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ITS67404
Assessment 2
GROUPPROJECT

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Instructions to students:

- The PROJECT should be attempted in groups of 3-5.
- Complete this cover sheet and attach it to your assignment – this should be your first page!
- Submit only softcopy to Times and must in pdf format ONLY.

Student declaration:
I declare that: ▪ ***I understand what is meant by plagiarism*** ▪ ***The implication of plagiarism have been explained to us by our lecturer*** ***This project is all our work and I have acknowledged any use of the published or unpublished works of other people.***

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Table of Contents

Demonstrate the Entrepreneurism Mindset

Introduction

As the world continues to face a waste management crisis, there is a growing need for innovative solutions to help reduce the environmental impact of waste. In response to this challenge, a new system has been developed that comprises of four main components: the Beautify bins for trash storage, the BeautifyAI bin for sorting out trash using AI and ML technologies, a GPS system for connecting truck drivers for trash collection, and a web application for monitoring the process and maintenance of the machine. The concept of an entrepreneurial mindset involves a way of thinking that embraces innovation, creativity, and risk-taking. In the current era, the application of entrepreneurial thinking has been vital in the development of modern technology, and the waste management industry is no exception. This report aims to explore how to demonstrate an entrepreneurial mindset while consistently demonstrating the self as an innovative agent of change in today's modern world for the system for waste management using smart recycling bins.

Target market

The target market for Smart Recycling Bins is landed household residents who require efficient waste management systems. These households generate a significant amount of waste, and the conventional methods of waste management may not be efficient enough to manage this waste. Smart Recycling Bins cater to this market segment by providing a modern, efficient, and sustainable waste management system that can handle their waste and help them reduce environmental pollution.

In order to expand the target market for Smart Recycling Bins, it is important to understand the demographics and psychographics of the target market. The target market is likely to be composed of households with higher disposable income and education levels, who are environmentally conscious and willing to adopt new technologies for sustainable living.

To reach this market segment, Smart Recycling Bins can leverage various marketing channels and outreach initiatives such as social media platforms, community events, online advertisements, and influencer marketing. They can also consider partnering with local homeowners' associations, apartment complexes, and property management companies to promote their product and services.

Moreover, Smart Recycling Bins can further expand their target market by considering partnerships with local municipalities, governments, and waste management agencies. By doing so, Smart Recycling Bins can provide a comprehensive waste management solution that serves the needs of the broader community. Such partnerships can help Smart Recycling Bins to access larger markets, promote their product and services, and build brand awareness.

To sum up, understanding the demographics and psychographics of the target market is critical for expanding the target market for Smart Recycling Bins. By identifying the target market's needs, preferences, and values, Smart Recycling Bins can tailor their product and marketing strategy to effectively reach and cater to this market segment. Moreover, partnerships and collaborations with relevant stakeholders such as homeowners' associations, municipalities, and waste management agencies can provide further avenues for expanding their target market and promoting their services.

Partnership and Collaboration

Partnership and collaboration are essential for the success of any innovative product or service. Smart Recycling Bins can partner with various organizations to improve their operations and expand their market. One such partnership could be with local waste management agencies to facilitate the collection of waste and ensure that the waste is disposed of sustainably.

Additionally, partnerships with technology companies can help improve the capabilities of the Smart Recycling Bins by integrating artificial intelligence, machine learning, and other innovative technologies. Collaboration with environmental organizations and educational institutions can also help raise awareness about the benefits of the Smart Recycling Bins and promote sustainability among households.

Furthermore, partnerships with local businesses, such as grocery stores, can also be beneficial for the Smart Recycling Bins. By placing the bins in convenient locations, households will be more likely to use them, and the businesses can benefit from being seen as environmentally conscious. Additionally, partnerships with manufacturers of environmentally friendly products can also be established to promote the use of such products and encourage proper disposal of the associated waste.

Through partnerships and collaborations, Smart Recycling Bins can expand their reach and influence, and provide more value to their target market while contributing to sustainability efforts.

Research and Development

Research and development play a critical role in the development of any innovative product or service. Smart Recycling Bins must invest in research and development to improve their operations, enhance the user experience, and increase the sustainability of the waste management system.

To achieve this, Smart Recycling Bins can conduct research to identify the specific needs of their target market and develop features that cater to those needs. This can involve carrying out surveys or focus groups to gather feedback on the current system and identify areas for improvement. Research and development can also help Smart Recycling Bins identify new technologies or materials that can be incorporated into their system to improve its performance.

In addition to conducting research, Smart Recycling Bins can also invest in the development of new products or features that can enhance their service offerings. This can involve developing new sensors, software or hardware components that can make the system more efficient, user-friendly and cost-effective. The development of these new products can be carried out in-house or in collaboration with other organizations, such as universities or research institutes. Overall, research and development should be an ongoing process that is continually evaluated and updated to meet the changing needs of the market.

Understanding the needs of target market

Understanding the needs of the target market is essential in expanding the market for the smart recycling bins. We can conduct market research to understand the specific requirements of landed household residents, local governments, and private companies. By understanding their needs, we can develop customized solutions that meet their specific requirements. We can also leverage customer feedback, surveys, focus groups, and online reviews to gain further insights into the target market's needs. Additionally, partnerships and collaborations with relevant stakeholders can help to further understand the target market and tailor our offerings accordingly. By understanding the needs of the target market, we can develop an effective and sustainable waste management system that meets the needs of our customers and contributes to environmental sustainability.

To develop an efficient and effective waste management system, it is essential to understand the needs of the target market. Smart Recycling Bins should conduct market research to identify the challenges faced by landed household residents in managing their waste. The research should also focus on identifying the features and benefits that would be most valuable to the target market.

Additionally, Smart Recycling Bins should consider gathering feedback from their existing customers to understand their experience and preferences. This can be done through surveys, interviews, or focus groups. By understanding the needs of the target market, Smart Recycling Bins can make necessary adjustments to their product and service offerings to better meet the needs of their customers. This will not only improve customer satisfaction but will also help the company stay competitive in the market.

Sustainability and social impact

Sustainability and social impact are essential to the success of any product or service. Smart Recycling Bins should ensure that their product is designed and developed with sustainability and social impact in mind. This can be achieved by incorporating green materials in the production process and designing the product to reduce environmental pollution. Additionally, Smart Recycling Bins should ensure that their product is safe and secure, and meets the standards and regulations set by the local government and environmental agencies.

The company should also focus on educating and empowering its customers to reduce their environmental impact. This includes providing customers with information on how to properly use and maintain the Smart Recycling Bins, and informing them about the environmental benefits of using the product. Additionally, Smart Recycling Bins should consider collaborating with local organizations and governments to develop community outreach programs to spread awareness about the benefits of the product and encourage its adoption.

Finally, Smart Recycling Bins should measure the social and environmental impact of their product. This includes tracking the amount of waste diverted from landfills, the reduction in greenhouse gas emissions, and other environmental benefits. The company should also evaluate the social impact of the system, such as its contribution to community engagement, education, and awareness. These metrics should be reported regularly to stakeholders to demonstrate the positive impact of the product.

Overall, Smart Recycling Bins should ensure that their product is designed with sustainability and social impact in mind and measure the impact of their product on the environment and society.

Sustainability and social impact are essential in expanding the target market for the smart recycling bins. We need to ensure that our product has a positive impact on the environment and society. We can achieve this by using sustainable materials, reducing waste, and creating job opportunities for the local community.

Smart Recycling Bins can implement several sustainability measures to reduce the environmental impact of waste management. For example, the bins can be made of sustainable and recyclable materials to reduce waste and promote recycling. Additionally, the smart recycling bins can be designed to consume less energy and promote energy efficiency. This can be achieved by using renewable energy sources such as solar panels to power the bins.

Furthermore, Smart Recycling Bins can have a positive social impact by creating job opportunities for the local community. The company can hire and train individuals from the local community to handle the installation, maintenance, and operation of the bins. This not only creates employment opportunities but also promotes community involvement and development.

To further promote the social impact of the product, Smart Recycling Bins can collaborate with local organizations to promote environmental awareness and educate the community on sustainable waste management practices. This can be done through workshops, seminars, and other awareness campaigns.

By promoting sustainability and social impact, Smart Recycling Bins can attract environmentally conscious customers and expand its target market.

Continuous innovation

Continuous innovation is critical for the success of any product or service. Smart Recycling Bins should strive to constantly improve the product and stay ahead of the competition. This can be achieved by leveraging data-driven insights to identify areas for improvement and continuously refining the product.

The company should also consider partnering with relevant stakeholders, such as universities and research institutes, to gain access to the latest technologies and innovate faster. Additionally, Smart Recycling Bins should use predictive analytics and machine learning to identify customer needs and trends and develop new features to address them.

Regular customer feedback should also be sought to identify areas for improvement and develop features that meet their needs. Smart Recycling Bins can also leverage user testing to ensure that any new features or changes are well-received by customers.

Finally, Smart Recycling Bins should consider offering incentives to customers who suggest product improvements or features. This will encourage customers to provide feedback and help the company to stay ahead of the competition.

Overall, continuous innovation is essential for the success of Smart Recycling Bins. By leveraging data-driven insights, partnering with relevant stakeholders, and gathering customer feedback, the company can stay ahead of the competition and ensure that their product meets the needs of their customers.

To remain relevant and competitive, it is important to continuously innovate and improve the smart recycling bins and waste management system. This can be achieved by conducting regular research and development, as well as soliciting feedback from customers and stakeholders. It is also important to stay up to date with technological advancements and industry trends, as this can help identify new opportunities for improvement and innovation.

One area of focus could be on increasing the efficiency and accuracy of the sorting process, as this can help to further reduce waste and increase recycling rates. This could involve incorporating new technologies such as artificial intelligence, machine learning, and computer vision, which could help to improve the accuracy of the sorting process and reduce the need for human intervention.

Another area of focus could be on enhancing the sustainability and social impact of the smart recycling bins and waste management system. This could involve incorporating more recycled and environmentally friendly materials in the construction of the bins, as well as exploring new ways to reduce waste and promote sustainability. It could also involve partnering with local communities and organizations to promote awareness and education around waste management and recycling.

Furthermore, continuous innovation could also focus on improving the user experience and increasing convenience for customers. This could involve implementing features such as mobile applications for tracking and managing waste, or integrating with smart home systems for more seamless integration into customers' daily routines.

Smart Recycling Bins could also explore new business models, such as offering subscription-based services for waste management, or partnering with other businesses to offer recycling and waste management services as part of a larger eco-friendly package.

Overall, continuously innovating and improving the smart recycling bins and waste management system can help to ensure that the product remains relevant, competitive, and effective in meeting the needs of the target market, while also promoting sustainability and social impact.

Opportunities that deliver value

Smart Recycling Bins and GPS Waste Management System is an innovative solution to the growing problem of waste management in today's world. The system comprises of several components, including the Beautify bins, the main BeautifyAI bin, the GPS system, and the web application. The smart recycling bins use advanced technologies such as artificial intelligence and machine learning to sort out trash efficiently, making the process more sustainable and efficient. In this report, we will identify the opportunities that deliver value when choosing this system of waste management using smart recycling bins and GPS system.

Opportunities for Value Creation

1. Efficient Waste Management: The smart recycling bins and GPS waste management system provide an opportunity for efficient waste management. By using advanced technologies such as AI and ML, the system can sort out trash more efficiently, reducing the need for manual labour and streamlining the process.
2. Sustainable Waste Management: The system also provides an opportunity for sustainable waste management. By promoting recycling and reducing waste, the system can help to reduce the environmental impact of waste disposal and promote a more sustainable future.
3. Reduced Costs: The use of advanced technologies such as AI and ML can also help to reduce the costs associated with waste management. The system can reduce the need for manual labour, reduce the costs of transportation, and streamline the process, resulting in cost savings for waste management organizations.
4. Improved Health and Safety: By reducing the need for manual labour in waste management, the system can also help to improve health and safety conditions for workers. The use of AI and ML can also help to identify hazardous materials in the waste stream, reducing the risk of exposure to harmful substances.
5. Better Data Management: The system also provides an opportunity for better data management. By using the web application that comes with BeautifyAI bins, waste management organizations can

monitor the progress, process, and maintenance of the machine in real-time, enabling more efficient data management.

6. Increased Convenience: The Beautify bins placed outside the residents' homes for trash storage also provide an opportunity for increased convenience. Residents no longer need to travel to waste disposal sites, reducing the time and effort required for waste disposal.
7. Promote Public Awareness: The system can also promote public awareness of waste management and recycling. By providing more efficient and sustainable waste management solutions, the system can raise public awareness of the importance of proper waste disposal and promote a more environmentally conscious society.

The Smart Recycling Bins and GPS Waste Management System offer several opportunities for value creation in the waste management industry. By using advanced technologies such as AI and ML, the system can provide efficient, sustainable, and cost-effective waste management solutions. The system can also improve health and safety conditions, promote better data management, increase convenience, and promote public awareness of waste management and recycling. The system's many benefits make it an attractive choice for waste management organizations and individuals looking to promote a more sustainable future.

Functional Requirements

Requirement ID	Requirement Description
FR01	The system must be able to identify and sort different types of waste
FR02	The system must provide real-time data on the status of the BeautifyAI bins and trash collection
FR03	The system must provide a web application for monitoring the progress, process, and maintenance of the machine
FR04	The system must be able to integrate with the GPS system to provide optimal routing for the trash trucks
FR05	The system must be able to detect when a Beautify bin is full and needs to be emptied
FR06	The system must be able to communicate with the trash truck drivers to inform them of the locations of the full bins
FR07	The system must be able to handle high volumes of waste and sorting at peak times
FR08	The system must be easy to use and require minimal maintenance
FR09	The system must be able to adapt to changes in waste management regulations
FR10	The system must be able to provide accurate and detailed reporting on waste management metrics

Functional Requirement Descriptions

FR01: The system must be able to identify and sort different types of waste, including recyclable, organic, and non-recyclable waste. This is a critical function of the system, as it allows for efficient and accurate waste sorting, which is essential for effective waste management.

FR02: The system must provide real-time data on the status of the BeautifyAI bins and trash collection, including information on bin fill levels, collection schedules, and sorting accuracy. This function is essential for optimizing the waste management process and ensuring that the system is operating effectively.

FR03: The system must provide a web application for monitoring the progress, process, and maintenance of the machine. This function is important for enabling effective system management, troubleshooting, and maintenance, as well as providing real-time access to important system data.

FR04: The system must be able to integrate with the GPS system to provide optimal routing for the trash trucks. This function is important for optimizing the waste collection process, reducing travel times and fuel costs, and ensuring that the system operates efficiently.

FR05: The system must be able to detect when a Beautify bin is full and needs to be emptied. This function is critical for ensuring that the system operates efficiently and that waste is not left uncollected.

FR06: The system must be able to communicate with the trash truck drivers to inform them of the locations of the full bins. This function is essential for optimizing the waste collection process, reducing travel times and fuel costs, and ensuring that the system operates efficiently.

FR07: The system must be able to handle high volumes of waste and sorting at peak times. This function is essential for ensuring that the system is able to meet the demands of high-volume waste management operations and that it operates efficiently and effectively.

FR08: The system must be easy to use and require minimal maintenance. This function is important for ensuring that the system is user-friendly and that it operates efficiently and effectively with minimal maintenance requirements.

FR09: The system must be able to adapt to changes in waste management regulations. This function is important for ensuring that the system is compliant with waste management regulations and that it is able to adapt to changes in regulations as they arise.

FR10: The system must be able to provide accurate and detailed reporting on waste management metrics, including waste collection, sorting accuracy, recycling rates, and other key performance indicators. This function is important for enabling effective waste management and monitoring the performance of the system over time.

Non-Functional Requirements

Non-Functional Requirement	**Description**
Scalability	The system must be able to handle a large volume of waste and be scalable to accommodate future growth. It must also be able to handle multiple users and devices.
Reliability	The system must be reliable and available 24/7 to ensure that waste collection is not interrupted. This means that the system must have backup measures in place in case of a failure.
Security	The system must be secure to protect user data and prevent unauthorized access. This includes implementing strong authentication and encryption measures.
Usability	The system must be user-friendly and easy to use for both residents and waste management personnel. The system should have a simple and intuitive interface that requires minimal training to use.
Performance	The system must have fast response times and minimal latency to ensure a smooth and efficient waste management process. The system must also be able to handle large amounts of data without slowing down.

Compatibility	The system must be compatible with a variety of devices and platforms to ensure widespread adoption. It must be able to integrate with other waste management systems and applications.
Maintainability	The system must be easy to maintain and repair in case of a failure. This means that the system must have a modular design and well-documented codebase.
Accessibility	The system must be accessible to all users, including those with disabilities. This means that the system must be designed to accommodate different assistive technologies and support different languages.
Compliance	The system must comply with all relevant laws and regulations, including those related to data privacy and waste management. This means that the system must be designed to protect user data and ensure that waste is managed in a safe and responsible manner.
Performance testing	The system must undergo performance testing to ensure that it can handle the expected workload and function optimally in real-world scenarios. This includes load testing, stress testing, and endurance testing.
Connectivity	The system should have a reliable and secure connectivity infrastructure to support data transfer between the sensors and the central system. It should be able to connect to various types of communication technologies such as Wi-Fi, Bluetooth, and cellular networks.
Bandwidth	The system should have enough bandwidth to handle the amount of data transmitted by the sensors in real-time. This is especially important when the system is deployed in large areas with a high density of sensors, such as in commercial or industrial areas.
Capacity	The system should have sufficient capacity to store the data generated by the sensors. The amount of storage required will depend on the number of sensors deployed, the frequency of data collection, and the duration of data retention.
Speed	The system should be able to process and analyse data in real-time to enable quick decision-making. The speed of the system should be optimized to minimize delays in data collection, processing, and analysis.

Scope of the proposed system

The proposed Smart Waste Management System is designed to automate and optimize the process of waste collection and disposal through the use of IoT technology. The system aims to improve the efficiency of waste management and reduce environmental pollution by providing real-time monitoring and analysis of waste generation, collection, and transportation.

In this system, the data involved is controlled by the waste management company, which has ownership of the waste collection bins and is responsible for managing the waste collection process. The amount of data involved in the processing will depend on the number of waste collection bins deployed and the frequency of data collection.

The scope of the proposed system includes the deployment of two types of smart waste collection bins - the Beautify Bins for households and the BeautifyAI Bins for commercial and industrial areas. The system will include sensors in these bins to monitor the waste levels, as well as a network infrastructure to transmit the data

to a centralized platform. The platform will then use machine learning algorithms to analyse the data and optimize the waste collection and disposal process.
However, the proposed system does not cover the actual waste disposal process, as this is typically managed by local waste management authorities. The system is also limited to the collection of solid waste and does not include the management of liquid or hazardous waste.
The system includes four key components: the Beautify bins placed outside the residents' homes for trash storage, the main BeautifyAI bin at each region of the country, which is used for sorting out the trash collected from all the Beautify bins with AI and ML technologies, the GPS system to connect the truck drivers for trash collection, and the web application that comes with BeautifyAI bins to monitor the progress, process, and maintenance of the machine.

The system covers the following activities:

- Placing and collecting the Beautify bins
- Sorting the collected waste in the main BeautifyAI bins using AI and ML technologies
- Truck drivers' routing and trash collection using the GPS system
- Monitoring the progress, process, and maintenance of the machines using the web application.

The system's data involves the amount of waste collected, sorted, and disposed of, the location of the waste, and the route taken by the truck drivers. The system also requires personal data such as the contact information of the customers and the truck drivers.
However, the system does not cover the following activities:

- Cleaning and maintenance of the Beautify bins by the customers
- Physical collection of the waste by the customers
- The disposal of hazardous waste that requires specialized treatment or handling
- The disposal of large and bulky waste items that cannot be accommodated in the Beautify bins

In conclusion, the proposed system provides an end-to-end solution for waste management using smart recycling bins and GPS. The system is designed to meet the needs of waste management companies and local governments responsible for waste collection and disposal. The system covers the people who control data involved in the IoT app/system and the amount of data involved in the processing. The scope of the system is defined, and the activities that are covered and not covered are identified.

Overall system architecture with explanation

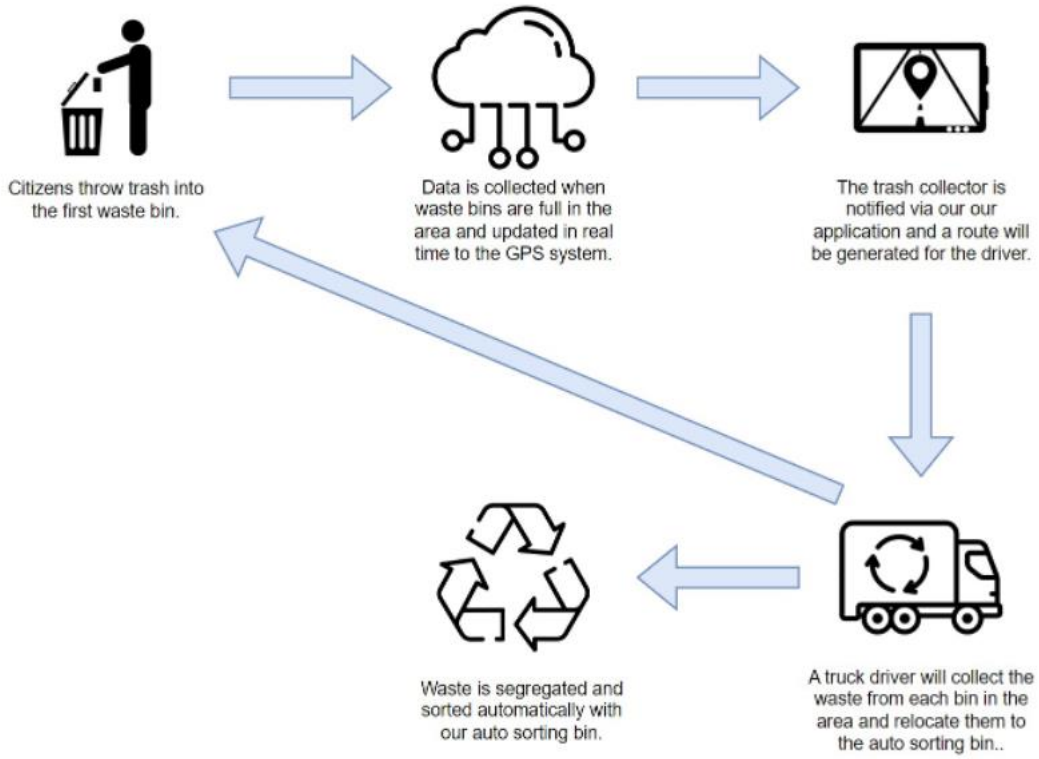

Figure 1: Overall system flow

The BeautifyAI system's waste collection process begins with the first bin, which features an infrared (IR) sensor that measures the waste level in the bin. Once the bin is full, the sensor sends a notification to the BeautifyAI application, alerting the system that the bin needs to be emptied. This feature helps ensure that waste is collected in a timely and efficient manner, reducing the risk of overflow and other issues that can arise when bins are not emptied regularly.

After receiving the notification, the BeautifyAI application notifies the truck drivers responsible for waste collection in the area. The application generates a route for the drivers to follow, ensuring that they can collect the waste from the full bin quickly and easily. By automating this process, BeautifyAI streamlines waste collection efforts and helps reduce the workload on drivers, allowing them to focus on other aspects of their job.

Once the waste is collected, the truck drivers transport it to the auto-sorting bin, which is the second bin in the BeautifyAI system. This bin is equipped with technology that allows it to automatically sort recyclable materials from non-recyclable waste. This feature helps ensure that recyclables are properly separated from other waste, improving the efficiency and effectiveness of the recycling process. By automating the sorting process, BeautifyAI makes it easier for waste management teams to recycle more efficiently and reduce their impact on the environment.

Strength and Weakness

Strength of the system

Efficient waste collection: The proposed loT solution for waste management can significantly improve the efficiency of waste collection. With the implementation of smart recycling bins and a GPS system, waste collectors can be notified in real-time when a bin is full and needs to be collected. This feature can help reduce the time and resources required for waste collection, as waste collectors can plan their routes more effectively and reduce the number of trips required to collect waste.
Moreover, with the integration of predictive analytics algorithms, waste collectors can anticipate when bins will be full and schedule collection accordingly. This will lead to a more efficient use of resources, as waste

collectors can plan their routes based on predicted waste generation. In turn, this will result in a reduction in carbon footprint, as the number of trips required for waste collection will be reduced.

Improved recycling efforts: The proposed loT solution can also lead to improved recycling efforts. With the implementation of smart recycling bins, waste can be sorted and recycled more effectively. The sensors within the bins can detect the type of waste being disposed of and sort it accordingly. This will result in a reduction in the amount of waste that is sent to landfills, as recyclable materials will be identified and sorted for recycling. Furthermore, the implementation of the loT solution can also improve the public's awareness of the importance of recycling. The availability of smart recycling bins in public spaces can encourage individuals to dispose of their waste responsibly and increase their recycling efforts. Overall, improved recycling efforts can lead to a reduction in carbon footprint, which is crucial for mitigating the impact of climate change.

Reduction of carbon footprint: The proposed loT solution can also contribute to a reduction in carbon footprint. The efficient collection of waste and improved recycling efforts can reduce the amount of waste sent to landfills, which in turn reduces the amount of methane gas produced. Methane gas is a potent greenhouse gas that contributes to climate change. Therefore, reducing the amount of methane gas produced can significantly reduce carbon footprint.
Moreover, with the implementation of predictive analytics algorithms, waste collectors can optimize their collection routes and reduce the number of trips required for waste collection. This can lead to a reduction in the carbon emissions produced by waste collection vehicles. The reduction of carbon footprint is critical for mitigating the impact of climate change and promoting sustainable development.

Integration with legacy waste management systems for greater efficiency: One strength of the proposed loT solution for waste management is the integration of the system with legacy waste management systems used by municipalities. By integrating with these systems, the loT solution can improve the efficiency of waste collection and reduce redundancy. The integration allows for the optimization of waste collection routes, leading to reduced fuel consumption and costs associated with waste collection. Additionally, the integration enables the system to access data from existing waste management systems, such as information on waste generation rates, leading to better resource management.

Predictive analytics algorithms for better resource management: Another strength of the proposed loT solution is the potential use of predictive analytics algorithms to forecast waste generation rates. By analysing data on historical waste generation rates and other factors such as population growth and weather patterns, the system can predict future waste generation rates. This enables better resource management by allowing for more accurate planning of waste collection and recycling efforts. Additionally, the predictive analytics can be used to identify areas that require more attention in terms of waste management, leading to a more targeted approach.

Use of GPS system to track and optimize waste collection routes: The use of a GPS system in the loT solution is another strength that can improve the efficiency of waste collection. The GPS system allows for real-time tracking of the waste collection vehicles, enabling the system to optimize the waste collection routes based on factors such as traffic conditions, waste generation rates, and the location of the recycling facilities. The optimization of waste collection routes leads to reduced fuel consumption and lower costs associated with waste collection.

Comprehensive disaster recovery plan to minimize system downtime: Finally, the proposed loT solution includes a comprehensive disaster recovery plan to minimize system downtime. The plan outlines the steps that should be taken in case of system failure or downtime, ensuring that the system can be quickly restored to full functionality. This is a strength of the system as it ensures that any disruption to the waste management process is minimized, leading to better overall efficiency and effectiveness.

Strengths of Arduino

Arduino sensors are popular for use in IoT systems due to their numerous strengths and advantages. Some of these strengths are:

1. Cost-effectiveness: Arduino sensors are popular in IoT projects due to their affordability and ease of use. Compared to other sensors, Arduino sensors are relatively inexpensive, making them accessible for hobbyists, students, and developers to create IoT projects on a budget (Tang, Yang, Liu, & Sun, 2018). The cost-effective nature of Arduino sensors makes them suitable for small-scale IoT projects,

such as home automation systems, environmental monitoring, and smart agriculture (Gupta, Singh, & Singh, 2021). In addition to being affordable, Arduino sensors are also easy to use and program. The Arduino platform provides a user-friendly interface, and the sensors are designed to be integrated easily with the platform. Furthermore, Arduino sensors are equipped with libraries and code examples that can be used to build IoT applications without requiring extensive knowledge of programming languages and electronics (Karim, 2021). This ease of use and accessibility makes Arduino sensors an excellent option for beginners and experienced developers alike. Moreover, Arduino sensors are versatile and can be used in a wide range of IoT applications. They come in different types, such as temperature sensors, humidity sensors, gas sensors, and motion sensors, among others, and can be used in various fields, such as healthcare, agriculture, and environmental monitoring (Pintea, 2021).

2. User-friendly: Arduino sensors are designed to be user-friendly and easy to use, with a large community of developers providing support and resources for beginners. Arduino sensors are popular for their user-friendliness and ease of use, which has contributed to their popularity among hobbyists and developers. Arduino sensors are designed to be plug-and-play, meaning that they can be easily connected to an Arduino board and used with minimal setup or configuration required. Additionally, the Arduino software and documentation are designed to be user-friendly, with a focus on providing clear and concise instructions for beginners. The community of developers surrounding Arduino also contributes to its strength as an IoT device. The Arduino community is large and active, with many developers sharing their knowledge and resources through forums, online tutorials, and other resources. This community provides a wealth of information and support for beginners, helping them to get started with Arduino sensors and learn how to use them effectively. One example of this support is the Arduino Forum, a popular online community where developers can ask questions, share their projects, and get advice and support from other Arduino users (Arduino, n.d.). Another example is the Arduino Project Hub, a website that hosts a wide range of Arduino projects and tutorials, providing users with inspiration and guidance for their own projects (Arduino, n.d.).
3. Versatility: Arduino sensors can be used in a wide range of IoT applications, from environmental monitoring to home automation and robotics. Arduino sensors can be used for a wide range of tasks, including environmental monitoring, home automation, and robotics. For instance, in environmental monitoring, Arduino sensors can be used to measure temperature, humidity, air quality, and other environmental factors that affect crop growth, indoor air quality, and weather conditions. In home automation, Arduino sensors can be used to control lighting, temperature, security systems, and other household appliances. In robotics, Arduino sensors can be used to measure distance, orientation, and acceleration to navigate and control robot movements. According to a study by Al-Fuqaha et al. (2015), Arduino sensors have been used in various IoT applications, including smart homes, precision agriculture, and smart cities. In smart homes, Arduino sensors have been used to control lighting, heating, and cooling systems, and monitor home security. In precision agriculture, Arduino sensors have been used to measure soil moisture, temperature, and humidity to optimize crop growth. In smart cities, Arduino sensors have been used for air quality monitoring, waste management, and traffic control.
4. Flexibility: Arduino sensors are highly customizable, with users able to modify and adapt them to meet their specific needs and requirements. Users can modify and adapt Arduino sensors to suit their specific needs and requirements, making them a popular choice for a wide range of IoT applications. For example, in a study conducted by researchers at the University of Engineering and Technology, Vietnam, an Arduino-based IoT system was developed for real-time water quality monitoring. The system was designed to be customizable, with users able to modify and add new sensors to meet their specific needs. The authors note that the "open-source and modular design of the Arduino platform makes it easy to customize and adapt for different applications" (Le et al., 2021). Another study conducted by researchers at the University of California, Los Angeles, used Arduino sensors to develop an IoT system for monitoring indoor air quality. The authors note that "the open-source nature of the Arduino platform allows for easy customization of the hardware and software to meet specific project requirements" (Zhang et al., 2018).
5. Open-source: Arduino sensors are built on open-source hardware and software, which makes them highly accessible and encourages collaboration and innovation in the IoT community. Arduino is built on open-source hardware and software, meaning that the design files, schematics, and source code are freely available for anyone to use, modify and distribute without restriction. This accessibility has led to a large community of developers, hobbyists, and enthusiasts who share their knowledge, code, and ideas to create new projects and applications. The open-source nature of Arduino sensors has also enabled companies to develop commercial products based on the platform, further expanding its reach and impact in the IoT space. According to a study by Gartner, "by 2020, more than 90% of IoT projects will use some form of open-source software stack, driving IoT innovation and growth." (Hype Cycle

for the Internet of Things, 2016). The open-source nature of Arduino sensors is a major factor in its popularity and widespread use in IoT projects. Moreover, as stated in a research paper by S. Diotalevi et al., "Arduino has become a de facto standard in the maker community, and it represents a simple and affordable solution to implement a wide range of projects" (Design and Implementation of a Smart Irrigation System Based on Arduino and Android). Arduino sensors' open-source nature allows for easy customization, which can be crucial in certain IoT applications, such as smart agriculture. The ability to adapt and modify the sensors to meet specific requirements makes them highly versatile and useful in a wide range of IoT applications.

Strengths of IoT cloud system

1. The use of Apache Hive and Apache HBase enables efficient and structured storage and processing of large volumes of data. Both are open-source, distributed data storage and processing systems commonly used in big data and IoT applications. Hive is a data warehousing and SQL-like querying system that extracts meaningful insights from large, unstructured datasets stored in the Hadoop Distributed File System (HDFS). HBase, on the other hand, is a NoSQL database that provides real-time, random read/write access to large, semi-structured or structured datasets.

   Using these two technologies in an IoT system, organizations can efficiently store and process large volumes of unstructured data generated by IoT devices. As described in the scenario, unstructured data from IoT devices is passed through an ETL process operated by Hive and then stored in HBase in a structured format. This enables efficient querying and analysis of the data using tools like Apache Spark, which can help organizations identify trends, patterns, and other meaningful insights that can inform decision-making.

   According to a study by Li et al. (2018), using Hadoop and its ecosystem, including Hive and HBase, can significantly improve the performance of data processing and storage in IoT applications. The study found that using Hadoop reduced data processing time and storage space by up to 50% compared to traditional relational databases. Another study by Zhang et al. (2019) also highlights the benefits of using Hive and HBase for IoT data processing and analysis. The study found that using these technologies can improve the efficiency of data processing and enable real-time analysis of IoT data.

2. The use of Apache Spark for data analysis provides fast and scalable processing of the stored data. Apache Spark is a powerful data processing engine that allows for fast and scalable processing of large datasets. It uses in-memory processing and can handle various types of data sources, making it suitable for IoT systems that generate large amounts of data. Spark provides a range of data analysis capabilities, including machine learning, graph processing, and SQL querying, which can be applied to the data stored in Apache HBase. This allows for real-time analysis and insights, enabling businesses to make quick and informed decisions based on the data.

   According to a study by Ma et al. (2021), Apache Spark has been widely adopted in IoT systems due to its ability to handle large and complex data, its support for various programming languages, and its ability to scale horizontally. The study also found that Spark is particularly useful for processing streaming data in real time, which is a key requirement for many IoT applications. Another study by Lee et al. (2019) found that Spark can significantly improve the performance of data processing and analytics in IoT systems compared to traditional approaches.

3. The integration of MPC controller and Intel XEON 4th gen scalable processor allows for optimized output. The integration of Model Predictive Control (MPC) and high-performance processors like Intel Xeon can optimize the output of IoT systems. The MPC algorithm uses mathematical models to predict the behaviour of the system and determine the optimal control inputs to achieve a desired output. Intel Xeon processors provide high processing power and support parallel computing, which can accelerate the MPC calculations and improve the system's performance.

   A study by Lin et al. (2021) proposed a novel MPC strategy for energy management in a smart home using a high-performance computing platform based on Intel Xeon processors. The results showed that the proposed strategy achieved significant energy savings and reduced the electricity bill compared to traditional methods. Another study by Zhao et al. (2020) applied MPC control to a microgrid system and used Intel Xeon processors to improve the real-time performance of the algorithm. The results

demonstrated that the optimized MPC algorithm could effectively balance the power supply and demand in the microgrid system.

4. The use of Unix-based Cron process enables automated execution of commands based on the optimized results. The Unix-based Cron process is a scheduling tool that allows for the automated execution of commands at predetermined intervals. In the IoT system described, the Cron process is used to execute commands based on the optimized results obtained from the MPC controller, allowing for efficient and timely updates of data on the Frontend. One of the main strengths of using Cron is its simplicity and reliability. It is a well-established and widely used tool in the Unix/Linux community, and is known for its ability to execute tasks accurately and efficiently. Additionally, Cron is highly customizable, allowing for a wide range of scheduling options and configurations.

   According to Zemlin and Balling (2000), Cron has been widely used in the Unix/Linux environment for many years and is considered a stable and reliable tool for scheduling tasks. The authors note that Cron is highly flexible and can be used for a wide range of applications, including system maintenance, data processing, and task automation. They also point out that Cron is easily configurable and can be customized to meet specific needs and requirements. Another advantage of using Cron is that it requires minimal resources and overhead. Since Cron is a simple command-line tool, it does not require significant memory or processing power, making it an ideal solution for resource-constrained systems.

Strengths of IoT Frontend system

1. Real-time traffic updates: Waze's strength lies in its real-time traffic updates, which can be valuable in various IoT applications that rely on accurate and up-to-date traffic information. For instance, in a smart city transportation system, Waze's real-time data can be utilized to optimize traffic flow and reduce congestion. Waze uses crowd-sourced data from its community of users to provide real-time updates on traffic incidents, road closures, and other relevant information. This allows for efficient and accurate routing decisions, which can save time and reduce fuel consumption. According to a study conducted by P. Huang et al. (2021), Waze's real-time traffic updates have been found to be more accurate than other navigation apps, such as Google Maps and Apple Maps, in predicting traffic congestion. The study also highlighted the importance of crowd-sourced data in providing real-time traffic updates, as it enables Waze to gather data from a large number of sources in real-time, resulting in more accurate and up-to-date traffic information. Furthermore, Waze's user-friendly interface and gamification features, such as rewards and badges for reporting traffic incidents, have encouraged its community of users to actively participate in providing real-time traffic data. This has resulted in a highly engaged user base, which continuously contributes to the accuracy and reliability of the traffic information provided by Waze.
2. User-generated data: Waze's community-driven approach is a significant strength for IoT systems. As users report incidents and update the platform in real-time, IoT systems can leverage this data to provide more accurate and up-to-date information to users. For example, an IoT system that uses Waze's data could adjust a driver's route in real-time to avoid a traffic jam or accident reported by the community. Research has shown that Waze's community-driven approach can significantly improve the accuracy of traffic predictions. A study by Bae et al. (2019) found that incorporating Waze's real-time data into traffic flow models led to a more accurate prediction of traffic congestion. Similarly, a study by Liao et al. (2017) found that using Waze's data improved the accuracy of traffic flow predictions for both highways and arterial roads. Overall, Waze's community-driven platform is a valuable resource for IoT systems that require real-time traffic information. By leveraging the collective intelligence of its users, Waze can provide highly accurate and up-to-date information to IoT systems, which can help improve their functionality and effectiveness.
3. Accuracy: Google Maps has access to a vast amount of data, including real-time traffic updates, road closures, and construction, which allows it to provide accurate and up-to-date navigation information to users. This accuracy is particularly useful for IoT systems that rely on location data, such as asset tracking or delivery logistics. Additionally, Google Maps offers a variety of customization options, such as the ability to choose different transportation modes, avoid tolls or highways, and view street-level imagery, which can be tailored to meet the specific needs of IoT applications (Google, n.d.).
4. Large user base: Google Maps' strength lies in its ability to provide real-time location-based data and services to IoT systems. The platform has a large and constantly growing user base, which enables it to collect and update its maps and data in real-time (Hwang et al., 2016). This makes Google Maps highly accurate and reliable, which is essential for IoT systems that require precise location data to function effectively. In addition to its accuracy and real-time data, Google Maps also offers a wide range of

features and functionalities that can be leveraged by IoT systems. For example, the platform offers APIs that enable developers to integrate location-based services into their IoT applications, such as geocoding, routing, and place search (Google, 2022). These APIs can be used to provide location-based services to users, such as personalized recommendations, real-time traffic updates, and location tracking. Moreover, Google Maps has a user-friendly interface that is easy to use and navigate, which makes it an ideal frontend for IoT systems. The platform offers various customization options, such as different map styles, colour schemes, and markers, which enable developers to create customized maps that suit their specific needs and requirements (Google, 2022). This level of customization and flexibility is beneficial for IoT systems that require a frontend that is highly adaptable and can be tailored to specific use cases.

Weaknesses of the system

High initial cost for implementation and ongoing maintenance: One of the major weaknesses of the proposed IoT waste management system is the high initial cost of implementation and ongoing maintenance. The cost of sensors, hardware, software, and other components can be prohibitive for many municipalities or organizations. Additionally, ongoing maintenance costs, including system updates and repairs, can also be significant. This may limit the adoption of the system, especially in resource-constrained communities.

Potential for user resistance to new technology or changes in waste management practices: Another potential weakness of the IoT waste management system is the possibility of user resistance to new technology or changes in waste management practices. Some individuals or organizations may be hesitant to adopt the new system or change their waste management habits, which could reduce the effectiveness of the system. Effective communication and education on the benefits of the system may be necessary to overcome this resistance.

Possible security vulnerabilities in the system's wireless communication and data storage: The IoT waste management system's wireless communication and data storage may be vulnerable to security breaches, which could compromise the integrity of the system and the privacy of the data. This could lead to unauthorized access to sensitive information or disruption of the system's operation. The system must incorporate robust security measures such as data encryption, firewalls, and access controls to mitigate the risk of security breaches.

Limited ability to handle certain types of waste: The IoT waste management system may have limited ability to handle certain types of waste, such as hazardous materials or bulky items. This may require additional waste management processes or systems to handle these types of waste, which could reduce the effectiveness of the IoT system.

Dependence on reliable wireless communication and data transfer for effective operation: The IoT waste management system's operation is highly dependent on reliable wireless communication and data transfer. Any disruptions in these systems could result in reduced efficiency or downtime of the IoT system. This could be a significant challenge, especially in areas with poor connectivity or network coverage.

Requires significant resources and management for successful implementation and maintenance: The implementation and maintenance of the IoT waste management system require significant resources and management. This includes managing the sensors and hardware, ensuring data accuracy and quality, updating the software, and providing ongoing maintenance and support. The availability of resources and management expertise may be a challenge for some municipalities or organizations, limiting the adoption and success of the system.

Weaknesses of IoT devices

Although Arduino sensors are commonly used in IoT systems due to their low cost, ease of use, and versatility, they also have some limitations and weaknesses that need to be taken into consideration. This section discusses the major weaknesses of Arduino sensors and proposes possible solutions to address them.

1. One of the main weaknesses of Arduino sensors is their relatively low accuracy compared to more sophisticated sensors. This is because they are designed to be low-cost and accessible to hobbyists and

developers, which often means sacrificing some level of accuracy to keep the price low. While the accuracy of Arduino sensors may be sufficient for certain applications, more advanced sensors may be required for others. Additionally, Arduino sensors have limited range and resolution, which further reduces their sensitivity and precision. This can make it difficult to detect and measure small changes in a system, which is important in many IoT applications. To mitigate this issue, research has shown that calibration techniques can improve the accuracy of Arduino sensors, reducing measurement errors and improving the reliability of readings (Balsamo et al., 2018). Additionally, studies have used machine learning algorithms to correct measurement errors and improve accuracy (Raza et al., 2018). To address limited range and resolution, some researchers have proposed using multiple sensors in a system to increase sensitivity and precision (Li et al., 2019). Other studies have explored the use of higher-end sensors, such as MEMS sensors, which offer higher accuracy and sensitivity than Arduino sensors (Garcia et al., 2018).

2. Arduino sensors, due to their low-cost nature, may lack the robustness and sophistication of more expensive sensors, making them more susceptible to noise and interference from various sources, including electrical and environmental disturbances. This can result in inaccurate or unreliable measurements, particularly in complex or harsh environments where interference is more likely to occur (Zhang et al., 2020). In addition, the use of long cables to connect the sensors to the microcontroller can also introduce noise and signal attenuation, further affecting the accuracy and reliability of the readings (Chen et al., 2021).
3. It is worth noting that Arduino sensors may require frequent calibration and maintenance to ensure accurate and reliable readings over time. This is because the sensors can drift out of calibration due to factors such as changes in the environment, aging of components, and wear and tear (Izadi et al., 2018). Regular calibration is necessary to ensure accurate measurements, and any deviation from the calibration settings should be corrected promptly. Frequent calibration and maintenance can be challenging in large-scale or distributed IoT systems since it can be time-consuming and costly to manually calibrate and maintain each sensor. If calibration and maintenance are not performed regularly, this can lead to increased downtime and reduced system performance.
4. Finally, Arduino sensors may lack advanced features such as wireless connectivity, data encryption, and remote monitoring and control. This can limit their compatibility and integration with other IoT devices and platforms, which can be a major drawback, especially in applications that require real-time data transmission, secure data transfer, and remote management and control.

Possible solutions to the weaknesses

1. For the weakness of accuracy, research has shown that calibration techniques can improve the accuracy of Arduino sensors, reducing measurement errors and improving the reliability of readings (Balsamo et al., 2018). Additionally, studies have used machine learning algorithms to correct measurement errors and improve accuracy (Raza et al., 2018). To address limited range and resolution, some researchers have proposed using multiple sensors in a system to increase sensitivity and precision (Li et al., 2019). Other studies have explored the use of higher-end sensors, such as MEMS sensors, which offer higher accuracy and sensitivity than Arduino sensors (Garcia et al., 2018).
2. To mitigate issues of noise, interference, and so on, researchers have proposed various approaches, including using shielded cables to reduce electromagnetic interference and adding additional circuitry to filter out noise (Gyorki et al., 2020). Furthermore, some studies have also explored the use of machine learning algorithms to enhance the accuracy and reliability of the measurements by filtering out noise and compensating for measurement errors (Naim et al., 2020).
3. To address the challenges of frequent calibration or maintenances, researchers have proposed various approaches to automate the calibration and maintenance of Arduino sensors. For instance, some studies have proposed using machine learning algorithms to automatically detect and correct sensor drift (Kumar et al., 2018). Other studies have proposed using self-calibrating sensors that can adjust their calibration settings automatically based on the readings (Izadi et al., 2018).
4. Finally, to address the limitation of advanced supportive features, researchers have proposed various solutions to enhance the functionality and compatibility of Arduino sensors. For example, some studies have suggested using wireless communication protocols such as Wi-Fi, Bluetooth, and Zigbee to enable wireless connectivity and real-time data transmission (Chen et al., 2016). Other studies have proposed using encryption techniques like Advanced Encryption Standard (AES) to secure the data transfer between sensors and other devices (Raza et al., 2013). Moreover, various IoT platforms and frameworks are available that support Arduino sensors and provide advanced functionalities such as remote monitoring, data visualization, and analytics. For instance, the Arduino IoT Cloud platform provides a comprehensive solution for connecting, managing, and analysing data from Arduino-based

devices (Arduino, n.d.). Similarly, other platforms such as Microsoft Azure IoT and Google Cloud IoT also support Arduino sensors and offer advanced features for data processing, storage, and analysis.

Weaknesses of IoT Cloud system

1. The use of multiple platforms and tools in the IoT cloud system can make it complex and difficult to manage. The system involves various components such as gateways, servers, and cloud platforms, which need to work together seamlessly. According to a study by Gartner, "the complexity of IoT solutions increases with the number of devices, data sources, and platforms involved, which leads to difficulties in integrating, managing, and scaling the solution" (Shah, 2017). The use of multiple platforms and tools can further complicate the system and make it difficult to manage. To solve this problem, simplifying the system architecture by reducing the number of platforms and tools used, where possible, can be an effective solution. For instance, "using a single cloud platform for data storage and processing can simplify the architecture and make it easier to manage" (Shah, 2017). By reducing the number of platforms and tools used, the system can become less complex, easier to manage, and more efficient.
2. The reliance on REST API for data transfer and updates can cause delays and potential security risks. IoT cloud systems often rely on REST API for data transfer and updates, which can cause potential delays and security risks. REST API operates on the HTTP protocol, which can lead to performance issues due to overheads and inefficiencies associated with HTTP. Moreover, REST API can be vulnerable to security breaches, such as man-in-the-middle attacks, as it transmits data in plain text format (Kumar et al., 2019). To mitigate these issues, it is recommended to implement secure and efficient data transfer protocols, such as HTTPS, to minimize security risks and improve data transfer speeds. HTTPS encrypts the data being transferred between the IoT device and the cloud server, which makes it more secure than HTTP. Additionally, HTTPS reduces the overhead associated with HTTP by minimizing the number of round trips required for communication (Botta et al., 2016).
3. The need for frequent optimization and data updates can put a strain on the MPC controller and Intel XEON 4th gen scalable processor. MPC controller and Intel XEON 4th gen scalable processor are critical components in the IoT cloud system. These components are responsible for processing data from sensors and executing control algorithms to ensure the smooth operation of the system. However, the frequent need for optimization and data updates can cause strain on these components, leading to decreased performance and potential system failures. One solution to this issue is to optimize the frequency of data updates to balance the need for real-time data with the strain on the system's resources. By reducing the frequency of data updates and focusing on the most critical data, the system can conserve resources and improve overall performance. Additionally, implementing efficient data transfer protocols and optimizing data storage can also help reduce the strain on the system. A study by Farooq et al. (2019) emphasized the importance of optimizing data transfer and processing in IoT cloud systems to minimize the strain on system resources. The study recommended reducing the frequency of data transfers and implementing efficient data storage and processing techniques to improve system performance. Another study by Miraz et al. (2020) highlighted the benefits of using edge computing to reduce the strain on cloud-based systems, allowing for more efficient data processing and optimization.
4. The lack of real-time monitoring and control may limit the system's responsiveness and ability to address issues promptly. Real-time monitoring and control are essential for ensuring the performance and reliability of IoT systems. Without these features, issues may go unnoticed for long periods, resulting in system downtime, decreased efficiency, and increased costs. In the case of the IoT cloud system, the lack of real-time monitoring and control may limit its responsiveness and ability to address issues promptly, potentially leading to costly disruptions. To address this issue, the implementation of real-time monitoring and control features is crucial. These features enable the system to detect and respond to issues promptly, minimizing downtime and increasing efficiency. Alerts and notifications are some of the critical features that can be implemented to provide real-time monitoring and control. For instance, the system can send alerts to system administrators or users when an issue arises or when a specific threshold is exceeded. These alerts can be sent through email, text messages, or mobile notifications, depending on the user's preference. Moreover, the implementation of real-time monitoring and control features can improve the system's overall performance and reliability. Real-time monitoring provides administrators with valuable insights into the system's behaviour, enabling them to make informed decisions and optimize the system's performance. Additionally, the ability to respond to issues promptly can minimize system downtime, leading to cost savings and increased efficiency.

Weaknesses of the Frontend system

1. Waze is known to consume a significant amount of battery, which can be a concern for IoT systems that rely on mobile devices. Due to the constant use of GPS and data, the app can quickly drain the battery of mobile devices, which can be a concern for IoT systems that rely on mobile devices for their operation. One solution to mitigate this issue is to optimize the app's settings to minimize its battery consumption. This can be done by turning off features such as the app's voice navigation and adjusting the app's power-saving settings. Another solution is to use external battery packs or power banks to extend the device's battery life. According to a study conducted by Mobile Enerlytics, a mobile app analytics company, Waze is among the top five battery-draining apps on Android devices (Perez, 2016). To address this issue, Waze has introduced a power-saving feature that can be activated in the app's settings, which reduces the app's battery consumption by disabling some of its features (Waze Support, n.d.).
2. The reliance of Waze on user-generated data can lead to inaccuracies and inconsistencies in the information provided, which can be a significant weakness for IoT systems that rely on accurate and reliable data. Users may report inaccurate information due to misunderstandings or malicious intent, leading to incorrect routing or other issues for IoT systems that rely on Waze. Additionally, areas with low usage may have insufficient data, which can result in incorrect or incomplete information being provided to IoT systems. One potential solution to mitigate this weakness is to implement data validation and verification techniques to ensure the accuracy and reliability of the data provided by Waze. This can involve comparing the data provided by Waze with other sources of information, such as traffic cameras or other traffic monitoring systems, to verify the accuracy of the information provided by users. Additionally, machine learning algorithms can be employed to identify and filter out inaccurate or unreliable data reported by users. Such algorithms can analyse various factors, including the frequency of user reporting, consistency of data reported, and the user's history of providing accurate data. This can help ensure that only reliable data is used by IoT systems. Furthermore, it may be beneficial to diversify the sources of data used by IoT systems to reduce their reliance on any single data source such as Waze. This can involve integrating data from multiple sources, such as Google Maps or other traffic monitoring systems, to provide a more comprehensive and accurate picture of traffic and routing information.
3. Another weaknesses of Waze and Google Maps is that their interfaces and features are not very customizable, which may limit their usefulness for IoT systems that require a high degree of customization. For example, some IoT systems may require specific map layers or custom UI elements that are not available in these platforms. The possible solution to mitigate this issue is to use a custom frontend that is designed specifically for the IoT system's needs. This can be achieved by building a custom map interface using a mapping API like Google Maps API or Mapbox API, which allows for more customization options. Alternatively, there are also third-party frontend solutions available that provide more customization options, such as Leaflet or OpenLayers.
4. Google Maps collects a significant amount of user data, including location, search history, and other information that can be used to track user behaviour. This can be a concern for IoT systems that require a high level of data privacy. With the rise of data breaches and privacy concerns, it is essential to take measures to mitigate this issue. One solution to this problem is to use Google Maps in combination with other tools that provide enhanced privacy features. For example, the use of VPNs (Virtual Private Networks) or Tor (The Onion Router) can help to mask the user's location and prevent the collection of personal data by Google Maps. Additionally, users can take advantage of Google Maps' privacy settings to limit the collection and use of their personal data. Another approach is to use alternative mapping and navigation services that prioritize data privacy. One such service is OpenStreetMap, which is a free and open-source mapping platform that allows users to contribute and edit map data without collecting personal information. Other alternatives include Mapbox and HERE Maps, which offer privacy-focused mapping and navigation services.
5. Google Maps requires an internet connection to function properly, which may be a limitation for IoT systems that operate in areas with poor connectivity. This can be a limitation for IoT systems that operate in areas with poor connectivity, such as remote or rural areas. In such cases, the IoT system may not be able to rely on Google Maps as a reliable source of location data, which can affect the overall performance of the system. To mitigate this issue, one possible solution is to use offline maps or caching techniques. Google Maps allows users to download maps for offline use, which can be beneficial for IoT systems that operate in areas with poor connectivity. This would enable the system to continue to function even if there is no internet connection available. Another solution is to use a hybrid approach that combines online and offline data sources. For example, the system could use Google Maps for location data when an internet connection is available, and switch to offline data

sources when the internet connection is lost. In addition to these solutions, it is also important to consider alternative frontend solutions that do not rely on an internet connection. For example, GPS devices or other location-based technologies may be used as an alternative to Google Maps in situations where internet connectivity is limited or unavailable.

Alternative designs

Initially, we envisioned a smart trash can model that would incorporate a wide range of sensors and features, such as ultrasonic sensors, PIR sensors, AI-powered robotic arms, and an automatic compactor. Our goal was to cater not only to households but also to various institutions and businesses that generate different types of waste. We aimed to optimize the sorting and disposal process efficiently, minimizing waste as much as possible. However, we encountered several challenges in the process.

Firstly, one of the major difficulties we faced was the excessive number of sensors installed in the smart trash bin model we had envisioned, such as ultrasonic sensors, PIR sensors, an AI-powered robotic arm, and an automatic compressor. Originally, we planned to equip the 80cm high trash bin with about 20 different types of sensors, but we realized that the cost would be much higher than expected, making it impractical to distribute to households individually, as it could lead to a significant increase in price. Additionally, the circuit design problem arose due to the excessive variety of sensors, making it challenging to determine how they would collaborate and function together. Considering these factors, we concluded that it would be difficult to sell the product as is, and we needed to make significant changes to the design specifications. As we progressed with the project, we realized that some of the sensors that were initially planned to be installed needed to be excluded due to insufficient functionality or precision. This further supported the need for a change in the plan.

First, we excluded some sensors from the original plan that were judged to be impractical due to their lack of precision and functionality. Additionally, we split the design of the single trash can into two designs: a household trash can, which is exclusively intended for use by people living in each general household and is specialized in accurately sorting and accumulating the waste they discard, and a sorting bin that aggregates the large functions such as AI-equipped robotic arms for compressing, from many household smart trash cans for easy collection by waste collection trucks, which was completely ignoring facilities and businesses. This allowed us to successfully cut costs and simplify the system. All the large functions such as AI-equipped robotic arms for compressing are aggregated into the sorting bin, and the sorting bin re-sorts and compresses the waste sent from many households' smart trash cans to achieve more efficient waste management.

Manage resources and potential risks

The implementation of the smart recycling bins and GPS system comes with various resources and challenges that need to be managed effectively to ensure that the system operates efficiently. The system comprises of the beautify bins, the main BeautifyAI bin, GPS system, and a web application that provides real-time monitoring of the waste management process. The following report will provide an overview of the resources and challenges that the system presents and how they can be effectively managed.

Resources

1. Wireless Capability: The smart recycling bins and GPS system rely heavily on wireless communication to transmit data between the devices and the web application. It is essential to ensure that the wireless capability is reliable and robust to ensure uninterrupted communication.
2. Functionality: The system must be designed to perform its intended functions effectively. It must be user-friendly and have all the necessary features that make waste management efficient and convenient.
3. Interoperability: The system must be designed to work seamlessly with other systems and devices that are essential for waste management. This includes the garbage trucks, recycling centres, and waste disposal facilities.
4. Secure Storage: The data collected by the system must be stored securely to prevent unauthorized access or data breaches. It is essential to use the latest encryption techniques and security protocols to ensure that the data is protected.
5. Immediate Boot Capacity: The system must have an immediate boot capacity to ensure that it can start up quickly in the event of a power outage or system failure.

6. Device Categorization (Troubleshooting): The system must have a device categorization feature that enables quick identification of faults and malfunctions. This will ensure that the system can be easily maintained and repaired.
7. Bandwidth: The system requires sufficient bandwidth to transmit data between the devices and the web application. It is essential to ensure that the bandwidth is adequate to prevent delays and interruptions.
8. Cryptographic Controls: The system must have cryptographic controls that protect the data and communication channels from unauthorized access and data breaches. It is essential to use the latest encryption techniques and security protocols to ensure that the data is protected.
9. Power Management: The system must have an efficient power management system that ensures that the devices have sufficient power to operate effectively. This will ensure that the system is always operational.
10. Expandability: The system must be designed to be expandable to accommodate future growth and new features. This will ensure that the system remains relevant and useful over the long term.
11. Strategic Planning: Establish a long-term plan that outlines the resource needs, allocation, and distribution of the system. This plan should consider the number of bins needed, the number of trucks required for collection, and the amount of manpower necessary for maintenance and repair.
12. Automation: Utilize automation technologies such as AI, ML, and computer vision to increase the efficiency and effectiveness of the sorting process. This will help reduce the amount of human intervention required and improve the accuracy of the sorting process.
13. Data Management: Implement a robust data management system that tracks the usage and performance of the smart recycling bins and GPS waste management system. This data can be used to identify areas for improvement and refine the system.

Challenges

Limited Wireless Coverage

The system relies heavily on wireless communication, and limited wireless coverage can affect the effectiveness of the system. It is essential to ensure that there is sufficient wireless coverage in all areas where the system is implemented.

One of the challenges with the limited wireless coverage is that it can cause issues with data transfer and communication between different parts of the system. This can lead to delays or interruptions in the transfer of data, which can impact the efficiency and effectiveness of the waste management process. It can also make it difficult to monitor and track the status of the different components of the system in real time.

Another challenge is that the limited wireless coverage can impact the ability to remotely access and manage the system, particularly in remote or hard-to-reach areas. This can make it difficult to troubleshoot and resolve issues, as well as to perform maintenance or upgrades on the system.

Additionally, limited wireless coverage can also impact the ability to provide real-time data and analytics on the waste management process. This can make it more difficult to identify trends and patterns in waste generation and management, and to make data-driven decisions on how to improve the system.

Overall, the limited wireless coverage challenges of the system can impact its overall effectiveness and efficiency, as well as the ability to monitor and manage it in real time. Addressing these challenges will be important for ensuring that the waste management system is able to operate at its full potential.

Integration with Legacy Systems

The system must be designed to integrate with existing legacy systems that may not be compatible with the new system. This requires careful planning and execution to ensure that the integration is seamless and efficient.

The integration with legacy systems can pose several challenges for the system. One of the major challenges is the incompatibility of the new system with the existing infrastructure, which can cause issues with data transfer and interoperability. Additionally, legacy systems may not have the necessary APIs or interfaces to easily integrate with the new system, which may require additional development and customization.

Another challenge is the need for data migration, which involves moving data from the legacy system to the new system. This can be a time-consuming and complex process that requires careful planning and execution to ensure that data is accurately and securely transferred.

Furthermore, legacy systems may have different security protocols or standards than the new system, which can create vulnerabilities in the system and increase the risk of cyber-attacks. It may be necessary to update or modify the legacy systems to meet the security requirements of the new system.

Lastly, training and support for the legacy system users and IT staff may be required to ensure a smooth transition to the new system. This may involve additional resources and expenses to provide the necessary training and support.

Cybersecurity Threats

The system presents potential cybersecurity threats, and it is essential to implement robust cybersecurity measures to protect the data and communication channels from unauthorized access.

As with any system that relies on technology and the internet, there are potential cybersecurity threats that must be addressed to ensure the security of the smart recycling bin and waste management system. Some of the cybersecurity threats that could pose a challenge to this system include:

1. Malware and viruses: Malicious software can be introduced into the system through various means, including phishing attacks, infected email attachments, or infected software.
2. Data breaches: This is the unauthorized access, theft, or exposure of sensitive information, which could include personal information of users or confidential information about the waste management system.
3. Hacking: This is the unauthorized access to a computer system or network, which can result in data theft or other malicious activities.
4. Denial of Service (DoS) attacks: This is an attack that aims to disrupt the normal functioning of a system by overwhelming it with traffic or requests, rendering it unable to respond to legitimate requests.
5. Social engineering: This is the use of deception to manipulate individuals into divulging confidential information or performing actions that can be used for malicious purposes.

Addressing these challenges requires implementing strong security measures, including firewalls, intrusion detection and prevention systems, and regular security assessments and audits. It also requires training employees and users to be vigilant against cybersecurity threats and to follow best practices for secure computing. Additionally, regular software updates and patches should be implemented to address any known security vulnerabilities.

Technical Support

The system requires technical support to ensure that it operates efficiently. It is essential to have a team of qualified technicians who can provide technical support and maintenance services.

Technical support challenges of the system can include the need for ongoing maintenance and updates to the hardware and software components. The smart recycling bins and associated technologies will require regular updates and repairs, which can be costly and time-consuming. In addition, the technical support team will need to have a deep understanding of the system and be able to troubleshoot any issues that arise in a timely and effective manner. This can be challenging if the system is complex and involves multiple components that must work together seamlessly.

Another challenge can be the need to provide technical support to users who may not be technically savvy or familiar with the system. The technical support team must be able to provide clear and concise instructions to users, and be patient and helpful when guiding them through troubleshooting steps. This can be particularly challenging if users are located in remote or hard-to-reach areas, where on-site technical support may not be readily available.

Cost

The implementation of the system requires significant investment, and it is essential to manage the cost effectively to ensure that the system is cost-effective.

There are several cost challenges associated with implementing a smart recycling bin and waste management system, including:

1. Initial Investment: The initial cost of implementing the system can be significant, including the cost of purchasing and installing the smart recycling bins, GPS systems, and other necessary hardware and software.
2. Ongoing Maintenance: The ongoing maintenance and upkeep of the system can also be a significant cost, including the cost of repairing or replacing any damaged or malfunctioning components, as well as updating and upgrading software and hardware as needed.
3. Training and Support: Providing adequate training and support to system users can also be a significant cost, including the cost of hiring and training support staff, as well as providing ongoing technical support to users.
4. Data Management: Effective data management is critical to the success of the system, but it can also be a significant cost, including the cost of data storage and processing, as well as the cost of implementing cybersecurity measures to protect sensitive data.
5. Integration with Legacy Systems: Integrating the smart recycling bin and waste management system with existing legacy systems can also be a significant cost, including the cost of modifying existing systems to accommodate the new technology and the cost of hiring experts to oversee the integration process.

User Resistance

The system may face resistance from users who are not familiar with the technology. It is essential to provide adequate training and support to ensure that users are comfortable using the system.

One potential challenge for the implementation of the smart recycling bins and waste management system is user resistance. This may be due to a lack of familiarity or comfort with the technology, concerns about privacy and data security, or simply a reluctance to change existing habits and routines.

To address this challenge, it is important to involve users and stakeholders in the design and implementation process, as well as to provide clear and accessible information about the benefits and operation of the system. This could include providing training and support to users, as well as ongoing communication and engagement to promote awareness and participation in the system. It is also important to ensure that the system is user-friendly, intuitive, and easy to use, in order to encourage adoption and minimize resistance.

System Downtime

System downtime can affect the effectiveness of the system and cause delays in waste management. It is essential to ensure that the system has adequate redundancy and backup systems to minimize downtime.

System downtime refers to the period of time during which the system is unavailable or inaccessible to users. This can be caused by a variety of factors such as power outages, system failures, and network disruptions. The challenges associated with system downtime include:

1. Reduced productivity: System downtime can lead to a significant decrease in productivity, as employees are unable to perform their tasks or access important data.
2. Lost revenue: Downtime can result in lost revenue, particularly for businesses that rely on their systems to conduct transactions or process orders.
3. Damage to reputation: Prolonged downtime can damage a company's reputation, particularly if it results in missed deadlines, dissatisfied customers, or other negative consequences.
4. Cost of recovery: In addition to lost revenue and productivity, downtime can also result in additional costs associated with recovering lost data or repairing damaged systems.

5. Employee frustration: Frequent system downtime can lead to employee frustration and dissatisfaction, which can impact morale and retention.

To address these challenges, it is important to have a robust system monitoring and maintenance plan in place to detect and prevent potential issues. This can include regular system backups, proactive maintenance, and disaster recovery plans. Additionally, having a support team available to quickly address and resolve any issues can minimize the impact of downtime on the system and the organization.

Data Management

There are several data management challenges that may arise in the smart recycling bin and GPS system. These challenges can include:

1. Data Security: With the large amount of data being collected and transmitted through the system, there is a risk of data breaches and unauthorized access. It is important to implement strong security protocols and encryption measures to ensure the protection of sensitive data.
2. Data Quality: The accuracy and quality of the data collected is critical to the success of the system. Issues such as data duplication, data inconsistency and errors in data entry can affect the integrity of the data and its usefulness.
3. Data Volume: The large volume of data generated by the system can create challenges in terms of storage and processing. Adequate storage solutions and processing capabilities will be needed to ensure the system can manage the data effectively.
4. Data Access: As the system involves multiple stakeholders, there may be challenges in providing appropriate access to data to different users. It will be important to implement access controls to ensure that data is only accessible by authorized users.
5. Data Interoperability: The system involves different technologies and devices, and there may be challenges in integrating the data collected by different sources. A standardized data format and communication protocol will be needed to ensure interoperability.
6. Data Privacy: The system involves the collection of personal data, such as the location of the smart recycling bins and GPS tracking of waste collection vehicles. It is important to comply with relevant data protection regulations to protect the privacy of individuals.

Managing the resources

To manage the resources and challenges of the smart recycling bins and GPS system, the following strategies can be employed:

1. Prioritize resource allocation: It is important to prioritize the allocation of resources towards critical areas such as wireless capability, functionality, interoperability, and secure storage. These resources are fundamental to the success of the system and should be given priority in terms of allocation.
2. Conduct regular system maintenance: To ensure the smooth running of the system, regular maintenance should be carried out. This includes routine checks on immediate boot capacity, device categorization (troubleshooting), power management, and expandability. This will help to identify potential problems and resolve them before they cause major disruptions.
3. Manage bandwidth effectively: Effective bandwidth management is important in ensuring that the system operates smoothly. This involves ensuring that there is enough bandwidth to handle the data traffic generated by the system. It also involves optimizing the use of available bandwidth to minimize congestion and ensure the system runs smoothly.
4. Implement cryptographic controls: To ensure the security of the system, cryptographic controls should be implemented. This involves encrypting data transmissions and storage, and ensuring that only authorized personnel can access the system.
5. Plan for scalability: As the system grows, it is important to plan for scalability. This involves ensuring that the system can handle an increase in data traffic and that the necessary resources are available to support growth.
6. Mitigate potential challenges: Potential challenges such as power outages and cyber-attacks can be mitigated by implementing backup power sources and cyber-security measures such as firewalls and intrusion detection systems.

In conclusion, effective management of resources and potential challenges is critical in ensuring the success of the smart recycling bins and GPS system. Prioritizing resource allocation, conducting regular maintenance, managing bandwidth effectively, implementing cryptographic controls, planning for scalability, and mitigating potential challenges can help to ensure the smooth running of the system and maximize its benefits.

Execution of the system

Tinkercad on the sensor's connectivity

The system contains two separate systems that are important to the function of the smart garbage disposal. The first system contains an input in the form of the PIR sensor and an output of two servo motors. This system controls the opening and closing of the lid when a person walks close to the smart garbage disposal. It works by having the PIR sensor detect movement. If the sensor detects movement, the system causes the servo motor to rotate 90 degrees opening the lid. After 1 second without movement the system automatically closes the lid. The 1 second delay is important as it prevents the lid from accidentally closing if the person using the garbage disposal was to stay still for too long. The second system is the smart garbage disposal fullness detection system. This system uses an IR break beam system to detect when the trash reaches a certain height. A break beam system works by constantly shining an IR beam into an IR detector. The system can den be used to detect the presence of an object if the IR detector can no longer detect the beam if something gets in the way of the beam. By placing the break beam system at a certain height, we can detect when the trash reaches that height and as such, inform the system that the garbage disposal is full. To prevent the beam from activating whenever trash enters the smart garbage disposal, the system only sends the alert to the system if the beam is broken for 2 seconds. After the system is alerted the garbage disposal then locks up for 10 minutes, preventing the lid from being opened automatically and preventing another message from being sent. This this ensures that the garbage disposal does not spam the system with messages about being full while also preventing the garbage disposal from accidentally being opened while full. Unfortunately, the circuit design software we used does not contain a break beam system. Instead, our diagram uses an IR sensor an IR remote as a stand in with the IR remote standing in for the IR emitter and the IR sensor standing in for the IR detector.

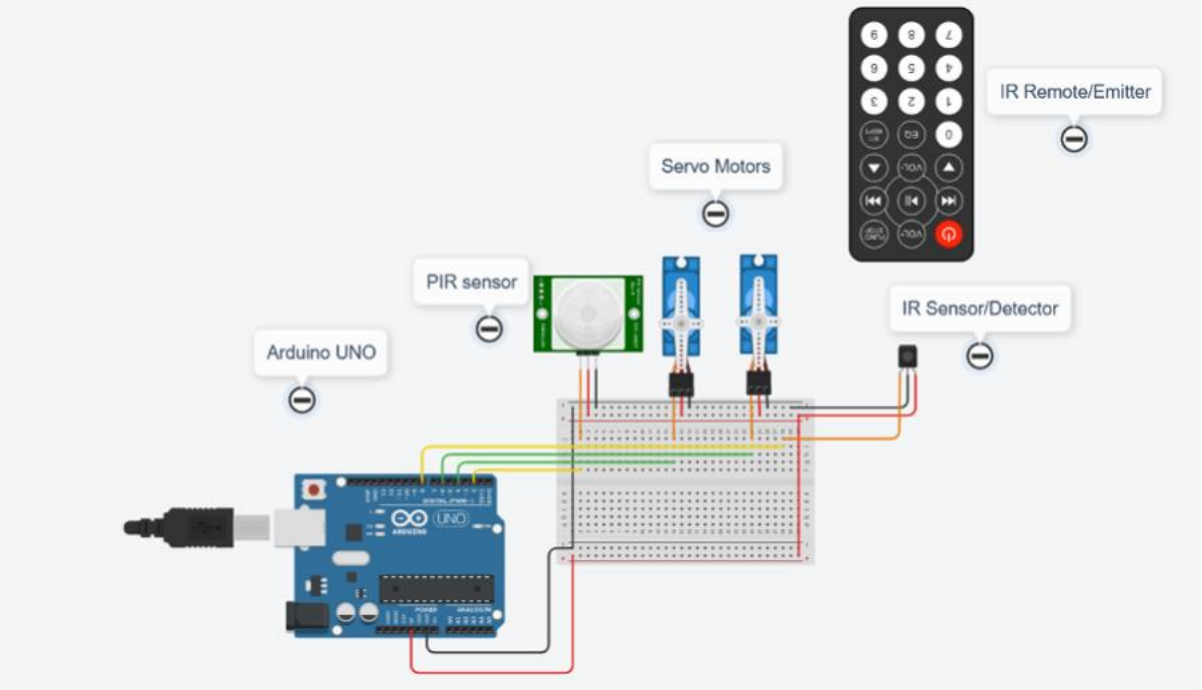

Figure 2: Tinkercad Diagram of some sensors used in the bin and their connectivity

Code

The code to run the system can be split into two parts. The first part handles the PIR sensor and the servo motors. The second part handles the IR sensor. The code starts by initialising all the of the pins and necessary variables. After the setup, the loop function is started. The loop is required to ensure that the code continuously

functions. The loop starts by ensuring that the servo motors are set to degree 0. This is to set the default state of the garbage disposal lid to close. Next, an if statement is used to check if the input from pin 2 is equal to or greater than 1. Pin 2 represents the PIR sensor. If the if statement is true, the servo motors are then set to degree 90. This represents the garbage disposal lid being open. After 1 second the servo motors are set back to degree 0 and the if statement is checked again. The 1 second delay is to prevent the lid from closing immediately if it detects no movement as when people are disposing their trash, they may stop moving. This system represents the PIR sensor and the servo motor system to control the garbage disposal lid.

The second system represents the IR sensor. It starts by checking if pin 8 is delivering an input of 0. Pin 8 represents the IR sensor. As the IR sensor is being used in a break beam system, an input of 0 indicates that the IR beam has been broken. If the if statement is true, the system waits 2 seconds before testing the If statement again. This is to ensure that the system does not accidentally activate if a piece of garbage crosses the IR beam while it is being thrown into the trash. After 2 seconds, if the if statement is still true, the system sends a message informing that the “Smart garbage disposal bin is full,” and a 10 minute delay is started. The 10-minute delay performs two separate tasks. The first is to prevent the system from sending the message rapidly. As the true system will be sending a message to the garbage disposal workers, a rapid stream of the exact same message would only serve as an annoyance and could distract the workers. The second task is that it prevents the garbage disposal from being opened automatically when the garbage disposal is full. This would prevent incidents where the garbage disposal accidentally releases some trash when someone walk too close the trash disposal.

```
// C++ code
//
#include <Servo.h>

Servo servo_4;

Servo servo_6;

void setup()
{
  servo_4.attach(4, 500, 2500);
  servo_6.attach(6, 500, 2500);
  pinMode(2, INPUT);
  pinMode(8, INPUT);
  Serial.begin(9600);
}

void loop()
{
  servo_4.write(0);
  servo_6.write(0);
  if (digitalRead(2) >= 1) {
    servo_4.write(90);
    servo_6.write(90);
    delay(1000); // Wait for 1000 millisecond(s)
  }
  if (digitalRead(8) == 0) {
    delay(2000); // Wait for 2000 millisecond(s)
    if (digitalRead(8) == 0) {
      Serial.println("Smart garbage disposal bin is full");
      delay(600000); // Wait for 600000 millisecond(s)
    }
  }
}
```

Figure 3: Code for the Tinkercad diagram

Beautify Bin

The Beautify bin's design is key to its function as a trash storage unit. When a user approaches the bin, it will automatically open using three tools: a 360-degree Passive Infrared Sensor with AI functionality to detect human motion, a DC motor, and a dual servo motor. The infrared sensor senses someone approaching the bin, and the DC motor rotates the dual servo motor, allowing the bin to open. When the trash is full, the infrared sensor checks the bin's status and sends a signal to the GPS system to mark the bin as full and in need of collection. The top of the bin has a polycrystalline solar panel that harnesses solar energy and stores it in a power bank to power the bin.

The bin also comes with retractable wheels for mobility and a Wi-Fi modem to increase the range of the Wi-Fi connectivity to the resident's household. After the signal is sent to the GPS system and the trash collectors comes and collect the trash, they are able to unmark it using a RFID tag to tap or bring close enough to be bin to remove it or unmark it from the GPS system, so this means the trash has been collected.

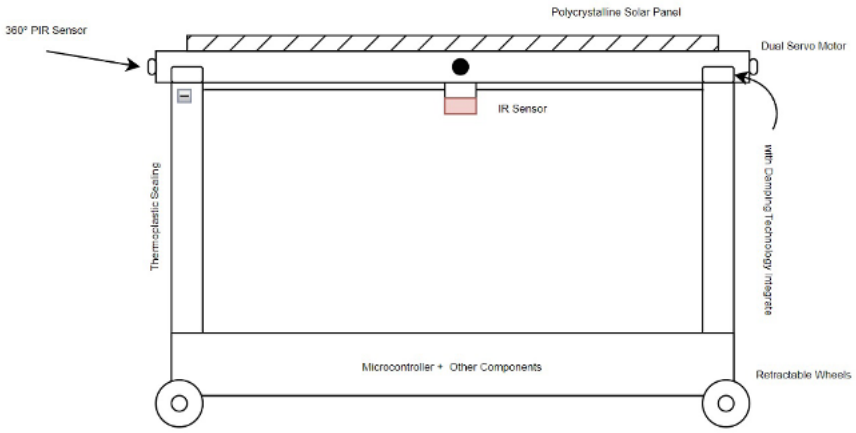

Figure 4: Beautify Bin's Design

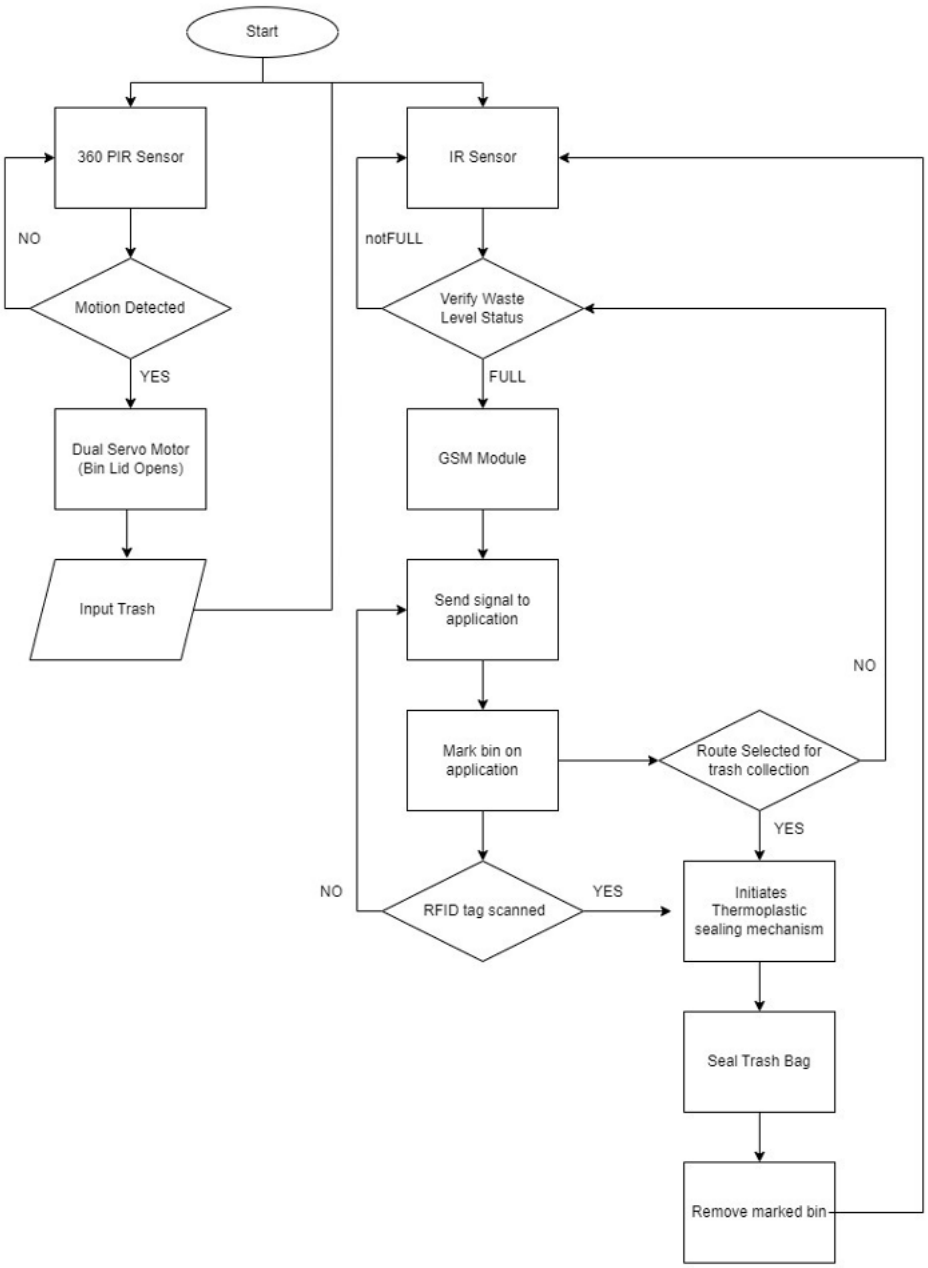

Figure 5: Software Flowchart for the Beautify Bin (Household trash storage bins)

BeautifyAI

The BeautifyAI Bin Is a sorting machine that sorts out the trash collected from all the Beautify bins using AI and ML technologies. The trash is thrown into the opening down the slanted slope and through the opening at the bottom to allow a few trash to be sorted at a time. The sorting takes place on the conveyor belt, and the pistons push the trash into their own bins based on their materials. The AI cameras identify and cooperate with the conveyor belt to sort out each trash. Whatever material the camera can't detect is placed into the unidentified materials section. The raspberry pi is the brain of the bin, and the power supply comes from electricity to power up the microcontroller, motor, and sensors. The infrared sensor detects the fill level of the bin and sends a message to the server to be updated to the web application to notify for collection. The organic waste bin has a gas sensor to detect harmful or strong gases, and the bio-enzymatic odour spray reduces or removes the smell.

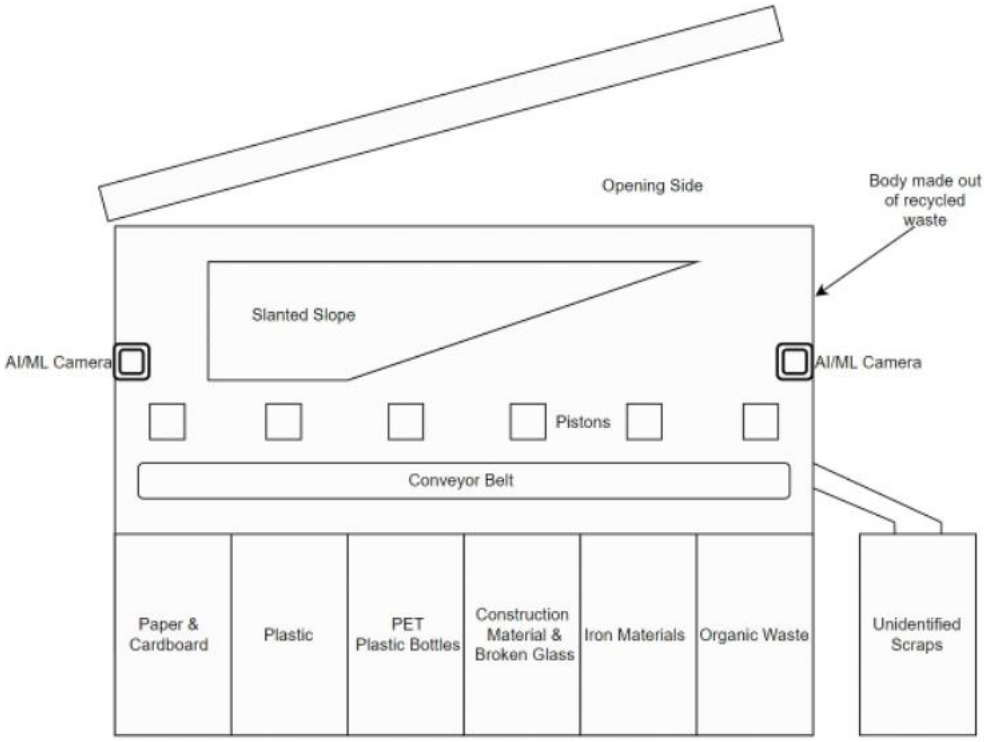

Figure 6: BeautifyAI Bin's Design

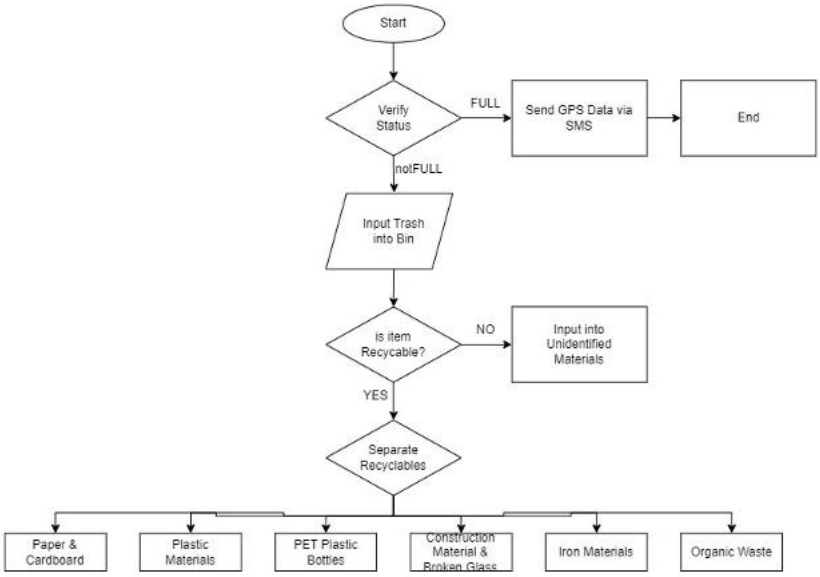

Figure 7: Software Flowchart for BeautifyAI Bin (Sorting bins)

GPS System

GPS system: Global Positioning System (GPS) technology, a high-precision radio navigation positioning system based on artificial Earth satellites, which provides accurate geographical location, vehicle speed and precise time information anywhere in the world and in near-Earth space. It allows the trash collectors to collect trash with an optimised route with the help of AI and ML from learning from past data and also current traffic data from the satellite.

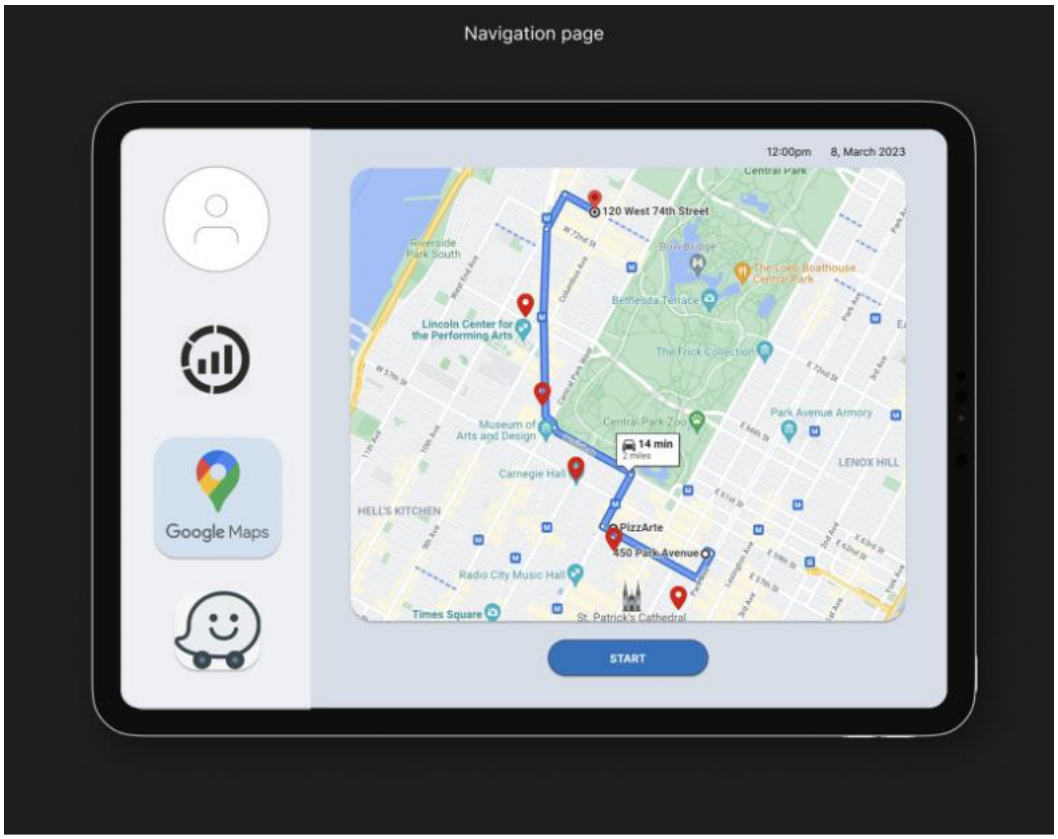

Figure 8: GPS UI Navigation Page

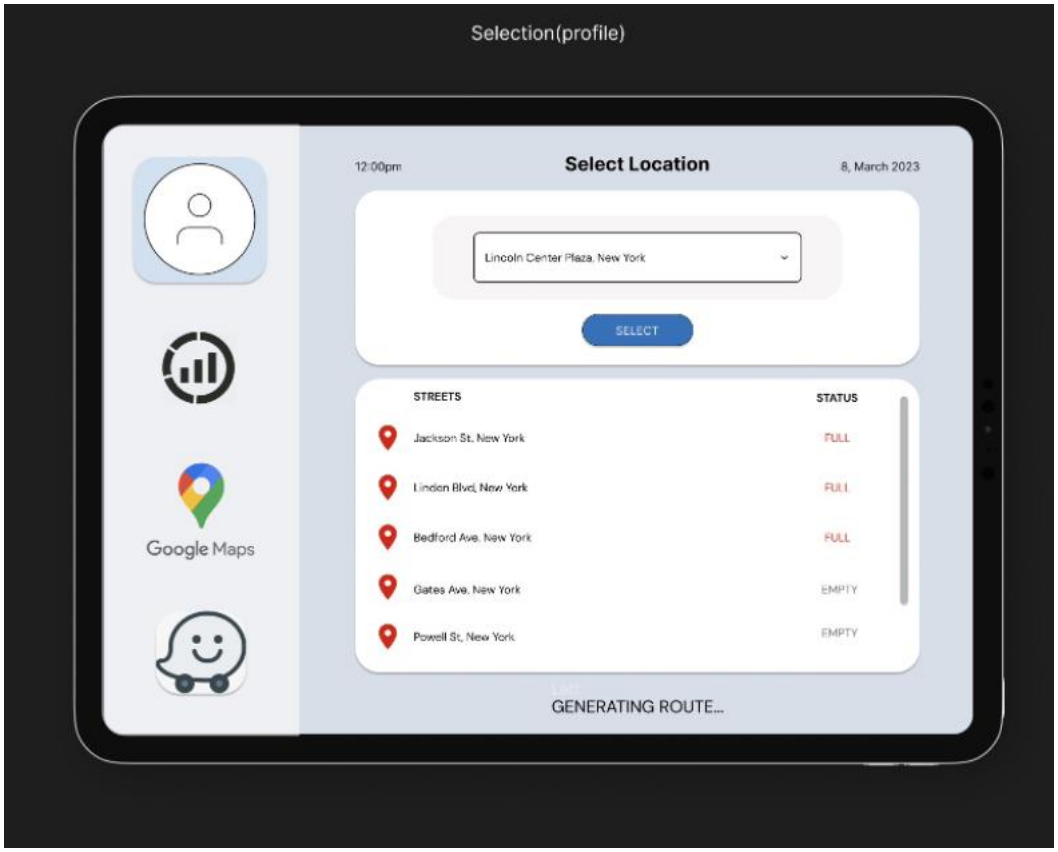

Figure 9: GPS UI Selection Page

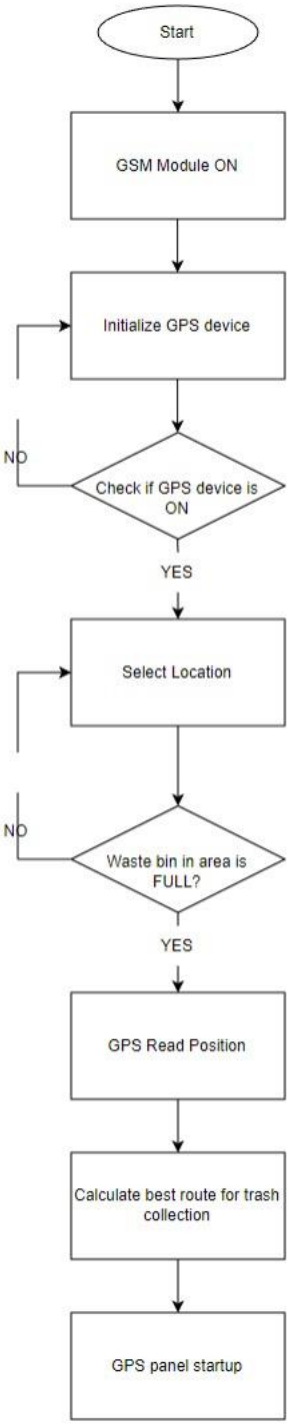

Figure 10: GPS Flowchart

Web Application

Web Application: Application software that that let users execute tasks online is known as a web application (or web app). Anyone having a live network connection can access web apps on the Internet. Web application has a client side and a server side. In our case, for those using BeautifyAI to allow them to keep track of the progress, process and maintenance of the machine.

Figure 11: BeautifyAI web application start-up page

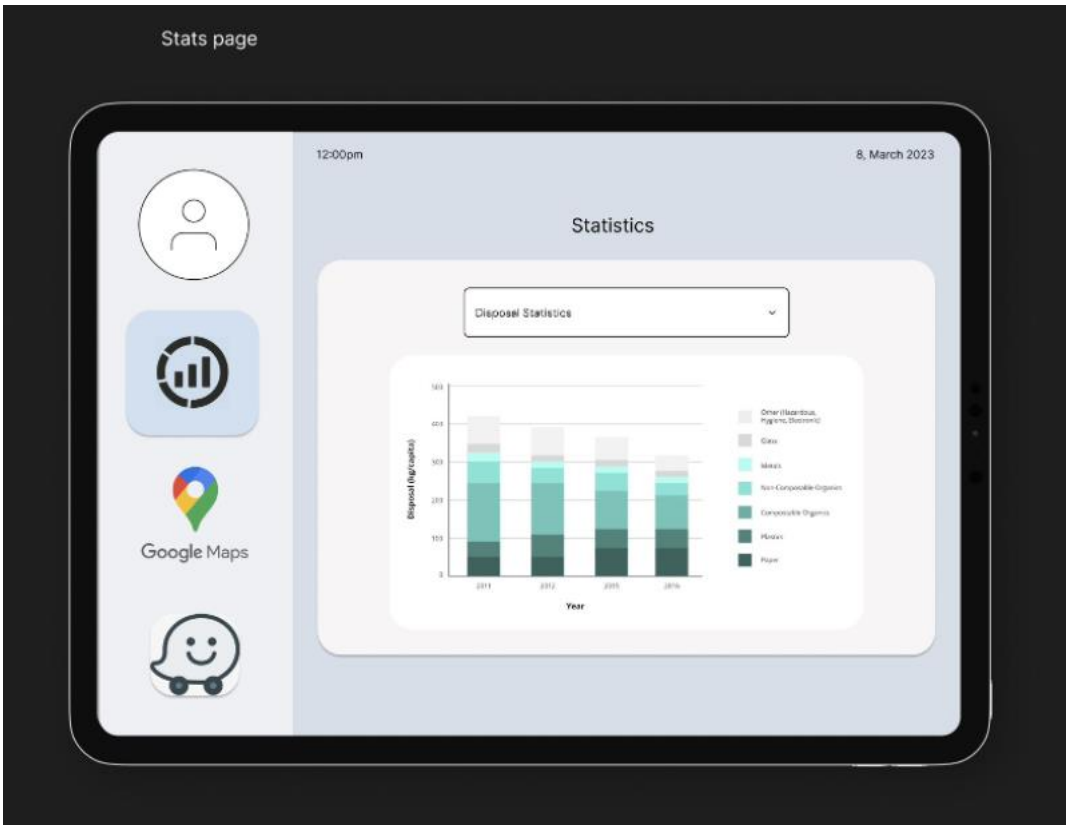

Figure 12: BeautifyAI web application front page

Hardware Explanation

Passive Infrared Sensor: PIR sensor is an electrical sensor that detects infrared (IR) light coming off nearby objects. We used it to have a 360^0 human detection when the human approaches the bin. When it detects the motion, it sends the message to system and causes the dual servo motor to rotate. This enables the bin to be opened so that the user can throw the trash. After the sensor detects that the user is away from the bin, the lid automatically closes with the help of the dual servo motor.

DC motor: A direct current (DC) motor is a type of electric motor that transforms electrical energy into mechanical energy. It then uses mechanical energy to generate kinetic energy that can be used to drive electrical equipment for other devices. The DC motor is relatively simple to control, it only needs to control the voltage level to control the speed. The DC motor is used to rotate the dual servo motor for opening and closure of the bin.

Dual Servo Motor: A rotating electromagnetic machine that operates on the principle of electromagnetic induction to convert mechanical and electrical energy. The generator absorbs mechanical power from the mechanical system and delivers electrical power to the electrical system. The motor absorbs electrical power from the electrical system and delivers mechanical power to the mechanical system. The dual servo motor comprises two types of servo motor, the AC servo motor, and the DC servo motor. With a constant load, the speed of a DC motor is exactly proportional to the supply voltage. Additionally, the frequency of the supplied voltage and the quantity of magnetic poles affect an AC motor's speed. The function of a servo motor is precise position control. Here, we will combine PIR sensor, Al recognition and dual servo motor to automate the opening and closing of the dustbin lid. The PIR sensor and AI recognition are only used to detect the movement of humans and not for the movement of other creatures. When a human approaches the bin, the system receives the PIR signal, analyses it, and outputs it to the dual servo motor so that it can open the bin lid. And vice versa when the human leaves a certain range. By means of electromagnetic induction, the lid is opened at a certain angle when the user or collector needs to use the bin and closed when it is not needed, thus eliminating the need for people to touch the lid with their bare hands and making it more hygienic and convenient.

Infrared sensor: It is an electronic device used to measure and detect infrared radiation in the surrounding environment. The sensor has two parts, a LED (light emitting diode) and a receiver. It acts as a proximity sensor for the contents inside the bin and works by emitting infrared light from the LED which reflects off the object and is detected by the receiver. The Infrared Sensor will know if the trash bin is full and will send a signal to the GPS system for the garbage to be sorted accordingly.

GSM Module: The SIM900A GSM Module was chosen as the GSM module because it is the smallest and cheapest available. GSM modules enable the connection of a computer or mobile phone to a GSM system. This has helped with the construction of the application. The message exchange between our system and bin is done by GSM module. Users can interact with our system and establish more effective two-way communication.

Solar Panel: Solar cells, also known as "solar chips" or "photovoltaic cells", are thin sheets of photovoltaic semiconductors that use sunlight to generate electricity directly. It is placed above the lid of the bin, where the solar panel has maximum exposure to sunlight and can store more light energy. The stored light energy is eventually converted into electricity, making the smart bin more energy efficient as solar energy is a free and renewable source of clean energy.

Power Bank:
Since our trash bins need constant power supply to operate 24/7, it needs a strong source of power. The solar panel on top of the bin collects energy from the sun and stores it in the power bank. During night time, when the need for throwing the trash arises, the trash bin can use power from the power bank and operate without any issues.

Backup Power Supply: An electrical device known as a power supply provides electricity to an electrical load. A power supply's primary function is to transform electrical current from a source into the proper voltage, current, and frequency needed to drive a load. It provides DC voltage to the components on board, enabling the components to activate and perform their functions. We use the rechargeable batteries as the backup power supply which have a 3 month lifespan per full charge, the bin would come in with a full charge of rechargeable batteries.

Thermoplastic Sealing: Thermoplastic sealing tape is a tape that is heated by special equipment (hot air seam sealing machine or high frequency heat sealing machine) to achieve a sealing effect (water and air leakage prevention). If we don't treat the opening when the bag is filled, it is most likely to leak, or the waste will be left behind and the unpleasant smell cannot be eliminated. When we use thermoplastic sealing technology, we can effectively improve the overall insulation properties of the bag and improve the hygiene and tidiness of the bin.

RFID tag: We will place RFID tags inside the bins so once the collection is done, the collector would just need to tap their RFID tag on the bin to remove the marked bin off in the GPS system. In addition, RFID is a technology that enables the rapid exchange and storage of information without contact, through wireless communication combined with data access technology, and then connected to a database system for contactless two-way communication, thus achieving the purpose of identification, for data exchange, in tandem with an extremely complex system.

Retractable Wheels: The wheels are used so that the bin can be moved while necessary trash sorting is done and also for easier mobility when it needs to be replaced/put in a new place. It makes the bin ideal for carrying large loads of trash when needed.

Wi-Fi Modem: Through its GPIOs, this module may be coupled with sensors and other application-specific devices with a minimum amount of pre-development work and runtime loading thanks to its robust internal processing and storage capabilities. And it can be used for network connectivity to transfer the information collected by the system one by one to management systems, cloud systems, databases, etc. for remote data transfer. It helps out bin to increase the range of the Wi-Fi connectivity to the residents household to connect to their Wi-Fi.

Gas Sensor: A gas sensor is useful in situations where it is necessary to monitor changes in the concentration of poisonous gases to keep the system secure and warn against any unforeseen hazards. To detect gases like oxygen, carbon dioxide, nitrogen, methane, and others, there are numerous gas sensors available. They may also be used to monitor the environment's air quality and find dangerous gas leaks. We use gas sensor in our organic waste bin.

Bio-enzymatic Odour Spray: Our organic waste bin will use the Bio-enzymatic Odour Spray to combat the issue of bad odour from organic waste. It utilizes the gas sensor, which detects any harmful/strong gases and depending on the situation, the odour spray goes off so that the harmful/strong odour gases can be eliminated.

Software Explanation

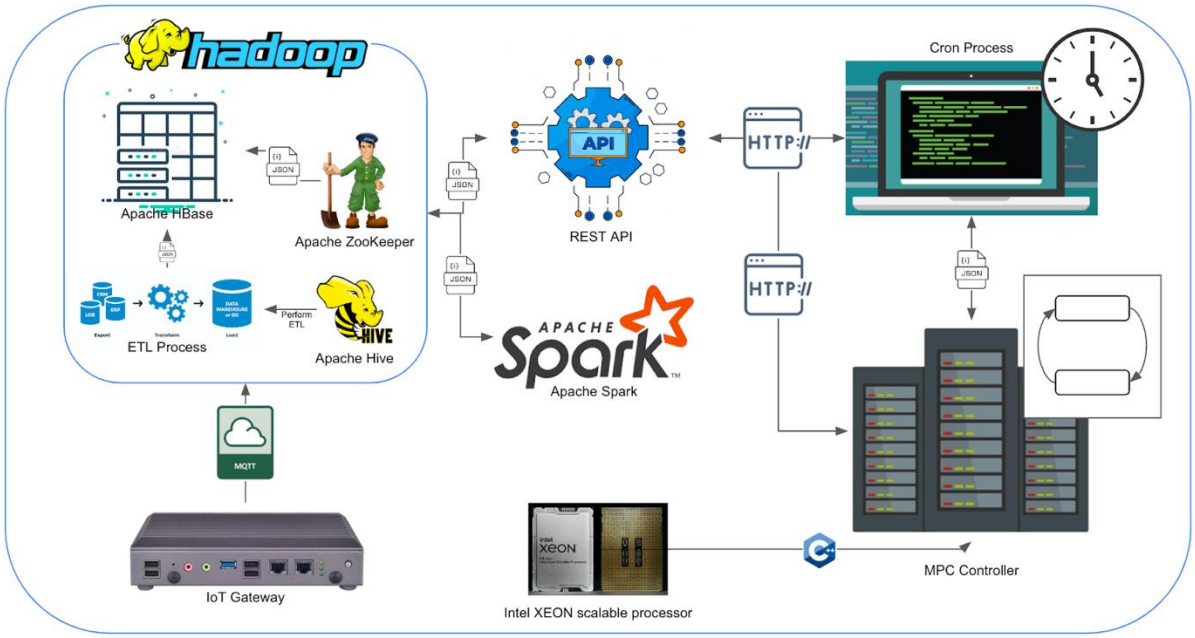

Figure 13: Overall system architecture of the backend system in IoT, which is mainly based on cloud systems

In IoT system architecture, the cloud plays a crucial role as a central hub for storing, processing, and analysing large amounts of data generated by IoT devices. IoT devices often have limited computing resources and storage capacity, so the cloud provides the necessary infrastructure to handle big data processing and storage. Additionally, the cloud allows for remote management and real-time monitoring of IoT devices, as well as providing APIs for integration with other systems and platforms. Overall, the cloud provides the scalability, security, and accessibility required to support the growing demands of IoT systems.

Below are the terminologies adopted in our cloud architecture:

- LEC-7230: LEC-7230 IoT Gateway is a device that serves as a bridge between local networks (e.g., LANs, Wi-Fi) and the Internet of Things (IoT). It typically collects data from IoT devices and forwards it to cloud-based services for storage, analysis, and visualization. The LEC-7230 may also be responsible for providing network connectivity, device management, and security functions for IoT devices. The exact features and specifications of the LEC-7230 may vary depending on the manufacturer and intended use case.

- Hadoop Ecosystem:

    - ETL Process: ETL (Extract, Transform, Load) is a process in data warehousing that involves extracting data from multiple sources, transforming it into a format that can be loaded into a data warehouse and then loading it into the data warehouse. In Hadoop, the same ETL process can be used to extract data from various sources, transform it into a suitable format, and load it into a Hadoop data storage system like HDFS. This is usually done using tools like Apache Pig or Apache Hive to perform the extract, transform and load operations in a Hadoop cluster.

    - Apache Hive: Apache Hive is a data warehousing and SQL-like query language technology built on top of the Hadoop Distributed File System (HDFS). It provides an interface for summarizing, querying, and analysing large data sets stored in Hadoop. Hive translates SQL-like queries into a series of MapReduce jobs that can be executed on a Hadoop cluster. The main goal of Hive is to provide a high-level, user-friendly interface for performing data analysis on large datasets stored in Hadoop and to make it easier for people with SQL backgrounds to work with big data. Hive provides many features such as partitioning, bucketing, and an optimized query execution engine to enable fast and efficient data analysis.

    - Apache ZooKeeper: Apache ZooKeeper is a distributed coordination service for distributed systems. It provides a centralized service for maintaining configuration information, naming, and providing distributed synchronization. ZooKeeper is designed to handle the coordination and management of large numbers of nodes in a distributed system. It provides a simple and consistent interface for clients to access and update configuration information and to coordinate with each other. ZooKeeper is used by many distributed systems, such as Apache Hadoop and Apache HBase, to provide coordination and management services. For example, in a Hadoop cluster, ZooKeeper is used to manage the configuration information for the cluster, to elect a leader node, and to coordinate updates to the cluster configuration. ZooKeeper is highly available and fault-tolerant, and is designed to be easy to set up and use. It provides features such as automatic failover, consensus, and transaction management, making it a popular choice for building highly available and scalable distributed systems.

    - Apache HBase: Apache HBase is an open-source, distributed, NoSQL database that is designed to provide scalable and high-performance storage for large amounts of structured and semi-structured data. It is a column-oriented database, meaning that data is stored in columns rather than rows, which makes it well-suited for handling big data applications where data is rapidly changing and the volume of data is very large. HBase is built on top of Apache Hadoop and is designed to work in a Hadoop cluster, making it well-suited for processing big data workloads. It provides features such as low latency data access, automatic sharding, and built-in support for distributed processing and parallel data processing. HBase provides a flexible data model that allows for the storage of unstructured and structured data, and provides a simple, table-based interface for reading and writing data. It also supports powerful querying and data analysis

capabilities, making it well-suited for use cases such as real-time data analytics and log processing. HBase is highly available and can be used to build high-performance, fault-tolerant, and scalable big data applications. It is widely used by companies in various industries to process and store large amounts of data and is considered one of the most popular NoSQL databases for big data processing.

- Apache Spark: Apache Spark is an open-source, fast and general-purpose cluster computing system for big data processing and analysis. It provides high-level APIs for data processing, machine learning, and graph processing, making it easy to build complex data processing pipelines. Spark is designed to handle large-scale data processing tasks efficiently and quickly, by utilizing in-memory processing and minimizing data shuffling between processing stages. It can process data stored in an Apache HBase. Furthermore, Spark provides several libraries and APIs that allow developers to write data processing applications in a variety of programming languages, including Java, Python, Scala, and R. It also integrates with other big data technologies such as Apache Hive, Apache HBase, and Apache Cassandra, allowing for seamless data processing and analysis across the entire big data ecosystem.

- REST API: REST (Representational State Transfer) API is a web service architectural style that provides a standard method for creating, retrieving, updating and deleting data using HTTP (Hypertext Transfer Protocol) requests. In the context of cloud computing, a REST API allows cloud services to be easily accessed and manipulated programmatically. REST API defines a set of endpoints, which can be called using HTTP methods like GET, POST, PUT, and DELETE. Each endpoint represents a specific resource or collection of resources, and the data returned from an endpoint can be used to interact with the corresponding cloud service. REST APIs are widely used for cloud services such as storage, databases, and application platforms because they provide a simple, flexible, and scalable way for developers to interact with these services.

- Cron Process: Cron is a time-based job scheduler in Unix-like operating systems, including Linux. It is used to schedule repetitive tasks, such as running scripts, at specified intervals. The cron process runs in the background and reads the cron configuration files to determine which tasks to run and when to run them.

- MPC controller: MPC (Model Predictive Control) is a control strategy used in process control and industrial automation. It uses mathematical models of a system to make predictions about its behaviour, and then adjusts control inputs to achieve a desired outcome. MPC controllers are commonly used in applications where the system being controlled has complex and dynamic behaviour, such as chemical processes, power plants, and robotics.

- Embedded systems (Intel 4th Gen Xeon Scalable Processors): Embedded systems can contribute to the calculation of online optimization algorithms in a MPC controller by offering improved performance, parallel processing capabilities, high memory and I/O bandwidth, virtualization support, and advanced security features.): Embedded systems are computer systems integrated into other devices or products to perform specific functions. They are designed to operate in real-time and often work in harsh environments, where reliability and stability are key requirements. Embedded systems are characterized by their limited computational resources and low power consumption, as they often run on battery power or have limited energy sources. They also typically have specialized hardware components and software tailored to the specific requirements of the application. For the concrete instance of Embedded systems, we would propose adoption of Intel Xeon Scalable Processors. The 4th Gen Xeon Scalable Processors offer improved performance over previous generations, which can result in faster and more efficient calculation of MPC optimization algorithms. Furthermore, The processors support parallel processing and multithreading, which can be used to accelerate the calculation of MPC optimization algorithms, and also offer advanced security features such as hardware-level encryption, which can be used to secure MPC calculations and protect sensitive data. In other words, Intel Xeon Scalable Processors can contribute to the calculation of online optimization algorithms in a MPC controller by offering improved performance, parallel processing capabilities, high memory and I/O bandwidth, virtualization support, and advanced security features.

- C/C++: C and C++ are widely recommended for implementing Model Predictive Control (MPC) algorithms due to several reasons:

- Performance: C and C++ are known for their high performance and low overhead, which is critical in real-time control applications such as MPC.
- Wide availability of libraries and tools: There are many libraries and tools available for C and C++ that can be used for MPC implementation, including linear algebra libraries, optimization solvers, and control libraries.
- Community support: C and C++ have large and active communities of developers and engineers, providing a wealth of resources, knowledge, and support for MPC implementation.
- Portability: C and C++ are portable programming languages, which means that MPC algorithms implemented in these languages can be easily ported to different hardware platforms and operating systems, making them suitable for a wide range of MPC applications.
- Low-level control: C and C++ provide low-level control over hardware and software, making it easier to implement complex MPC algorithms and optimize performance.

Initially, the vast amount of data from IoT devices would be processed to the cloud according to the below terminologies and processes:

1. IoT Devices: The IoT devices collect data from their sensors or other sources and format it into a suitable data format for transmission, such as JSON or XML.
2. Local Network: The IoT devices transmit the data to the LEC-7230 IoT Gateway via a local network, such as Wi-Fi or Ethernet.
3. LEC-7230 IoT Gateway: The LEC-7230 acts as a bridge between the local network and the cloud. It receives the data from the IoT devices and processes it according to the configured rules and protocols.
4. Cloud Connectivity: The LEC-7230 establishes a secure connection with a cloud service provider, such as Amazon Web Services (AWS) or Microsoft Azure, using a protocol such as MQTT, HTTPS, or CoAP.
5. Data Transmission: The LEC-7230 forwards the data to the cloud service provider, which stores it in a database or data storage system.
6. Data Processing: The cloud service provider processes the data and makes it available for analysis and visualization.

Data from IoT devices is typically collected and transmitted to an IoT gateway, which acts as a central point for collecting, processing, and transmitting data from IoT devices. The IoT gateway can then process the data and pass it on to an ETL (Extract, Transform, Load) process for further processing and analysis.

In the ETL process, the data from the IoT gateway is extracted, transformed, and loaded into Apache HBase, a NoSQL database that is designed for storing and processing large amounts of structured and semi-structured data. The data can be transformed into a format that is suitable for storage in HBase, such as JSON, and loaded into the database using a data ingestion process. Apache ZooKeeper plays a crucial role in managing the coordination and synchronization of data storage in Apache HBase. By managing the configuration, data distribution, and state of the HBase cluster, ZooKeeper helps to ensure that the data stored in HBase is consistent, up-to-date, and readily available for processing and analysis.

Once the structured data is stored in HBase cluster, it can be easily accessed and analysed using Apache Spark. Spark uses the HBase API to read data stored in HBase cluster, performs a wide range of data processing tasks, including batch processing, interactive queries, and real-time streaming, then writes the processed data back to HBase.

Processed data is sent to the REST API via JSON file. The REST API would receive the command from the MPC controller specifying the optimal frequency for sending data packets. The REST API could then use the Cron process to schedule the data packet transmission to occur at the specified frequency. The Cron process would trigger the REST API to send the updated information data packets to the frontend via HTTP protocol at the specified intervals.

Frontend

Waze and Google Maps are two popular navigation applications that can support waste collectors to efficiently collect wastes using various technologies. Waze is a community-based navigation app that allows users to share real-time traffic and road information, including accidents, road closures, and other hazards. It uses this data to provide drivers with the best route to their destination, taking into account current traffic conditions. Waste collectors can use Waze to plan their routes, avoid traffic jams, and navigate through narrow streets and other obstacles. Google Maps is a popular mapping and navigation application that provides users with turn-by-turn directions, real-time traffic updates, and information about local businesses and points of interest. Waste collectors can use Google Maps to plan their routes and optimize their collection schedules based on real-time traffic data and other information.

Both Waze and Google Maps support various technologies that can help waste collectors efficiently collect waste. For example, they can integrate with GPS tracking systems, allowing waste collectors to monitor the location of their vehicles in real-time and optimize their routes accordingly. They can also support RFID and barcode scanning technologies, allowing waste collectors to track the location and status of waste containers and optimize their collection schedules based on current levels of waste. In terms of data format, both Waze and Google Maps support JSON and XML formats for transmitting data, so the high integrity with REST API in the cloud backend system could be anticipated.

The proposed software aims to monitor the status of waste disposal by providing detailed information on the total amount of waste generated and the specific quantities of different waste categories. The intended users are residents who utilize waste bins. The application will be available for mobile devices using iOS and Android platforms, as well as for personal computers running MacOS, Windows, and Linux operating systems via web browsers. To ensure reliable data transfer and high data integrity, the application will utilize an API that supports both JSON and XML. Real-time updates on waste generation will be periodically received and displayed to users. The user interface will consist of four pages, namely the Dashboard, Waste Data Information, Latest News, and User Profile.

Conclusion

In conclusion, the proposed loT solution comprising of smart recycling bins and a GPS system has the potential to revolutionize waste management in communities. The system offers numerous benefits such as efficient collection of waste, improved recycling efforts, reduction of carbon footprint, and ultimately a cleaner environment. However, the success of the system depends on the effective management of resources and overcoming the challenges that may arise.

Future Enhancements

Looking into the future, there are several enhancements that can be made to the proposed loT system to improve its performance and impact. One area of improvement could be the use of blockchain technology to improve transparency and accountability in waste management. Another area of enhancement could be the integration of the loT system with smart city technologies such as autonomous vehicles to optimize the waste collection process. Additionally, the development of predictive analytics algorithms could enable the system to forecast waste generation, leading to better resource management.

Technology Milestones

In the first year, the focus should be on improving the system's functionality, interoperability, and wireless capability to ensure reliable data transfer and communication. This milestone involves improving the hardware and software aspects of the system, including upgrading the sensors and ML algorithms for more accurate waste sorting.

In the second year, the system should be expanded to cover more areas and integrate with legacy systems. This milestone involves the integration of the GPS system with legacy waste management systems used by municipalities to improve efficiency and reduce redundancy.

In the third year, the system's security should be improved to mitigate cybersecurity threats, including data encryption and firewalls. This milestone also involves the development of a comprehensive disaster recovery plan in case of system downtime.

Success and Failure Analysis

Entrepreneurialism and innovation are critical to the success of the proposed loT solution. Successful implementation of the system requires a clear vision, effective leadership, and a strong entrepreneurial mindset to drive innovation. However, failure to address challenges such as cost, user resistance, and system downtime could lead to the failure of the loT system.

In conclusion, the proposed loT solution for waste management has significant potential for improving the environment and optimizing the waste management process. Future enhancements in the system's functionality, integration, and security, coupled with effective management of resources, will lead to greater success.

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