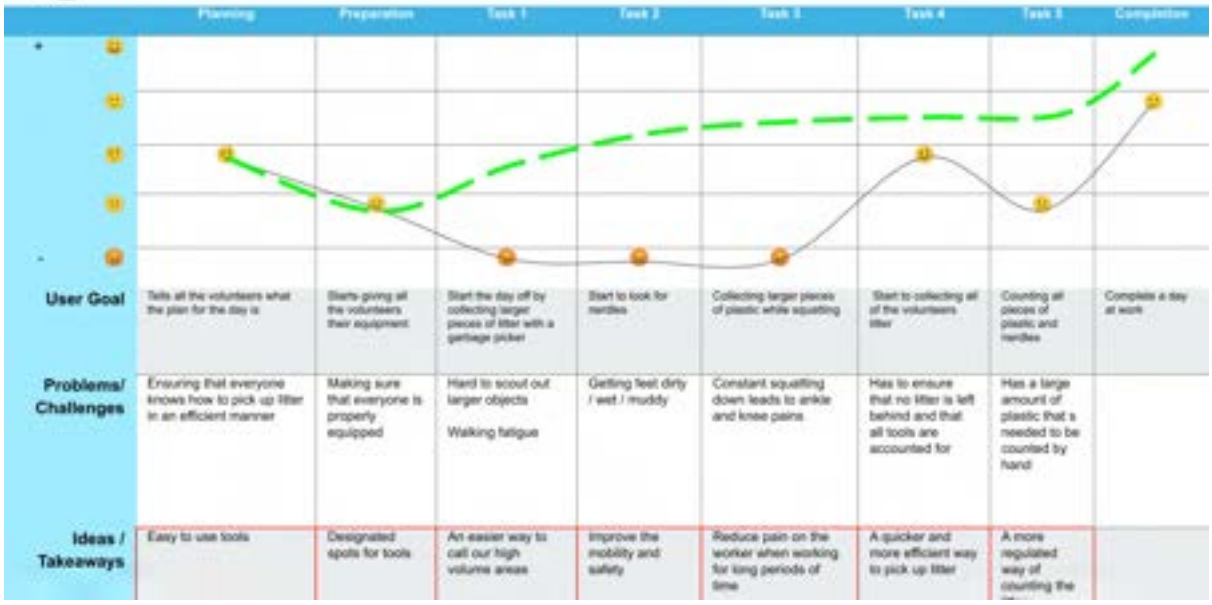
SECONDARY USER Shoppers: contribute to the litter from over use of shopping bags, might become disgusted and not wanting to shop if litter becomes out of control		Toronto Stationary Garbage bins PRIMARY/SECONDARY Pros: helps keep surrounding area clean. -organizes the litter into garbage and recycling -makes the user clean up the area. -easy to use. -foot peddle makes it so the user does not need to get dirty. Cons: if not constantly empty it can over flow adding to more litter on the streets. -animals can get into the garages and get stuck.		Residential Housing SECONDARY/ TERTIARY housing use Garbage bins that can over flow- drifting into the streets and clogging drains
SECONDARY USER Students: Bring litter with them to school and disposes of it within the era, might not want to enroll because of how the litter is not being controlled		Toronto Curb Side Pickup Bins PRIMARY/SECONDARY Pros: allows home owners to reduce litter within their homes. -lid provides a secure way to hold garbage within it. -garbage trucks picks up bin once a week. -garbage /recycle/ organic organization. Cons: garbage truck some times throw bins around spreading litter -if over filled litter might over spill into the streets. -home owners do not always organize their trash appropriately (garbage /recycle/ organic)		Schools SECONDARY schools/ Universities house local and out of town residents who bring garbage from their homes to the city where garbage bins might already be at full capacity
SECONDARY USER Driver: vehicles usually dont have internal Garbage storage so drivers throw trash out side the window		Street Sweeper PRIMARY/TERTIARY Pros: clean up city streets at night -mobile. -dont need to carry or lift anything. Cons:might spread more litter into the side walk/ drains. -needs one or more to operate. -can only clean one side of the road at a time.		Tourist Destinations (museums, aquariums,zoos) SECONDARY tourist bring out of area garbage with them and are also not as caution of the way the dispose of garbage because they do not live in the area
SECONDARY USER Potential Residents: might become turned off from living in that area due to excessive litter. curious about the impact the litter has on the environment				Restaurants/ fast food SECONDARY restaurant are notorious for using one time use items such as straws or paper plastic cups which leads to litter. restaurants also can be out doors which promotes smoking and might not have enough ash trash for users
SECONDARY USER Tourist: becomes turned off from coming back to the city due to the visual appeal of the litter. tourist tend not to care if they litter because they do not live in the area				
TERTIARY USER Product Maintenance: always having to fixed broken products from over use.				
TERTIARY USER Distributor: has to sell the product to the market, has to make sure the product works				
TERTIARY USER Trash emptier: the last part of the process. has to endure the smell of hours of hot trash that has been collected, has to carry large amounts of trash				

D - Result Analysis





USER EXPERIENCE MAP

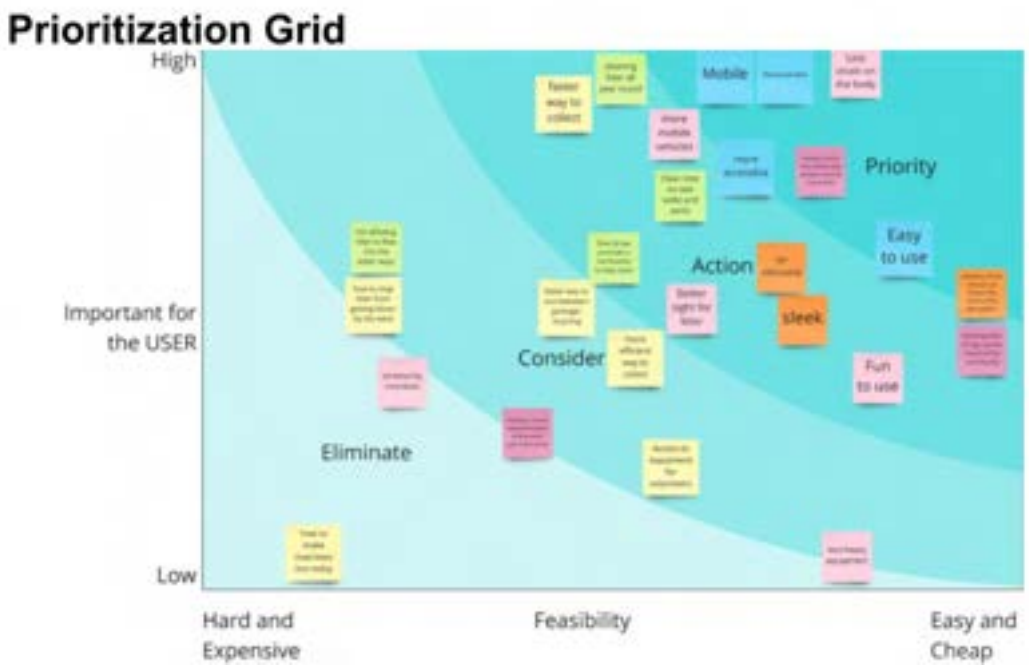


	Planning	Preparation	Task 1	Task 2	Task 3	Task 4	Task 5	Completion
User Goal	Tells all the volunteers what the plan for the day is	Starts giving all the volunteers their equipment	Start the day off by collecting larger pieces of litter with a garbage picker	Start to look for nerdles	Collecting larger pieces of plastic while squatting	Start to collecting all of the volunteers litter	Counting all pieces of plastic and nerdles	Complete a day at work
Problems/ Challenges	Ensuring that everyone knows how to pick up litter in an efficient manner	Making sure that everyone is properly equipped	Hard to scout out larger objects Walking fatigue	Getting feet dirty / wet / muddy	Constant squatting down leads to ankle and knee pains	Has to ensure that no litter is left behind and that all tools are accounted for	Has a large amount of plastic that s needed to be counted by hand	
Ideas / Takeaways	Easy to use tools	Designated spots for tools	An easier way to call our high volume areas	Improve the mobility and safety	Reduce pain on the worker when working for long periods of time	A quicker and more efficient way to pick up litter	A more regulated way of counting the	

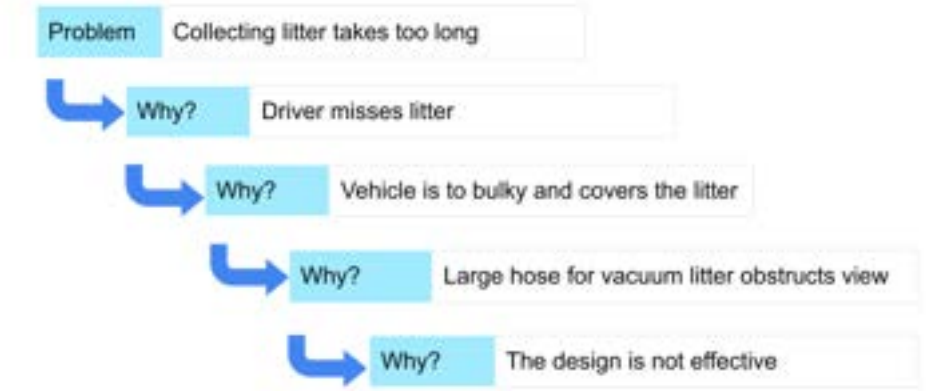
Existing Solutions

Exercising solution	Description	Advantages	Limitations
Solution 1 Garbo Grabber	The GarboGrabber is comprised of 2 components, a trash picking stick and a plastic bag holder. The stick has a long arm with a trigger to pick up small pieces of trash, to reduce litter.	Has a trigger for picking up one piece at a time Two components (picker and garbage bag holder)	Put strain on the users body
Solution 2 Hand Foldable Pick up grabber	This product has a larger hand to pick up bigger pieces of trash and can also fold in on itself to become more compact.	Can reach further distances Can pick up small to medium sized litter	Can easily malfunction
Solution 3 All – terrain ride on vacuum	Tackle outdoor cleaning challenges on all terrains and in hard-to-reach places. This easy-to-operate all-terrain rode-on litter vacuum sweeper keeps your facility looking its best while reducing your cost to clean.	Vacuum suction allows for quicker work time All terrain ride on	Had to maneuver into small areas
Solution 4 Electric Back pack	Is a lightweight yet sturdy Backpack mounted litter collector c/w a 75mm diameter vacuum unit.	Medium sized vacuum hose can such up medium to small sized litter	Can become heavy after long use


Intent
goals, benefits,
needs, wants,
Social impact,
aesthetics
Goals
Benefits
Needs
Wants
more accessible
Easy to use
Mobile
faster way to collect
more mobile vehicles
Fun to use
Social impact
Aesthetics
sleek
Better sight for litter


Prioritization Grid
High
Important for the USER
Low
Priority
Action
Consider
Eliminate
Easy to use
sleek
Fun to use
Hard and Expensive
Feasibility
Easy and Cheap

Root Cause analysis



Immediate Needs

Marketing- **Existing Need**
Easier *to collect litter*
Convenience (Portable)
Durable
Weather resistance, Comfortable, Safe

Psychology
Human Needs & Benefits
Easy- control of environment, mastery
Convenience- control, mastery
Durability: value, securing resources
Weather resistance, Comfortable, Safe
Moral obligation to keep the environment clean

Latent Needs

Marketing- **Latent Need**
Safe *vehicle to drive and protect the user*
Storage *for litter*

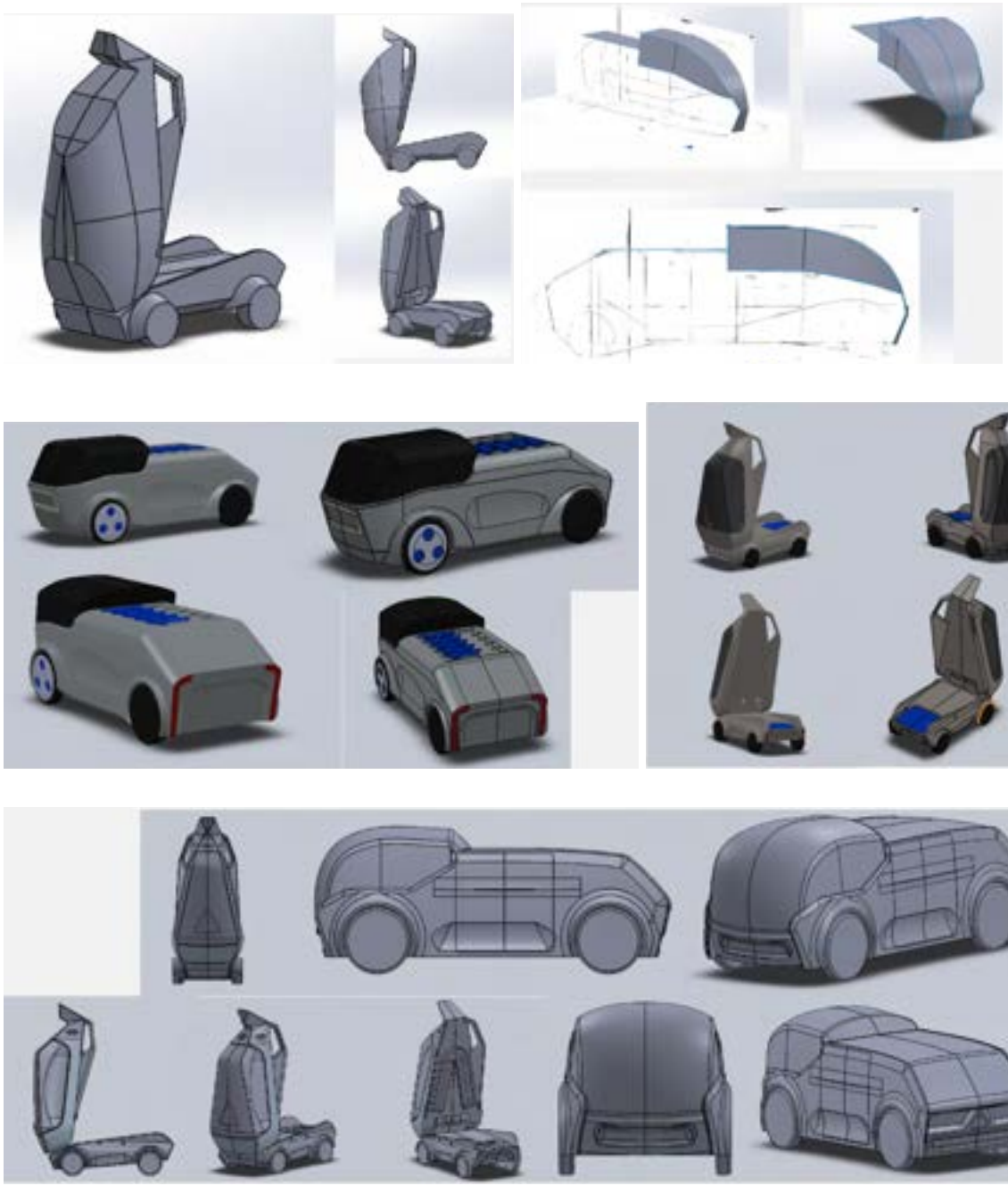
Psychology
Social interaction - waste collectors and the community
Self-Actualization-
Insuring that the litter is collected

Wants/Wishes

Marketing- **Incipient Needs**
Avoiding back ***pain***
Easily see *to see litter when driving*
Feedback *- visual representation when container is full*

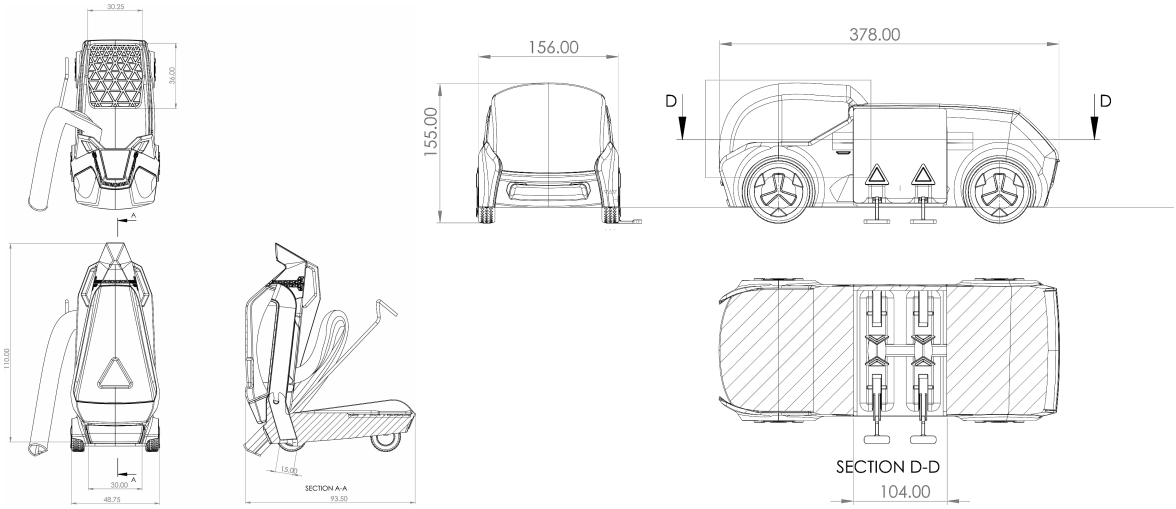
Psychology
Wants/Wishes
Wants a mobile vehicle that is comfortable and reduces on physical pain

E - CAD Development



F - Physical Model Photographs

G - Technical Drawings



H - Bill of Materials

Bill Of Materials		
Scooter		
Component	Material	Cost
Chassis	Carbon Steel	$2,000
Body panel	Aluminium	$800
vacuum motors	Various materials	$975
batteries	Lithium battery	$1,000
Rims	Aluminium alloy	$300 x 4
Tires	rubber	$ 80 x 4
OLED Display	Various Materials	$600
Litter Compartment	Acrylic	$10
Standing Mat	Synthetic rubber	$5
Hose	Rubber	$10
Total:		**$6,800**

Bill Of Materials		
Truck		
Component	Material	Cost
Chassis	Carbon Steel	$15,000
Body panel	Aluminium	$8,000
vacuum motors	Various materials	$2,000
batteries	Lithium battery	$8,000
Rims	Aluminium alloy	$800 x 4
Tires	rubber	$100 x 4
Solar Panel	Various materials	$2,000
Total:		**$38,600**

I - Sustainably info

Before the Sustainability study can be conducted, literature was reviewed to understand how to properly implement features that would promote sustainability. The literature reviews provided information on materials, manufacturing, health and safety with the vehicle industry. Many sources were used in creating the sustainability report, the main Literature that was used was **Life cycle targets applied in highly automated car body manufacturing – Method and algorithm** and **Sensitivity Analysis in the Life-Cycle Assessment of Electric vs. Combustion Engine Cars under Approximate Real-World Conditions.** These pieces of literature aided in both the materials/manufacturing and sustainability.

During research, it was found that vehicles that use both aluminium and steel are more inclined to become recycled. Aluminium and steel are extremely recyclable, in which can both

be recycled indefinitely. At the end of a vehicle's life cycle, each can be taken apart and resold back to its manufacturers to create a circular economy.

Also, vehicles that use lithium batteries are seen to have an increase in sustainability. The batteries can be recharged thus mitigating the use of gas to operate the vehicles. Gas-powered products emit hazardous air pollutants such as nitrogen oxides (NOx), particulate matter (PM), carbon monoxide (CO), and sulphur oxides(SOx) that aid the process of climate change. (*Air Pollution From Cars, Trucks, Vans and SUVs*, 2017). Products that use rechargeable batteries create zero emissions thus making it an extremely efficient alternative to methods.

As Electric vehicles become more popular, many charging options have become more prominent in the design world. Most parklots have now implemented electric car parking zones, which allow the user to charge their car. Within recent years vehicles have become more sustainable by implementing solar panels into the cars design. These solar panels allow the car to recharge its internal battery thus making itself sustainable.

Health and Safety

Vehicle emissions have a direct impact on the health and safety of the operator. If the Vehicle emissions become too much it can lead to having aggravated asthma, reduced lung capacity, and increased susceptibility to respiratory illnesses, including pneumonia and bronchitis. (*Cleaner Air | US Department of Transportation*)

J - Approval forms & plan

THESIS TOPIC APPROVAL:

Student Name:	Thomas Pantano
Topic Title:	How may we improve litter collection in cityscape areas?

TOPIC DESCRIPTIVE SUMMARY (Preliminary Abstract)

As more residents move to dense urban areas, the environment becomes negatively impacted. According to Time Magazine, "There has been an influx in overall garbage dense urban areas, resulting in the creation of more litter". The surrounding area in cities where wildlife resides becomes affected by the number of micro-plastics that leach off of the litter into their water and food supplies. Litter can also affect the drainage system within cities leading to the creation of floods and other environmental impacts. The rate at which litter is being collected is overshadowed by the numerous amount of litter that is being spread within these cities. Currently, there are very few efforts within Toronto to minimize the amount of litter that the residents generate and dispose of. The purpose of this thesis project is to complete an in-depth study on the daily process of how waste management workers handle litter, and also the process of how the litter is being addressed by the city. The data will be collected from observation, surveys, and one-to-one interviews. These research methods will assist in investigating and better understanding of litter treatments from the residents who live within a city and the workers who maintain it. Results from this data analysis will support in developing a design solution to mitigate litter problem in dense urban areas.

Student Signature:		Instructor Signature:	
Date:	27/09/2021	Date:	07 October 2021

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

Student name:	Thomas Pantano
Topic/Thesis Title:	OPTIMIZING URBAN LITTER COLLECTION

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	[X] **CAD Design and Development Phase**
Comments:	- Initial CAD started well as of week #7/February 22nd, continue with detailing and refinement. - Refinement CAD progress well as of week #8/March 8th, still to refine some detailing.

Design is reviewed and approved to proceed for the following:	[X] **Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comments:	- Once CAD is completed, can move forward to model fabrication from week #9 onward.

Instructor Signature(s):	
Date:	8th March, 2022

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

thomas pantano

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

n01234261

Date of Issue: **26 September, 2021**

K - Advisor Meetings and Agreement Forms

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 / 4502

SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Research Study Topic: How might we improve litter collection in cityscape areas?

Investigator: Thomas Pantano / 647-524-7025 / thomas.pantano@outlook.com

Sponsor: Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction

My name is Thomas Pantano, I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that help improve litter collection within desnse urban areas , to promote a healthier environment". These problems include environmnetall issues sucha as water pollution, air pollution, disrupting animals habitats and overall aesthetics. The results will be contributed to my Senior Level Thesis project.

Purpose of the Study

This study is being conducted as an aid in designing a a product that is capable of improving litter collection within a dense urban area. The product to be designed is inspired by current efforts to clean litter and help the environment. With you help, I plan to address this problem This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures

If you volunteer to participate in this study, your activities in interacting with a machine /device /equipment /vehicle will be observed and documented. Your activities will be documented by means of a digital camera / video camera while operating the machine. You will also be asked questions pertaining to the machine /device /equipment /vehicle and how you use it.

Confidentiality

Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal

Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

If at any point during the session, you feel uncomfortable and wish to end your participation, please let the moderator know and they will end your participation immediately.

Humber Research Ethics Board

This research project /course has been approved by the Humber Research Ethics Board. If you have any questions about your rights as a research participant, please contact Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca**

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HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 / 4502

SENIOR LEVEL THESIS ONE & THESIS TWO

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☒ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

Rochelle Byrne	RByrne	October 14, 2021
Participant's Name	Participant's Signature	Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: 647 - 524 - 7025

Email: thomas.pantano@outllok.com

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**

Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**

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HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

IDSN 4002 /4502

SENIOR LEVEL THESIS ONE & THESIS TWO

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How might we improve litter collection in cityscape areas?

Investigator: Thomas Pantano / 647-524-7025 / thomas.pantano@outlook.com

Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, Rochelle Byrne *(First Name/Last Name)*, have carefully read the Information Letter for the project How might we improve litter collection in cityscape areas?, led by Thomas Pantano. A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact « insert student Name » at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☒	☐
Review	I give consent for review by the Professor	☒	☐

Privacy

All data gathered is stored anonymously and kept confidential. Only the principle investigator /researcher, « insert student Name here » and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or « insert student Name /Phone Number /Email Address ».

Verification of having read the Informed Consent Form:

☒ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Rochelle Byrne	RByrne	October 14, 2021
Participant's Name	Participant's Signature	Date

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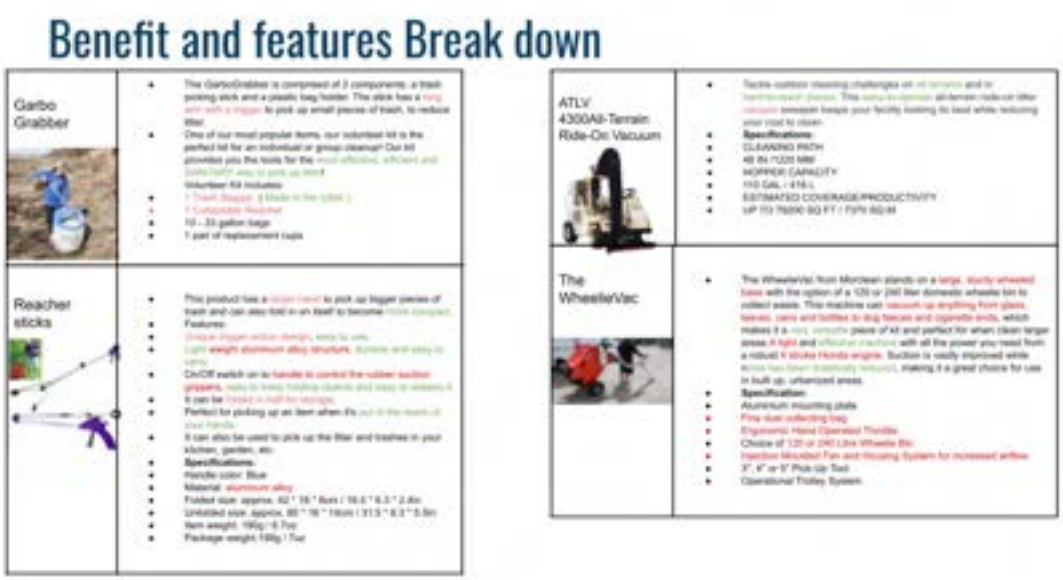
L - other supportive raw Data



Product Benefits

						
Garbo Grabber	hand Foldable Pick Up Grabber Gripper Reacher sticks	All-Terrain Ride-On Vacuum Sweeper	The WheelieVac	Electric BackPack Vacuum	Curbside pickup	Green Machines Air Sweeper
Benefits						
Effective Compact	Easy to use Compact Durable material	Easy to use Reaches hard areas comfortable	Effective Quiet	Light Environmentally friendly Easy to use	Easy to use Durable material	Quiet Environmentally friendly Comfortable Easy to use
Terms	Effective, compact, durable, easy to use, comfortable, environmentally friendly, quiet					

Product Features

						
Garbo Grabber	hand Foldable Pick Up Grabber Gripper Reacher sticks	All-Terrain Ride-On Vacuum Sweeper	The WheelieVac	Electric BackPack Vacuum	Curbside pickup	Green Machines Air Sweeper
Features						
Handle Garbage storage Long arm Picks up small objects collapsible	Handle Picks up small objects Collapsible Large grabber	Ride on Garbage storage Vacuum Mechanical Maneuverable Picks up small objects	Vacuum Mechanical Garbage Storage Picks up small objects	Garbage storage Mechanical	Handle Garbage storage	Mechanical Ride on Maneuverable
Terms	Garbage storage, collapsible, picks up small objects, ride on ,mechanical, maneuverable, vacuum suction					

M - Topic specific Data

The generation and cost of litter resulting from the curbside collection of recycling

Travis P. Wagner [a], Nathan Broaddus [b]

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Abstract

This study examined the generation of litter, defined as spillage and uncollected residue, from a curbside collection system for residential recycling. The primary recycling containers used in the study were 18-gal (68 L), open-top bins. The study, conducted over a seven-week period, was comprised of both an urban and suburban area. Six litter characterizations were conducted in which all new litter larger than 1 in.^{2} was collected, segregated, counted, and weighed. We found that each week the open-top recycling bins contributed approximately 20,590 pieces of litter over 1 in. in size per every 1000 households, which resulted in the generation of 3.74 tons of litter per 1000 households per year. In addition to the bins having no top, the primary root causes of the litter were constantly overflowing recycling bins, the method of collection, and material scavenging. Based on an estimated cost of litter cleanup ranging from $0.17 to $0.79 per piece of litter, the direct economic costs from the collection of litter and loss in recycling revenues were estimated at US$3920 to US$19,250 per 1000 households per year. Other notable impacts from the litter, such as increased risk of flood damage from storm drain impairment and marine ecosystem damages exist, but were not monetized. The results strongly suggest that modification of the curbside collection system would decrease the amount and associated cost of litter by replacing existing curbside collection containers with larger volume containers with covers and by modifying the task-based incentive system to emphasize litter prevention rather than the current aim of completing the task most quickly.

The generation and cost of litter resulting from the curbside collection of recycling

Travis P. Wagner [a], Nathan Broaddus [b,*]

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ARTICLE INFO

Article history:
Received 2 October 2015
Revised 3 February 2016
Accepted 3 February 2016
Available online 13 February 2016

Keywords:
Curbside collection
Recycling
Collection containers
Litter
Municipal solid waste
Marine litter

ABSTRACT

This study examined the generation of litter, defined as spillage and uncollected residue, from a curbside collection system for residential recycling. The primary recycling containers used in the study were 18-gal (68 L), open-top bins. The study, conducted over a seven-week period, was comprised of both an urban and suburban area. Six litter characterizations were conducted in which all new litter larger than 1 in.^{2} was collected, segregated, counted, and weighed. We found that each week the open-top recycling bins contributed approximately 20,590 pieces of litter over 1 in. in size per every 1000 households, which resulted in the generation of 3.74 tons of litter per 1000 households per year. In addition to the bins having no top, the primary root causes of the litter were constantly overflowing recycling bins, the method of collection, and material scavenging. Based on an estimated cost of litter cleanup ranging from $0.17 to $0.79 per piece of litter, the direct economic costs from the collection of litter and loss in recycling revenues were estimated at US$3920 to US$19,250 per 1000 households per year. Other notable impacts from the litter, such as increased risk of flood damage from storm drain impairment and marine ecosystem damages exist, but were not monetized. The results strongly suggest that modification of the curbside collection system would decrease the amount and associated cost of litter by replacing existing curbside collection containers with larger volume containers with covers and by modifying the task-based incentive system to emphasize litter prevention rather than the current aim of completing the task most quickly.

1. Introduction

The curbside collection of residential recyclables has been shown to significantly increase a municipality's recycling rate (see for example Folz, 1991; Everett and Peirce, 1993; and Jenkins et al., 2003). The added convenience with curbside recycling increases resident participation and thus the amount collected (Wagner, 2013). In 2011, the US had more than 9800 residential curbside collection programs serving 73% of the U.S. population (US EPA, 2013). Many types of curbside recycling containers are available, varied by volume, color, style, cost, messaging, use of Radio Frequency Identification (RFID) technology, which permits recycling data collection at the household level, and durability. Because recycling collection is managed at the municipal level and various types of collection containers are available, there is wide variety in the recycling containers used throughout the US (Lane and Wagner, 2013). The 18-gallon (68 L) plastic open-top bin (17″ w × 22″ l × 16″ h) is one of the more popular containers, due principally to it being the cheapest available option at approximately $10 each. In contrast, at $50 each, 64-gallon carts can necessitate a relatively major capital investment for a mid-size city. For example, a mid-sized city with 50,000 households considering the adoption of a cart program would face a cost of some $2.5 million. Based on a study by Lane and Wagner (2013) on the use of recycling containers in the US, of the 782 responses, 178 municipalities (with a combined population of 17.184 million) used open top bins with a capacity of 18 gallons or less. From this data, the prevalence of the use of this type of collection container is clear.

Although the capital cost of purchasing small open-top bins is substantially less than that of rolling carts, it is important to assess direct and indirect costs associated with their use (to be sure, there likely are other capital costs to the collection trucks depending on whether carts will be collected automatically, semi-automatically, or manually). One such cost comes from their contribution to litter from the open-top design, which more easily transforms recyclable

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http://dx.doi.org/10.1016/j.wasman.2016.02.004