LifeAutomation

April 6, 2021

Dr. Craig Scratchley
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Re: ENSC 450W/440 Proposal for an Autonomous Waste Cart System

Dear Dr. Scratchley,

Please find the document attached below that outlines the proposal for implementing our smart moving waste cart, Bin Buddy. The purpose of Bin Buddy is to eliminate the need of people having to manually bring out their own garbage. After the easy initial calibration of the boundaries by the homeowners, Bin Buddy will take care of moving the waste carts at scheduled days and times.

The document enclosed outlines the scope of the project, project risks, project benefits, market, and competitors. Additionally, company details, project planning phases, and cost considerations will also be addressed.

Four computer engineering students and one systems engineering student - Aigerim (Ayoka) Omirbekova, Emily Chen, Jeongwon (Julia) Kim, Kira Nishi-Beckingham and Sheetal Puri - make up our amazing LifeAutomation team. Strong with the computer engineering background, our team brings our software experience to the table with a blend of robotics to tinker our project into realization.

Thank you for your time in reviewing our design specifications. Should there be any questions regarding the document, please reach out to our Chief Operations Officer, Jeongwon (Julia) Kim, via email jka183@sfu.ca or phone at (604) 441-7044.

Sincerely,

Kira Nishi-Beckingham
Chief Executive Officer
LifeAutomation

Enclosed: Proposal for an Autonomous Waste Cart System

Project Proposal

Bin Buddy

Partners: Aigerim (Ayoka) Omirbekova
Emily Chen
Jeongwon (Julia) Kim
Kira Nishi-Beckingham
Sheetal Puri

Contact Person: Jeongwon (Julia) Kim
jka183@sfu.ca
(604) 441-7044

Submitted To: Dr. Craig Scratchely, ENSC 405W
Dr. Andrew Rawicz, ENSC 440
School of Engineering Science
Simon Fraser University

Issue Date: April 6th, 2021

Executive Summary

A rotating waste collection schedule is established in many cities in North America and by-laws are enforced, imposing narrow time windows to wheel the carts out. To alleviate the risk of being issued a fine or a violation ticket, or missing a collection due to poor timing, Bin Buddy's goal is to automate the waste cart pickup process.

Bin Buddy aims to target owners of single detached homes and is suitable for both the typical working population as well as the elderly of disabled, where bringing the waste cart to the front of the driveway quickly becomes a cumbersome chore. To date, there is no solution in the market although proof of concepts, such as SmartCan by the Rezzi company [1], do exist.

Bin Buddy attaches to existing city waste carts using the cylindrical rod situated at the front of the cart. Following a pre-inputted schedule in Bin Buddy's mobile app, Bin Buddy will autonomously wheel the cart to the pickup location and back after being emptied on waste collection days. The smart waste cart system will actively avoid large obstacles, such as cars on the driveway, while navigating to its docking location after an initial boundary calibration.

Waste collection remains a necessity in everyone's regular routine. With the growing demand and trend of the Internet of Things (IoT), LifeAutomation aims to bring a new blue ocean technology into the market. The top 3 companies in the North American waste market: Waste Management, Republic Services, and Waste Connections generated over 30 billion in revenue in 2019 [2]. Although Bin Buddy will first set foot as a consumer product, as a 3-year projection goal, LifeAutomation aims to work directly with waste collection companies to increase revenue.

The LifeAutomation team consists of 5 motivated Engineering students with backgrounds in computer and systems engineering. Bin Buddy's proof of concept and engineering prototypes are projected to be completed by the end of April and August of 2021, respectively. The total cost of these prototypes is estimated to be $600. The members of LifeAutomation are actively seeking for funding and is expected to receive partial coverage of costs from the Engineering Science Student Society Endowment Fund and the Wighton Development Fund. Any additional funds will be directly reinvested into further research and development of Bin Buddy.

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1. Introduction

Stand-alone or semi-detached houses follow waste collection schedules that are established individually within each city. To date, most cities adopt a rotating collection schedule for the different carts: organics, recyclables, and garbage. Many cities also have by-laws, imposing narrow time windows to place the carts out for collection [3]. With these restrictions, this weekly cumbersome chore can result in missed collections due to timing, or costly fines issued by city authorities. By-law violations in the city of Coquitlam in British Columbia, for example, can result in fines up to $500 [3]. Additionally, the heavy load of a waste cart can pose a physical challenge and put a strain on the elderly or disabled, especially for those living independently.

Over the last decade, many cities have transitioned to an automated waste collection service using mechanical arms, including the top 3 companies in the North American waste market: Waste Management, Republic Services, and Waste Connections [2]. However, bringing the waste cart out for pickup remains a manual task for residents. LifeAutomation believes that Bin Buddy can be a solution to automating the waste collection service. Bin Buddy attaches to city waste carts using the existing cylindrical rod situated at the front of the cart.

Figure 1. 1: Bin Buddy System

Because driveways come in all shapes and sizes, setting up Bin Buddy is a two-step process involving a schedule calibration in the mobile app, as well as a physical boundary setup to help Bin Buddy know how to navigate the user's driveway. Following the setup, the smart waste cart system will autonomously wheel the cart to the pickup location and back after being emptied on waste collection days. Figure 1.1 displays the Bin Buddy system.

2. Scope

The scope of this project includes the design, assembly, and testing of a prototype of Bin Buddy. The Bin Buddy prototype will be able to perform the following main tasks:

1. Pull a waste cart, while following a line down the driveway
2. Recognize when the waste cart is emptied
3. Follow a schedule input by the user via the mobile application
4. Send alerts to the user when it is stuck via the mobile application

The prototype will be able to pull a load of up to 50kg, however, the final product will be scaled up to pull a load of up to 150kg matching the load requirements for the largest waste cart available. The prototype also uses a Raspberry Pi 3 B+ as a microcontroller which will be converted to a custom board for the final product in order to reduce cost and power consumption.

This product is designed to fit onto waste carts around the lower mainland, however, the mechanical design can be modified in the future to allow Bin Buddy to fit onto carts across the world.

Figure 2.1 provides a high-level overview of the Bin Buddy system and how the subsystems are connected.

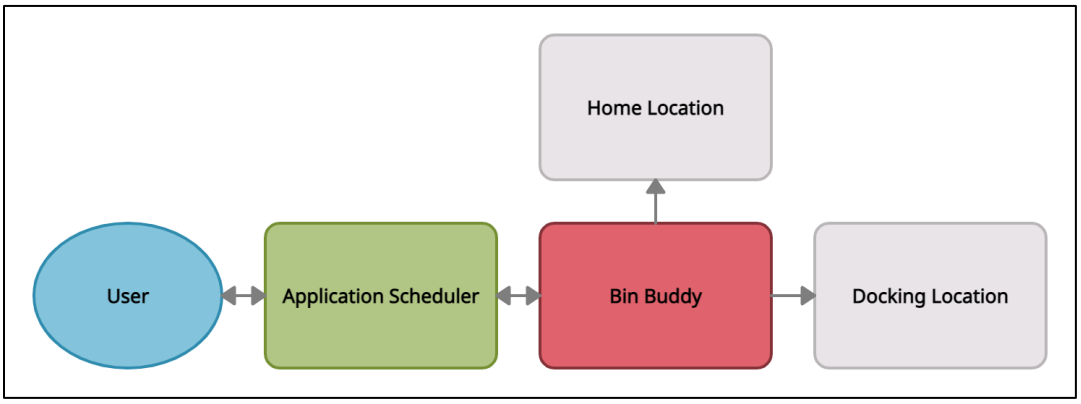

Figure 2. 1: High-Level Overview of the Bin Buddy System

3. Project Risks/Benefits

3.1 Benefit: Accessibility

Bin Buddy will bring out the waste cart on a schedule, allowing people with accessibility inconveniences to live more independently. After the initial setup, Bin Buddy will navigate itself to and from the front of the driveway on a set schedule managed by the user to follow the city's collection schedules.

3.2 Benefit: Flexibility

Bin Buddy introduces more freedom into the user's busy day schedule by taking care of the mundane chore for the user. For those with irregular work hours or those going away on an extended vacation, Bin Buddy will allow that extra flexibility in scheduling.

3.3 Benefit: Affordability

Bin Buddy prototypes are projected to range from $300 to $500. According to our user survey, potential consumers have responded positively to purchasing Bin Buddy in that price range. Furthermore, having Bin Buddy bring out the waste cart on schedule within the constrained window of time set by the by-laws, users can avoid paying fines. These fines can range from $150 to $500. Therefore, Bin Buddy serves to cover more than its cost for long-term users.

3.4 Risk: User Safety

Because Bin Buddy will have a heavy load of the waste cart attached, safety for the users must be considered. The product must travel below a certain speed to avoid inflicting bodily harms as well as have a braking system to lock the wheels in place to prevent rolling away when parked. A secure clamping mechanism will also be designed to reduce the risk of the system falling off if not securely attached, which can potentially cause bodily harm or product damage.

3.5 Risk: Electronic Hazard

In terms of the electronics component of Bin Buddy, the circuitry will be enclosed in a waterproof case to offer protection from water, especially since Bin Buddy will operate and be stored in an outdoor environment. All circuit components will be hidden from the user to prevent mishandling and damage to the device.

3.6 Risk: Software Data Leakage

Although Bin Buddy will store minimal confidential data, data leakage is a risk in the software. To reduce this risk, the database will be hosted on the cloud by MongoDB Atlas. As a fully managed cloud database, the data will be more secure than creating a local database managed by the LifeAutomation team. Additionally, confidential information like passwords, will be encrypted before being stored in the database.

4. Market/Competition/Research Rationale

4.1 Market Analysis

Our initial target market includes all people in private dwellings around the lower mainland. As of 2016, there are 1,099,698 private dwellings in the lower mainland [4], each of which can potentially use one or more Bin Buddy devices. Though this is our initial target market, the market for Bin Buddy has potential to expand Canada wide and even international with small modifications to ensure the mechanical design can fit on different waste carts.

For our initial market, the users have a financial motivation along with the removal of a menial task from their to-do list. Around the lower mainland, residents can be expected to receive fines from their city just for having their garbage bin out during non-specified hours. Some cities provide as little as a 2-hour window in which residents can take out their bin which is clearly an inconvenience as seen by the number of warning and fines administered. In Coquitlam, there were 339 warnings and 62 $500 fines given by the beginning of June in 2018 [5]. In fact, a father received one of these $500 fines for taking his garbage bin out early in hopes that his morning routine with his infant son would be slightly less busy [5]. These fines are not limited to a one-time payment, and residents of private dwellings can expect to receive a fine each time their garbage bin is out during non-specified times.

Something else to note is that a large portion of our target market is elderly people who may not necessarily be capable of taking out their waste cart multiple times a week. The Bin Buddy system would require a one-time setup with the help of a friend or family member and would allow the seniors to have their garbage taken care of. This portion of the target market is projected to continue to grow, Studies show that the number of seniors in Canada's population is projected to rise from 17.2% in 2018 to up to 29.5% in 2068 [6].

The demand for Bin Buddy will increase as the target market population continues to grow, leading to the financial motivation to purchase the system.

4.2 Competition

There is only one other commercial project to solve the waste cart problem and that product is not yet in the market, providing the LifeAutomation team with an advantage. However, in the event that this product does come to the market before Bin Buddy, an analysis must be conducted.

SmartCan

SmartCan, as seen in Figure 4.1, is a product created by a startup named Rezzi. Using the same attachment method as Bin Buddy, SmartCan attaches to the metal bar commonly seen on city garbage bins. Much like Bin Buddy, SmartCan also utilizes a mobile application to "set a schedule and take-out location" [1]. Though there is minimal information online about SmartCan, upon inspection, the design looks very unstable. Since the system is expected to navigate a driveway that is likely bumpy and has possible small obstacles such as twigs or pebbles, SmartCan seems to be prone to tipping with its thin wheels and narrow base. Interestingly, SmartCan has been seen on various talk shows, proving that there is interest in this type of product [1]. However, the SmartCan design will not be compatible with waste carts around the lower mainland, which is Bin Buddy's initial target market.

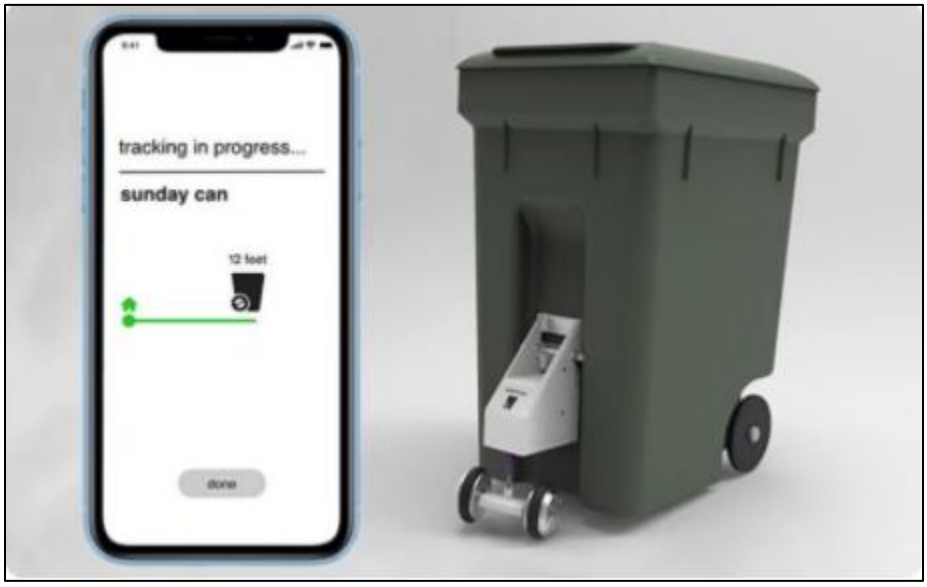

Figure 4. 1: SmartCan by the Rezzi Company

5. Company Details

Kira Nishi-Beckingham
knishibe@sfu.ca
Chief Executive Officer

Kira is a 5th year Computer Engineering student who is interested in using technology to solve problems. She has previously worked as an Applications Engineer at Broadcom and as a Software Engineer at Kardium. With extensive experience in working with multiple programming languages as well as coming up with innovative programmatic solutions, Kira is responsible for system communication and integrating the hardware and software for Bin Buddy.

Julia Kim
jka183@sfu.ca
Chief Operations Officer

Julia is a senior Computer Engineering student with interests in computer networks and cyber security. Previously, she has worked as an application security analyst at PNI Media and as an IT security analyst at ICBC. Experienced in C, C++ and Python from her academic background, Julia is responsible for the hardware and software integration of Bin Buddy.

Sheetal Puri
sheetal_puri@sfu.ca
Chief Technology Officer

Sheetal is a senior Systems Engineering student with interests in robotics and automation. Previously she has worked as a research assistant developing an automated telescope tracking mount, and as an Instrumentation engineer at STEMCELL Technologies where she worked on mechanical design for a cell manipulation machine, failure testing, and implementing calibration program and GUI. Sheetal is responsible for integrating the mechanical and electronics for Bin Buddy.

Emily Chen
eca83@sfu.ca
Chief Financial Officer

Emily is a senior Computer Engineering student interested in finding solutions to real world problems. Previously she has worked as a GUI developer at Safe Software on their FME Desktop application, and as a junior developer at PNI Media, maintaining their e-commerce platforms for on-demand printing and shipping. Emily is responsible for integrating the hardware and software for Bin Buddy.

Ayoka Omirbekova
aomirbek@sfu.ca
Chief Marketing Officer

Ayoka (Aigerim) is a senior Computer Engineering student with interests in embedded software development and firmware. Currently, she is working part-time as an Embedded Software Developer at BWL, and previously, she has worked as a Software Developer in Embedded Appliances at Motorola Solutions and Quality Assurance Developer at BGC Engineering. With experience in diverse software projects at different stages, Ayoka is responsible for the software and hardware integration of Bin Buddy.

6. Project Planning

Bin Buddy has 3 main design phases, by the end of which certain requirements must be met. Table 6.1 lists those stages and their acronyms, used further in this document:

Table 6. 1: Product Phases

Product Phase	Acronym
Alpha Phase (Proof of Concept)	POC
Beta Phase (Engineering Prototype)	EP
Production Phase (Final Product)	FP

The Alpha Phase is expected to be completed by the end of ENSC405W in Spring 2021. The high-level functionalities of Bin Buddy expected to be completed in this phase are:

1. Moving from a defined point A to a defined point B, following the line.
2. Understanding when the waste cart has been emptied or when it is stuck.
3. Recognizing small and large obstacles and navigating over small obstacles.
4. Communicating with Bin Buddy's software application containing a basic interface.
5. Implementing an emergency stop button to power off the entire system.
6. Remaining stable at angles of up to10 degrees.

The Alpha Phase prototype is intended to demonstrate the basic functionality of Bin Buddy's system as well as portray its intended size. Figure 6.1 presents a detailed Gantt chart of the first phase of the product.

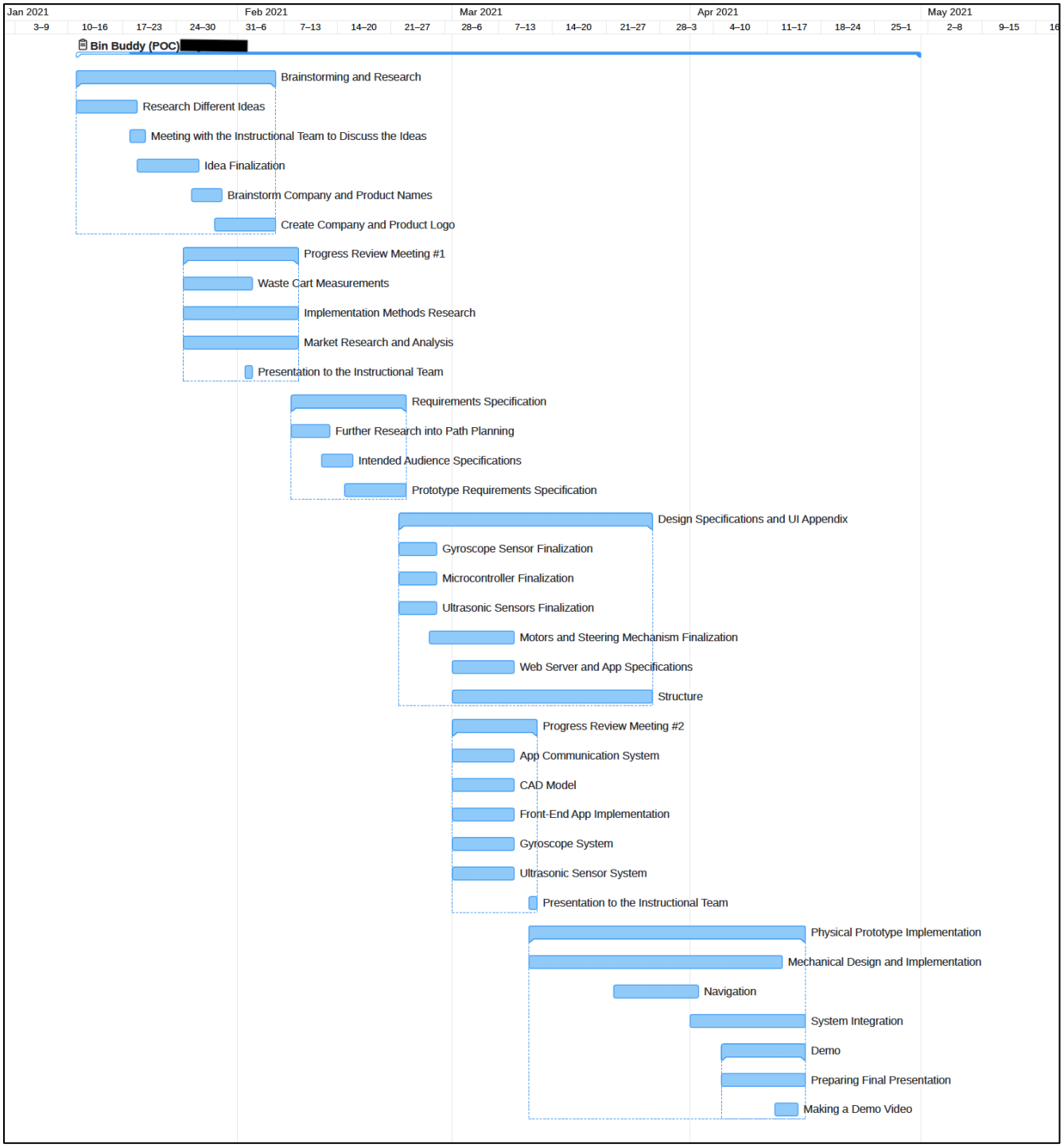

Figure 6. 1: Bin Buddy POC Gantt Chart

The Beta Phase will be completed by the end of ENSC440 in Summer 2021. This phase includes the expansion of Bin Buddy's functionalities and improvements of the appearance design. The high-level functionalities of Bin Buddy expected to be completed in this phase are:

1. Avoiding large obstacles while on route to the docking locations.
2. Following the waste collection schedule inputted by the user.
3. Implementing a more robust structure.
4. Adding more software functionalities such as alerting the users in case of needing attention/user action.

Figure 6.2 displays the plan for the Beta Phase.

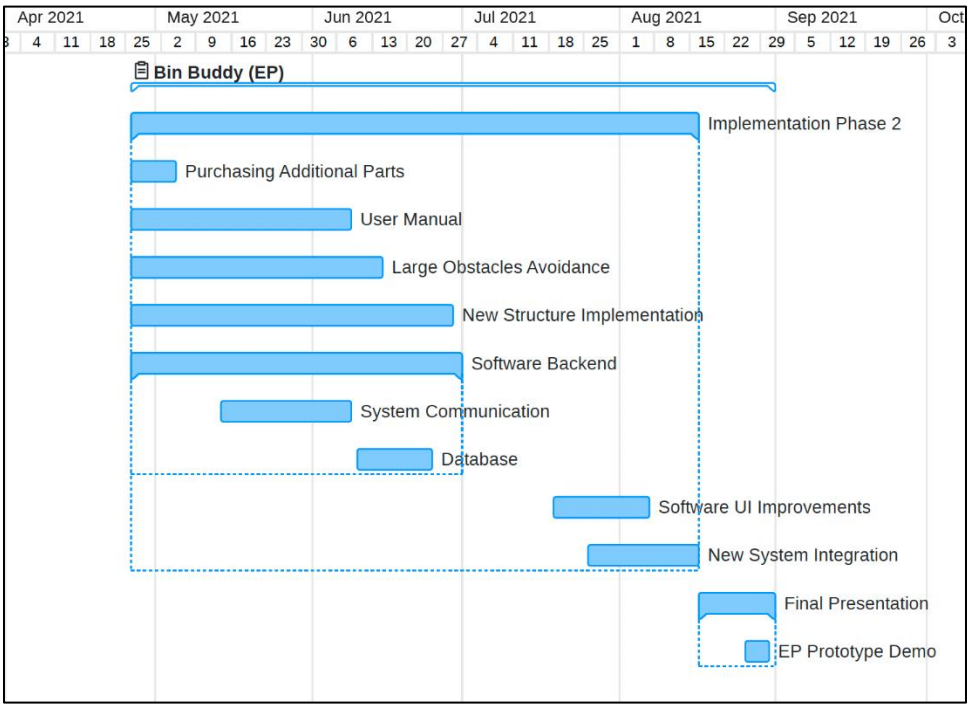

Figure 6. 2: Bin Buddy EP Gantt Chart

The Production Phase of the project (FP) is intended to be completed after ENSC440. This phase will cover the final design and cost optimization of the product.

7. Cost Considerations

7.1 Estimation of Project Costs

Table 7.1 breakdowns the cost of each component for the proof-of-concept phase. Components will be reused in the engineering prototype. Some structural parts will be replaced to increase the stability, and to finetune the appearance of the product. The addition of these new components in the engineering prototype will not contribute significantly to an increase in the total cost.

Table 7. 1: Bin Buddy Component Cost Breakdown

	Component	Qty	Price ($/Unit)	Subtotal ($)
Mechanical	Wood 1x6x6	1	17.53	17.53
	2x2x6 Fir	1	10.76	10.76
	Everbilt Shelf Bracket	2	1.55	3.10
	Nuts	6	0.12	0.72
	Screws	6	0.32	1.92
	Washer	6	0.14	0.84
	Wheels Set	1	28.88	28.88
	Flange Coupling Connector	2	2.99	5.99
	8mm to 8mm Coupler Set	1	9.43	9.43
	Linear shaft	1	20.14	20.14
	Mounted ball bearing set	1	7.99	7.99
Hardware	Raspberry Pi 3B+ Kit	1	99.99	99.99
	Ultrasonic Sensor (HC-SR04)	3	6.85	20.55
	Gyroscope/Accelerometer Sensor (MPU-6050)	1	4.33	4.33
	Raspberry Pi Camera Module	1	22.99	22.99
	Geared Permanent Magnet DC Motor	2	37	74
	MDDS30 SmartDriveDuo Motor Driver	1	86.84	86.44
	Emergency Power Button + Wires	1	32	32
	Anti-spark connectors	1	4.06	4.06
	12V 4.5Ah Sealed Lead Acid Battery	2	34.99	69.98
	5V 3A Portable Charger for the MCU	1	19.99	19.99
Miscellaneous	Waste Cart Size Exchange	1	10	10
			Total Tax ($)	46.09
			Total Cost ($)	597.72

7.2 Potential Funding Resources

7.2.1 Engineering Science Student Endowment Fund (ESSEF)

The Engineering Science Student Endowment Fund is supported by SFU's Engineering Science Student Society (ESSS). Projects may fall into four categories: Competition, Entrepreneurial, Class, and Miscellaneous. Life Automation's product, Bin Buddy, fulfills the Class category. An application for this fund will be submitted in May of 2021.

7.2.2 Wighton Engineering Development Fund

The Wighton Engineering Development Fund is organized by SFU's department of Applied Sciences. Projects benefiting society are treated preferentially [7], placing Bin Buddy in an advantage because of its intention to reduce a physical strain on the elderly and the disabled. An application for this fund will also be submitted in May of 2021.

7.2.3 Personal Funding

The remainder of the cost of the product, not covered by ESSEF and the Wighton Engineering Development Fund, will be distributed evenly among Life Automation's team members. The range of potential contribution cost per member will be $100-$150.

8. Conclusion

LifeAutomation intends to bring a new product to the market that will automate the mundane chore of wheeling the waste cart out on waste collection days. The product, Bin Buddy, allows home dwellers to automate a part of their chore routines. With a scheduled frequency following the city's waste collection schedule, Bin Buddy will bring out waste carts to and from the pick-up area while avoiding large obstacles within a virtual or physical boundary.

Bin Buddy will provide various benefits such as accessibility, flexibility, and affordability while reducing potential risks in its design. With the large market space for expansion and one visible competitor, Rezzi, Bin Buddy is projected to develop over the course of three incremental phases: Alpha Phase, Beta Phase, and Final Product. Cost estimates and potential funding resources, such as the Engineering Science Student Endowment Fund and the Wighton Engineering Development Fund, are being considered over the development phases of Bin Buddy.

The engineers of LifeAutomation plan to dedicate all their technical and soft skills to deliver a new, robust product to the market that will serve its intended purpose.

9. References

[1] A. Murray and J. Aronson, "Rezzi," [Online]. Available: https://www.rezzicompany.com/. [Accessed 28 March 2021].

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[3] "Coquitlam," [Online]. Available: https://www.coquitlam.ca/157/Collection-Calendar-Guidelines. [Accessed 28 March 2021].

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