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Using Circular Economy to Manage Organic and Inorganic Waste with Internet of Things-Based Monitoring System

Ritzkal[1*], Bayu Adhi Prakosa[1], Muhammad Rifki[1], Egit Setiawan[1], Andi Eko Kristus Pramuko[1], Suhadi Suhadi[2], Syafrial[3]

[1] Informatics Engineering, Universitas Ibn Khaldun, Kota Bogor 16162, Indonesia
[2] Informatics Engineering, Universitas Bani Saleh, Kota Bekasi 17113, Indonesia
[3] Information System, Universitas Binaniaga Indonesia, Kota Bogor 33024, Indonesia

Corresponding Author Email: ritzkal@ft.uika-bogor.ac.id

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ABSTRACT

When it comes to waste management, the circular economy strategy seeks to reduce waste as much as possible, maintain the utilization of materials, and regenerate natural systems. The technology of Industry 4.0 is incorporated into the creation of an intelligent waste management system that contributes to the achievement of sustainable development goals. The approach that is utilized is a combination of a framework and a circular economy method. This approach includes the following steps: 1. Needs Planning; 2. Identification of Ways of Working; 3. Waste Collection Concept; 4. System Functional Analysis; 5. System Non-Functional Analysis; 6. Waste Separation Concept; 7. Network Topology Design; 8. System Workflow Design; 9. Waste Processing and Waste Packaging; 10. Website Display; and 11. Waste Sales Concept. Among the outcomes of this research are the following: 1. the acquisition of a device that utilizes the Internet of Things to separate organic and inorganic garbage; 2. the acquisition of a waste processing information system that operates in real time, allowing for the ability to view the quantity of waste that is accessible and to check the price of plastic waste per kilogramme. According to the findings of this study, a significant number of the waste monitoring systems that are now in use have not been able to successfully combine the management of organic and inorganic waste into a single comprehensive platform. Additionally, there are restrictions that need to be solved in terms of real-time monitoring, accessibility, and convenience of use for administrators and stakeholders. These are all challenges that stand in the way.

1. INTRODUCTION

Waste is becoming an increasingly pressing global issue, as human population and activities increase. Effective waste management is needed to reduce adverse impacts on the environment, such as land, water, and air pollution. One approach that is increasingly being adopted is the concept of circular economy. This approach focuses on the reutilization and recycling of materials to reduce waste and extend the product life cycle [1, 2]. In this context, waste management, both organic and inorganic, plays an important role [3].

Organic waste, such as food waste and agricultural waste, can be processed into compost or energy [4], while inorganic waste, such as plastics and metals, can be recycled into new products [5]. However, waste management faces several critical challenges. The lack of efficient and real-time monitoring systems makes it difficult to track, categorize, and process waste optimally. Many existing systems rely on manual processes or delayed reporting, limiting their ability to support immediate decision-making and effective resource utilization [6].

Previous studies have explored various waste management methods from both technical and managerial perspectives. However, current monitoring systems still have major limitations. Many focus only on either organic or inorganic waste rather than integrating both into a single comprehensive framework [2]. Additionally, most waste monitoring solutions rely on post-fact reporting, where data is collected and analyzed only after waste has reached processing sites, delaying decision-making and reducing operational efficiency [7]. These limitations hinder efforts to optimize waste sorting, processing, and recycling strategies.

The circular economy approach in waste management aims to minimize waste generation, maintain material usage, and regenerate natural systems [8]. To enhance waste handling, innovative solutions have been developed, such as electrically controlled systems utilizing Black Soldier Flies for organic waste with IoT-based monitoring [9] and MASARO technology for producing organic fertilizers and animal feed [10]. In plastic waste management, biodegradable plastics reduce environmental impact by breaking down more easily than traditional plastics, supporting recycling and composting efforts, and contributing to sustainability [11]. In the case of inorganic waste, sensor-based IoT solutions and data analysis techniques like SAW have been introduced to improve waste sorting and identification [12, 13]. Furthermore, Industry 4.0 technologies are being integrated into waste management systems to support sustainable development goals (SDGs) [14]. However, despite these advancements, significant gaps remain, particularly regarding real-time monitoring, accessibility, and user-friendly interfaces for waste administrators and stakeholders [15]. Implementing circular economy principles in waste management can unlock significant economic value, particularly in developing economies [16].

Furthermore, existing research often fails to fully address the needs of end users, such as waste management administrators. Many existing systems are not intuitive, making them difficult to access or use effectively for operational and managerial decision-making [17]. Another major limitation is the lack of real-time tracking capabilities, which prevents stakeholders from accessing up-to-date waste data whenever needed, ultimately reducing efficiency in waste handling and processing [18].

The implementation of an IoT-based waste monitoring system significantly contributes to the circular economy by enhancing waste tracking, classification, and processing. By automating data collection and real-time monitoring, the system ensures that waste is efficiently sorted at the source, reducing contamination and increasing the value of recyclable materials. This helps in creating a closed-loop system, where waste is not merely discarded but repurposed into new materials and products, minimizing landfill dependency and promoting sustainability.

Additionally, real-time monitoring allows local governments, businesses, and recycling industries to optimize waste collection schedules and reduce operational costs. By knowing the exact amount of organic and inorganic waste available, industries can plan their processing needs more efficiently, reducing waste overflow, pollution, and resource mismanagement.

The system also plays a critical role in sustainable waste management practices by integrating with smart city initiatives. Through data analytics and IoT connectivity, authorities can track waste generation trends, identify high-waste-producing areas, and implement targeted policies for waste reduction. Furthermore, the system's ability to analyze waste composition enables better decision-making regarding material reuse, composting strategies, and circular supply chain models.

By providing real-time insights, enhancing waste segregation efficiency, and promoting data-driven decision-making, the proposed IoT-based system serves as a foundation for achieving a sustainable circular economy. This ensures that waste is continuously reintegrated into production cycles, reducing environmental harm and fostering economic benefits, particularly in developing regions where waste mismanagement is a prevalent issue [19, 20].

The system is expected to provide real-time information on the amount of incoming waste, so that it can be optimally utilized in the implementation of circular economy.

2. METHOD

Figure 1 shows how the research method approach is used. The stages are Planning, Analysis, Design, Application and Testing.

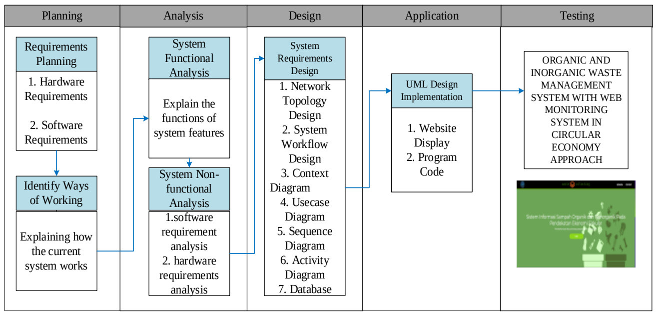

Figure 1. Research methods

2.1 Planning

Planning is the systematic process of formulating goals, strategies, and actions to be taken to achieve desired results. It involves identifying goals, analyzing the current situation, developing a plan of action, allocating resources, and determining the steps necessary to achieve the expected results. Planning can pertain to a variety of areas, such as business, project, financial, personal, or organizational, and aims to provide clear guidance to achieve success by minimizing uncertainty and optimizing the use of resources.

2.2 Analysis

Analysis is the process of describing, examining, and understanding the elements of a situation or information to gain deeper insight or a better understanding of a particular topic, the analysis used by researchers is divided into two, namely:

1) Functional System
2) Non-functional system analysis

2.3 Design

Design is a process that involves planning, conceptualizing, and creating solutions that can meet specific needs or goals. Usually, design is related to creating something that has good functionality, aesthetics, and user experience. The term “design” can refer to a variety of contexts.

2.4 Implementation

Implementation is the implementation stage or the real result of the plan or concept that has been formulated. It includes the implementation of concrete steps, resource allocation, team coordination, and practical actions to realize the website system.

2.5 Testing

Testing is the process of testing a product, system, or software to identify problems, errors, or defects that may exist. It involves executing programs or functions in a control environment, with the aim of verifying whether the product operates according to expectations and meets predefined requirements.

This research method also uses a circular economic process shown in Figure 2.

Figure 2. The circular economy method [21]

The description of Figure 2 is as follows:

1) Collecting: Waste is collected from various sources, possibly including households, businesses, and industrial facilities.

2) Separating: The collected waste is sorted and separated into different categories based on its type or composition. This might involve separating recyclables, organics, and other materials.

3) Processing: The separated waste undergoes further processing to transform it into usable products or energy. This could involve recycling, composting, or converting waste into energy through processes like incineration or anaerobic digestion.

4) Packaging: The processed materials or products are packaged for distribution or sale. This ensures that they are ready for the market and meet appropriate standards.

5) Selling: The packaged products or energy are sold to consumers or businesses. This generates revenue that can be used to fund the waste management operations and potentially share profits with stakeholders [22].

Figure 1 and Figure 2 are combined into a concept of the circular economy method shown in Table 1.

Table 1. Research methods with circular economy

No	Methods	Circular Economy	Research Methods with Circular Economy
1.	Planning	Collection	1. Needs Planning 2. Identification of Ways of Working 3. Waste Collection Concept
2.	Analysis	Separation	1. System Functional Analysis 2. System Non-Functional Analysis 3. Waste Separation Concept
3.	Design	1. Shredding 2. Packaging	1. Network Topology Design 2. System Workflow Design 3. Waste Processing and Garbage packaging
4.	Implementation	Selling	1. Website Display 2. Garbage Sales concept
5.	Testing		Testing

2.6 Circular economy method and research alignment

The circular economy method applied in this study consists of the following key steps: Collection, Separation, Processing, Packaging, and Selling. These steps are aligned with the research methods to enhance the efficiency of waste monitoring and management using IoT technology. The relationship between the circular economy approach and research methods is detailed below:

Planning – Collection Stage

1) In the planning phase, the needs for an IoT-based waste monitoring system are identified, including hardware and software requirements.

2) The collection stage in the circular economy method involves gathering waste from various sources, such as households and businesses.

3) The IoT system is designed to automate waste collection tracking, ensuring accurate data collection on the quantity and type of waste gathered in real time.

Analysis – Separation Stage

1) Functional and non-functional analyses are conducted to define system requirements.

2) The separation stage involves sorting waste into organic and inorganic categories. The IoT system incorporates sensors to detect and classify waste automatically.

3) This stage ensures that recyclable materials are properly identified, minimizing contamination and improving resource recovery efficiency.

Design – Processing and Packaging Stages

1) The system design phase focuses on developing the network topology, workflow processes, and data processing mechanisms.

2) The processing stage in the circular economy involves converting waste into useful products such as compost, energy, or recyclable materials.

3) The IoT monitoring system tracks the processing progress, providing real-time data on waste conversion efficiency.

4) The packaging stage ensures that processed materials are appropriately stored and prepared for distribution. The system records packaging details and updates inventory data.

Implementation – Selling Stage

1) The implementation phase involves deploying the web-based waste monitoring system.

2) In the selling stage, recycled materials or processed waste are made available for sale.

3) The IoT system provides live updates on the quantity and price of recyclable materials, enabling efficient transactions and better resource utilization.

Testing and Evaluation

1) The final phase includes testing the system's functionality, data accuracy, and user accessibility.

2) The effectiveness of the circular economy method in optimizing waste management is evaluated.

3) Real-time monitoring and analytics are assessed to ensure the system meets operational and environmental sustainability goals.

The integration of the circular economy method with IoT-based monitoring brings significant improvements in waste management by:

1) Enhancing real-time waste tracking: The system allows immediate data retrieval on waste collection, separation, and processing.

2) Improving waste sorting efficiency: Automated classification reduces human error and ensures accurate waste categorization.

3) Supporting data-driven decision-making: Real-time insights help optimize resource allocation and recycling processes.

4) Reducing environmental impact: Proper waste tracking minimizes landfill disposal and encourages material reuse in a circular economy framework.

By aligning the research methodology with circular economy principles, this study ensures that the IoT-based waste monitoring system contributes to sustainable waste management practices while promoting economic benefits through optimized recycling and waste processing.

3. RESULT

To describe the results in this study is a step in describing the research methods used and has been explained in the previous stages. The stages in this result consist of:

3.1 Planning

Based on the problems taken by researchers, it is planned that organic and inorganic waste management requires a monitoring system that can support the needs. The following is the framework of the planning stage (planning):

(1) Planning

This needs planning includes software requirements described in Table 2 and hardware requirements which will be described in Table 3. Software and hardware planning aims to ensure that all technology resources needed to support operational, development, and business or project goals can be available, optimized, and used efficiently. The following hardware and software requirements are used.

Table 2. Hardware requirements

No.	Hardware Name	Function
1	Laptop	As a tool for writing final assignments and programming websites and Wi-Fi modules.
2	Wi-Fi Module	As an internet-integrated network communication tool between the device and the website.
3	Automatic waste sorting device	As data collection by sensors that have been installed.

Table 3. Software requirements

No.	Software Name	Function
1	*Arduino IDE*	To program the Wi-Fi module that will be connected to the website.
2	*Visual code studio*	To program the website design with HTML and CSS.
3	*XAMPP*	To create a local server for the website database.
4	*Microsoft Viso*	To create UML
5	*Figma*	To create a website display design

Selection of Hardware and Software Components

The selection of hardware and software components for the IoT-based waste monitoring system is based on performance, cost-effectiveness, and system compatibility. The goal is to enhance real-time waste tracking, accurate categorization, and efficient data processing.

Rationale for Hardware Selection

The Load Cell Sensor is chosen for its accuracy in measuring waste weight, ensuring precise data collection. Compared to strain gauge sensors, it offers higher sensitivity and better durability. The Ultrasonic Sensor is used to detect bin fill levels, providing real-time monitoring to optimize waste collection schedules. It is preferred over infrared sensors due to its ability to function in diverse lighting conditions.

Infrared and Optical Sensors are integrated to classify waste into organic and inorganic categories with high precision. These sensors offer superior object recognition compared to capacitive sensors, which may struggle with material differentiation. The Mechanical Sorting Mechanism automates waste separation, reducing human error and increasing efficiency. Finally, the Wi-Fi Module (Wemos ESP8266) enables real-time data transmission, offering better range and internet connectivity than Bluetooth modules.

Rationale for Software Selection

The Arduino IDE is selected for programming hardware components due to its open-source nature, ease of use, and extensive community support. Visual Studio Code is used for website and database development, offering flexibility in coding and debugging. XAMPP provides a local server environment for database management, streamlining data access and storage. Figma is employed to design an intuitive user interface, improving accessibility and user experience.

Advantages of Selected Components

1) Cost-effective: Affordable and reliable components ensure efficient system functionality.

2) Real-time Monitoring: Sensors and Wi-Fi modules enable instant data updates for informed decision-making.

3) Automation & Efficiency: Reduces manual intervention, enhancing speed and accuracy.

4) Scalability: The system can be expanded with additional sensors to improve coverage.

Limitations Compared to Other Options

1) Power Dependency: The system requires a continuous power supply, limiting deployment in areas with unstable electricity.

2) Sensor Accuracy: Some materials may need additional processing for precise classification.

3) Initial Cost: Although cost-effective in the long run, the initial investment is higher than manual sorting methods.

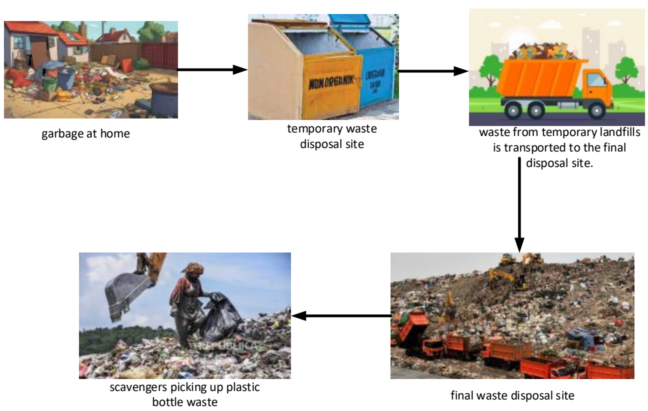

Figure 3. Waste collection concept

Figure 3 describes waste collection, which begins with:

(2) Identify How to Work

Initial sorting includes 1) Collect all the waste to be identified and separate the waste into two large groups, namely waste that is easily decomposed (organic) and waste that is not easily decomposed (inorganic). 2) Visual Observation which includes Organic waste generally comes from living things, has a darker color, moist texture, and often emits odors. Examples: food waste, leaves, twigs, fruit peels and Inorganic waste comes from inanimate objects, has a lighter color, a hard or slippery texture, and is generally odorless. Examples: plastic, glass, metal, paper. 3) Simple Tests that include the Decay Test: Place a sample of organic waste in a closed container and observe for a few days. If the waste changes color, emits a pungent odor, and small worms or insects appear, then it is organic waste and Burning Test: Try burning a small sample of inorganic waste. If it burns hardly or not at all, then it is inorganic waste. Caution: Perform the burning test carefully and in a safe place. 3) Detailed Grouping including Organic Waste: After going through the decomposition test, further categorize organic waste based on its type, e.g., food waste, leaves, twigs, etc. and Inorganic Waste: Group inorganic waste based on the type of material, such as plastic, glass, metal, paper, cardboard, etc.

(3) Waste Collection Concept

Based on observations made both observing one of the plastic waste buying and selling businesses and processing food waste into compost carried out in Bogor district and conducting interviews from one of the plastic waste buying and selling businesses, waste is divided into two types, namely organic and inorganic waste, in the concept of circular economy, waste collection is the most important stage. Therefore, it is better to collect waste based on its type, for example inorganic waste, plastic bottles made of PET (Polyethylene Terephthalate), a type of plastic often used for beverage packaging, can be recycled into new products such as polyester fabrics or new bottles if collected properly. An example of inorganic waste, banana peels are biodegradable waste and can be processed into compost which is useful for fertilizing the soil with proper management. Inorganic waste such as PET plastic bottles and organic waste such as banana peels can provide significant economic and environmental benefits. As a result of the process, we can conclude that 1) Availability of Trash Bins: There are public trash bins in every corner of the compound, but there is no clear division between organic and Inorganic waste. 2) Type of Waste: The majority of waste found is organic waste (food waste, fruit peels) and inorganic waste (plastic, paper). 3) Waste Disposal Behavior: Most residents dispose of waste carelessly, not sorting. 4) Some residents were seen throwing plastic waste into the small river that flows in the compound. 5) Waste Sources: Plastic waste is sourced from various sources, such as markets, households, and small industries.

3.2 Analysis

This stage includes functional analysis, non-functional analysis and waste separation concept.

1) System functional analysis

The functional analysis of the system includes the processes that will be carried out by the system and the information generated according to the function of the web system [23]. The website that is built is expected that users can log in to monitor waste data carefully which is explained as follows:

a). Admin logs into the website by entering NIA and password on the login page.

b). The website displays a dashboard containing admin data, incoming trash, daily data and logout.

c). If the admin opens the admin data, the admin can manage the admin data.

d). If the admin opens the incoming garbage, the admin can view and manage the garbage data which contains some information such as:

1. Real-time waste data for monitoring how many kilos of waste are collected at a given time.

2. Show enteries, to display how much data in the form of tables is displayed on the website.

3. Search column, to search for waste data by entering the year-month-date as follows [2024-02-14].

4. Waste data information table containing the following Time, to display Year, month, and date, Weight of organic waste in kilograms, Weight of inorganic waste in kilograms, Height of organic waste in CM, Height of nonorganic waste in CM.

2) Non-functional system analysis

Non-functional requirements analysis is needed to determine the specifications of system requirements, including the elements or components required from development to implementation. Non-functional requirements analysis is divided into two, namely software requirements analysis and hardware requirements analysis as described below:

a) Software requirements analysis

This analysis is needed to find out the minimum specifications needed to build a software. can be seen in the following Table 4:

Table 4. Software requirements analysis

No.	*Supporting Software*	Brief Explanation
1.	*Visual code studio*	To design the website source code
2.	*XAMPP*	As a website local server
3.	*Microsoft*	For thesis writing
4.	*Arduino IDE*	To design source code for Wi-Fi devices and modules
5.	*Microsoft Word*	For final project writing
6.	*Figma*	For website design

b) Hardware requirements analysis

The minimum laptop hardware specification requirements needed by users to run the website can be seen in the following Table 5:

Table 5. Hardware requirements analysis

No.	Device	Recommended
1	Laptop Prosessor	144 Hz
2	RAM	4 GB
4	Operating System	Windows 7-10

3) Waste separation concept

Waste separation is an important stage in realizing the concept of circular economy, where the waste that has been collected will be separated based on their respective types and needs. The following are two points of explanation of the concept of waste separation in this study:

a) Waste separation

Based on observation, waste is generally divided into two types: organic and inorganic. In daily life, waste separation is often done manually, so a system that supports the process is needed. To speed up the separation, the organic and inorganic waste sorting device can be equipped with a directional door that directs the waste to the appropriate place based on its type [24]. Therefore, this system is expected to help simplify waste separation, so organic and inorganic waste sorting tools are needed to speed up the process.

b) Waste separation analysis

In the waste separation process, it is necessary to analyze the waste separator to find out how the system separates the waste. Here's a flowchart of how the system works:

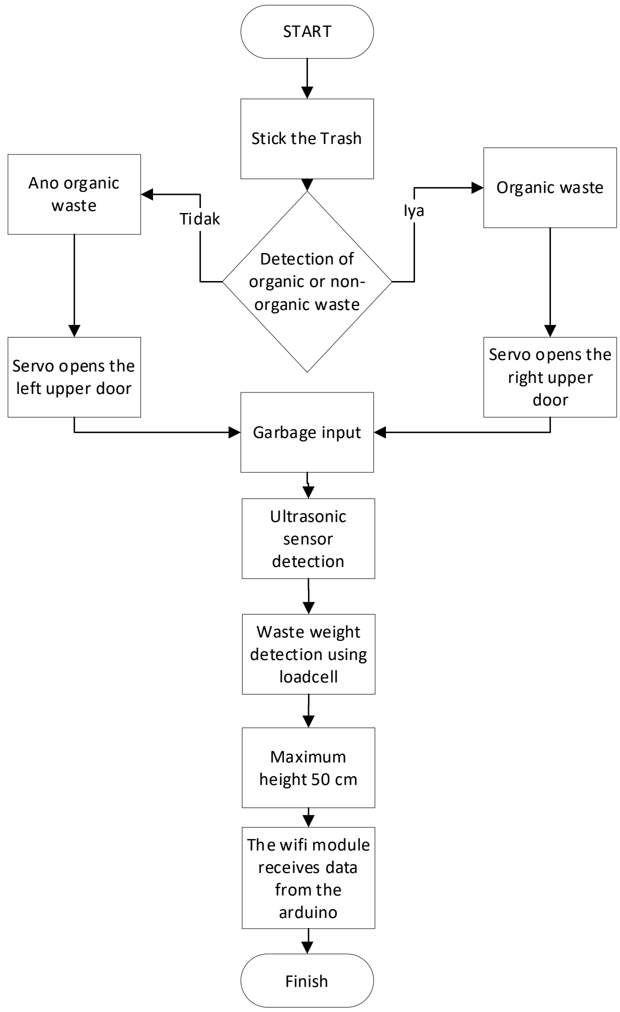

Figure 4. Flow chart of waste separation

The workings of the device in Figure 4 begin after the waste is weighed on the sensor that detects the waste. If the waste weighed is organic waste, the door on the cannon will automatically open; if the waste weighed is inorganic waste, the door on the left will automatically open. Finally, the waste will be moved to the designated waste location. The prepared sample will be weighed by a loadcell with a maximum capacity of 10 kg. If the sample length exceeds 50 cm, the ultrasonic sensor will detect the sample length, then the sample data will be sent to the website through the Wemos ESP 8266 device and stored in the database [25]. This research introduces an automatic waste sorting device that improves efficiency and accuracy in waste management.

1. Automatic Waste Sorting Device

The device uses IoT technology with sensors to detect and classify waste. It consists of several key components, including a Load Cell Sensor to measure waste weight, an Ultrasonic Sensor to detect bin fill levels, and Infrared & Optical Sensors to identify whether the waste is organic or inorganic. A Mechanical Sorting Mechanism then directs the waste to the correct bin, while a Wi-Fi Module (Wemos ESP8266) transmits real-time data to a web-based system.

When waste is placed on the platform, the sensors analyze its properties, and the system automatically sorts it into the appropriate category. The data is updated in real time, allowing for continuous monitoring and optimization of waste processing.

2. Advantages of Automatic Sorting

Automating waste sorting offers several benefits. It is faster and more accurate than manual methods, reducing sorting time and improving precision. The system provides real-time data tracking, enabling continuous monitoring of waste levels and better decision-making. Additionally, automation reduces labor costs, as it minimizes the need for human intervention. The system is also scalable, meaning it can be implemented across multiple waste management facilities.

3. Limitations of Automatic Sorting

Despite its advantages, the automatic sorting system has some limitations. The initial setup cost can be high due to the investment in hardware and software. Sensor limitations may arise, as some complex materials might require additional processing. Regular maintenance and calibration are necessary to ensure long-term functionality. Additionally, the system is dependent on a continuous power supply, which could be a challenge in areas with unstable electricity access.

4. Impact on Waste Management

The implementation of an automatic waste sorting device significantly enhances recycling efficiency. By ensuring accurate waste separation, it reduces contamination and improves the quality of recycled materials. Real-time monitoring helps businesses and authorities optimize collection schedules, allocate resources efficiently, and make data-driven decisions. Ultimately, this system supports a more sustainable, cost-effective, and environmentally friendly approach to waste management.

3.3 Design

At this stage the researcher designs a website system that will later be implemented on the website created, in making this design the researcher takes 3 stages of design and explanation, namely:

1). Tool design

In this tool design explains the workflow of the tool from garbage that has not entered the tool until it becomes data to be displayed on the website. The following is an image of the tool design.

Based on the above sample, the sensor will determine whether the sample is organic or inorganic. If the sample is already sorted, it will settle to the sample location that has already been supplied, and the loadcell will measure the sample size accordingly. If the sample is organic or inorganic, the ultrasonic sensor will detect the sample length. If the sample is small, the ultrasonic sensor will determine whether it is small or not. Every piece of data that is entered into a storage area will be retrieved using a Wi-Fi module that connects to a website. Then, the data will be stored in a database. We can see tools design in Figure 5.

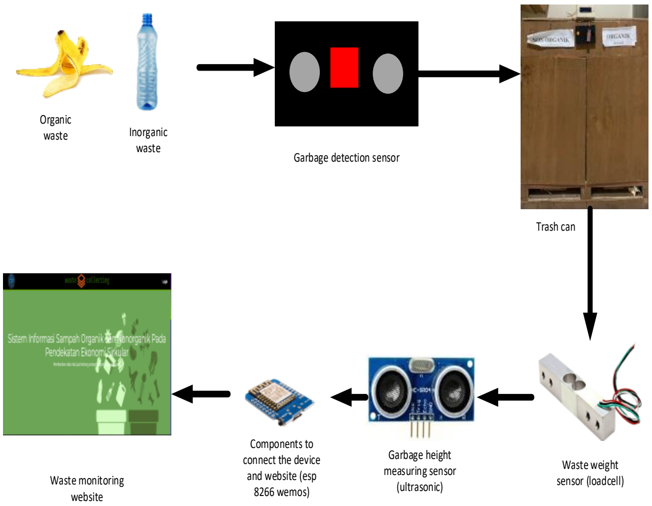

Figure 5. Tool design

2). Topology

The following topology design adapts to the system. Can be seen in the picture:

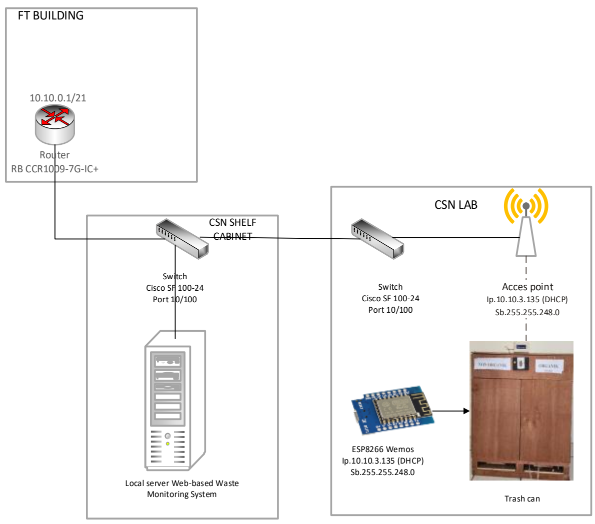

Figure 6. Network topology of the garbage separator

From Figure 6 there is a waste sorting device which contains a Wemos Wi-Fi module, the IP address of the Wi-Fi module is 10.10.xx.xx and subnet mask 255.255.xxx.xx, the Wi-Fi module gets the IP address automatically from the server, the Wi-Fi module is connected to an access point with SSID HS-NCC without using a cable (wireless), the access point serves as a source of internet providers to connected electronic devices to connect to local networks or the internet, the IP address of the access point is 10.10.xxx.xxx and subnet mask 255.255.xxx.xxx, the access point is connected to a switch located in the CSN lab using a physical cable, the CSN lab switch is connected to a switch located in the CSN rack, both of these switches use the same device, namely the Cisco SF 100 using 24 ports and supporting speeds of 10/100 mbps. The only device connected to the CSN switch is a web server. This web server is used to initiate the system for monitoring, storing, and transferring data. After that, the network's edge is connected to a router. The router in question uses the RB CCR1009-7G-IC+ type of device with IP address 10.10.xx.xx/xxx. Its primary function is to connect local networks to the internet.

3). Waste shredding and packaging

Waste shredding and packaging are essential for efficient waste processing, transportation, and recycling while reducing environmental impact and supporting a circular economy.

Packaging Materials and Methods

Organic waste is packaged using biodegradable materials like paper bags and compostable containers, ensuring safe decomposition into compost or bioenergy. Inorganic waste is stored in recyclable materials like HDPE bags and metal containers, preventing contamination and facilitating efficient recycling.

Environmental and Economic Impact

Sustainable packaging reduces single-use plastics, prevents pollution, and lowers waste generation. Biodegradable packaging decomposes naturally, while recyclable packaging conserves resources and cuts energy use. Proper packaging also enhances waste market value, improves transport efficiency, and reduces operational costs.

Circular Economy Alignment

Effective packaging supports waste minimization, resource recovery, and material reuse. By improving composting and recycling efficiency, waste management systems can maximize material recovery, reduce environmental harm, and create economic value, reinforcing circular economy principles.

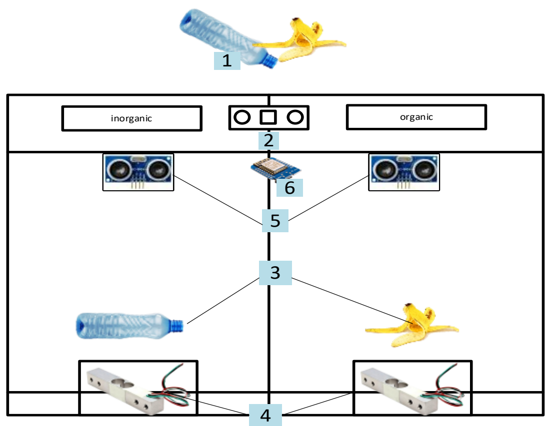

Figure 7. Waste shredding and packaging

From Figure 7 explains the process of sorting waste, the waste that is put into the tool is adjusted to the number in sequence, following the description of the number above:

1. Prepare organic or inorganic waste such as plastic bottles and banana peels.
2. The waste is attached to the sensor installed in the waste sorting device and detects that the waste is organic or inorganic.
3. Organic and inorganic waste goes into the bin, if inorganic waste goes to the left door, and if organic to the right door.
4. Then the organic and inorganic waste is weighed using a loadcell with a maximum capacity of 10kg.
5. Then the ultrasonic sensor measures the height of organic and inorganic waste to determine whether the trash can is full or not, in this tool the full waste height limit has been set at 50cm.
6. Data on the weight and height of the garbage is sent via the 8266 Wemos Wi-Fi module to be displayed on the website.

After the waste sorting stage in the next tool is the waste packaging stage, packaging waste in waste management that has been separated based on its type such as organic and inorganic is an important step to ensure that the handling process runs well and neatly, in line with the circular economy concept. In a circular economy, waste is considered a resource that can be processed and reused. Organic waste is packed in compostable bags or biodegradable containers to be processed into fertilizer at composting facilities, while inorganic waste such as plastic, metal, and glass are packed in strong plastic bags and sent to recycling centers to be processed into new products. With proper packaging, we not only manage waste better, but also support the reuse and recycling cycle, minimize waste, and create new economic value from materials that were previously considered useless.

3.4 Implementation

Application is a method to carry out what has already been planned in order to get the desired results. In this study, the two phases are, respectively, UML implementation and the clearly visible website test results.

1. Website Display

a. Homepage

The homepage is the main page that contains important information and a summary of system activities or data. The home page, as shown in the following image. We can see the homepage in Figure 8.

Figure 8. Homepage

b. Trash In

Displaying the results of the actual display of incoming waste data in the organic and inorganic waste management system in the form of a website. Can be seen in the following image.

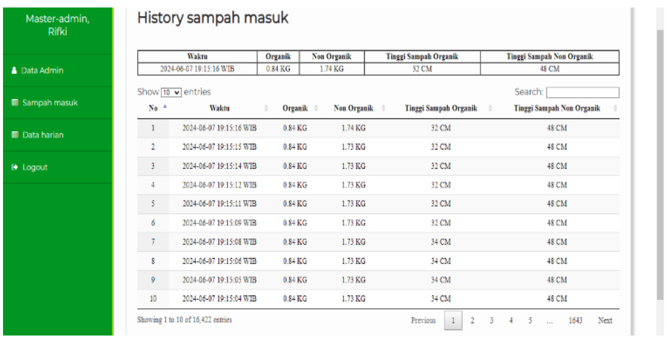

Figure 9. History of garbage

From Figure 9, to show the amount of waste entering the bin, the image above shows that the waste was weighed and measured for height. The data integrated directly into the website includes the year, month, and date of waste entry, the weight of organic and inorganic waste in kilograms, and the height of organic and non-organic waste in kilograms. This information provides a complete picture of the overall amount and weight of waste collected.

c. Daily Waste Report

Display the daily report data of the organic and inorganic waste management system in real-time via the web. This is shown in the following image.

Figure 10. Daily waste report

Figure 10 displays detailed information about the amount of waste that comes in every day, calculated by weight and height. This information includes the date, month, and year when the waste was full, the total weight of organic and inorganic waste in kilograms, and the total height of organic and non-organic waste in centimeters on the same day.

2. Garbage Sales Concept

On the webpage, you can calculate the total amount of waste and the cost for organic and non-organic waste. This is shown in the following image. We can see the garbage sales concept in Figure 11.

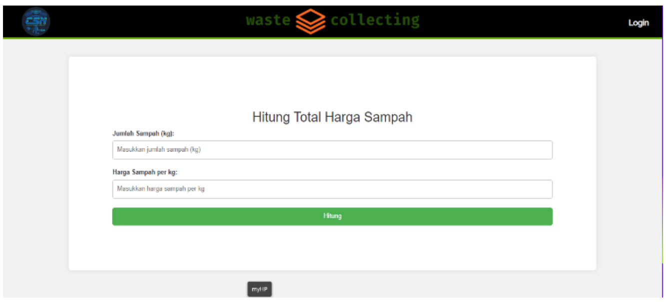

Figure 11. Garbage sales concept

The daily waste calculation page shows how to calculate waste for sale, using the amount of waste in kilograms and the price of waste in rupiah. Then, the total price of waste to be sold is calculated.

4. CONCLUSIONS

Effective and sustainable waste management is an important element in supporting the implementation of a circular economy. In an effort to reduce the negative environmental impact of waste, the circular economy approach offers solutions that emphasize recycling and reusing materials. However, waste management, both organic and inorganic, faces significant challenges, especially in terms of efficient monitoring and management. Through this research, it was identified that many existing waste monitoring systems have not been able to integrate organic and inorganic waste management in one holistic platform. In addition, limitations in terms of real-time monitoring, accessibility, and ease of use for admins and stakeholders are obstacles that need to be overcome. Therefore, this research proposes the development of a web-based monitoring system that is able to monitor and manage organic and inorganic waste data simultaneously. This system is designed to provide real-time information on the amount of incoming waste, so that it can support fast and precise decision-making in the waste management and sales process. Thus, this system not only helps optimize the waste management process, but also contributes to supporting the transition towards a more effective and sustainable circular economy.

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