PREFACE

The 1st International Conference on Applied Sciences and Smart Technologies (InCASST 2023) has been organized by the Faculty of Science and Technology, Sanata Dharma University, Yogyakarta, Indonesia. This event was held on October 18–19, 2023, in Yogyakarta, Indonesia. As an effort to contribute in distributing research outcomes, especially in the search for renewable and clean energy, waste management, environmental management, and sustainable agriculture. InCASST 2023 presented four honorable international keynote speakers from representative countries: 1) Prof. Tokuro Matsuo, Advanced Institute of Industrial Technology - Japan; 2) Prof. Ir. Sudi Mungkasi, Ph.D., Sanata Dharma University-Indonesia; 3) Assoc. Prof. Dr. Peerapong Uthansakul, Suranaree University of Technology – Thailand, and 4) Assist. Prof. Dr. Eng. Rando Tungga Dewa, The Republic of Indonesia Defense University-Indonesia. This event selected local researchers and overseas fellows to share their best research works at this conference to reach a broader network of researchers. After a rigorous selection process, the Scientific & Editorial Board decided to publish 46 papers in E3S Web of Conferences, open-access proceedings in environment, energy, and earth sciences, managed by EDP Sciences, and indexed on Scopus, Scimago.

The published papers have passed all necessary improvement requirements following the Web of Conferences standard, reviewer's comments, and similarity tests by the Turnitin program. We want to thank the official committee, scientific & editorial boards, and organizing partners. Thanks to our co-host partners, Universitas Katolik Widya Mandala Surabaya, Universitas Prasetya Mulya, and Institut Teknologi Nasional Yogyakarta, for trusting and supporting this conference. Finally, we would like to briefly thank all presenters and attendees for their participation in sharing wonderful ideas and making creative decisions to inspire further research and exchange scientific reasons. We hope this time, all papers can be compiled into scientific works as the first publication of the 2023 InCASST. Lastly, we hope this conference encourages further research collaboration and see you at the next conference.

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Science and Technology Disruption in the Post Pandemic Era with Sustainable Development for Better Life Quality

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Important Dates

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- Accepted Notification : August 22, 2023
- Early Bird payment : April 30, 2023
- Late payment : August 31, 2023
- Full Paper Submission of Accepted Abstract : September 18, 2023
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SCADA for waste sorting system as an environmental conservation effort

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Abstract. Improperly managed household waste has led to environmental pollution. The methods of reducing, reusing, and recycling are effective in reducing waste volume. Therefore, waste needs to be sorted by type. Automated waste sorting using the SCADA (Supervisory Control and Data Acquisition) system consists of Capacitive Proximity Sensors, Inductive Proximity Sensors, and Infrared Proximity Sensors to detect the types of waste, a PLC TM221CE40R as the controller, and an Android-based HMI (Human Machine Interface) to monitor real-time waste bin fill levels. The types of waste to be sorted are organic, inorganic, and metal. The system comprises 1 main bin for users to deposit waste and 3 waste bins for the sorted materials. When users deposit a certain type of waste, the sensors detect the type of waste. This information triggers the motors of the 3 waste bins to rotate and stop right beneath the main bin, matching the waste type. The bottom of the main bin opens, allowing the waste to enter the appropriate container. Test results have shown that the system is capable of correctly sorting all types of organic and metal waste. However, for inorganic waste, the system correctly sorts only when the waste is clear in color.

1 Introduction

The production of trash in Indonesia always increases every year, and the trash produced is always increasing. Waste production always increases due to increased needs, so it is followed by additional waste production. Trash is always mixed without being sorted so the trash becomes piled up. The public's trust in the behavior of disposing of waste. It is very possible that the community may perceive the act of littering as something not wrong or sinful [1]. Trash can be reprocessed with several methods, such as reduce, reuse, and recycle, which means that trash will be sorted and processed into items that can be reused so that trash production can be reduced. However, not all trash can be carried out through the 3R process, the trash must be sorted according to their needs. In fact, waste recycling in Indonesia is still relatively small, it is below 10 percent. Waste recycling in Indonesia is only three percent [2]. In this case, humans often dispose of waste not according to the type of waste, so the waste is not properly sorted according to its type. Along with the development of technology,

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something that is usually done conventionally by human labor is developing into an automated system that is operated by machines. This is one part of the evidence of technological development and is a form of obtaining an effective and efficient work system so that optimal results are obtained. This system uses PLC (Programmable Logic Controller) as an automation system. PLC can analyze input signals and set the output status according to the programmer or user's wishes [3]. PLC is used as a controller in the garbage sorting process so that the garbage can be sorted according by the type.

SCADA (Supervisory Control and Data Acquisition) is a system on a PLC that functions to monitor the performance of the system controlled by the PLC. SCADA systems are very useful for industries that use the concept of automation in their production processes to carry out monitoring that can be accessed in real-time through animation on the interface. In this final project, the SCADA used is the HMI Modbus application installed via a smartphone. Modbus in this final project uses TCP/IP communication with Ethernet media. This protocol has become a standard communication protocol in the industry, and now Modbus is the most commonly used two-way communication protocol. most commonly used as a medium for connecting industrial devices or other electronic media with computers [4]. other electronic media with computers [4].

Through this control system with PLC M221, waste can be sorted efficiently and also monitored. PLC based system is proposed due to inherent advantages like modular design, provision to make required short-term adjustments without having a large impact on the whole system, flexibility, cost, less wiring, ets [5]. Waste sorting will be monitored using HMI with the Modbus application on the Android smartphone in real-time. Previous research used several sensors to detect the type of garbage, such as Capacitive Proximity Sensor, Inductive Proximity Sensor, Infrared Proximity Sensor, and Photoelectric Sensor [6]. These sensors have different functions. These three sensors are installed at the top of the tool, where this sensor functions to detect the type of waste, whether organic, inorganic, or metal waste. The infrared sensor confirms that an object has been detected. If the inductive sensor does not detect the object, it is a non-metallic material. If the capacitive sensor detects the object, then the object is organic [6]. The waste sorters here have a system that is almost the same as in previous studies. Different from previous studies that can only sort two types of waste, this PLC-based waste sorter can sort three types of waste, namely inorganic, organic, and metal waste. In previous research the system has not done Automatic sorting, the trash can only opens according to the type of waste identified. The advantage of this PLC-based Waste Separator is that it can be sorted automatically using a DC motor that will rotate the plate which will stop and sort the waste. In addition, the full status of the garbage can be monitored through a smartphone.

2 Research methods

2.1 Sensor detects the type of waste

In this system, waste will be sorted into three categories: organic waste, inorganic waste, and metal waste. To ensure proper waste sorting, three types of proximity sensors are required: capacitive proximity sensor, inductive proximity sensor, and infrared proximity sensor. These three sensors function like switches, providing input in the form of 1 and 0 for logical data to the PLC.

By using the three types of sensors, each sensor can detect objects with different criteria. The capacitive proximity sensor can detect solid objects except transparent-colored objects, as proven through several experiments, which are visible in Table 1. The inductive proximity sensor can detect objects made of metal, and the infrared proximity sensor can detect all solid objects regardless of color.

Table 1. Capacitive proximity sensor usability trial.

Object Criteria	Results
Solid-colored objects (green, red, blue, brown) of various shapes and sizes (bottles, paper, plastic)	Success
Colorless/clear objects made of plastic, various shapes and sizes	Unsuccessful
Colorless/clear objects made of glass, various shapes and sizes	Unsuccessful
Colored glass objects of various shapes and sizes	Success
White color objects of various shapes and sizes	Success
Metal objects of various shapes and sizes	Success

Through the data collected from each sensor, specific criteria can be established for effective waste sorting. For organic waste, any colored organic waste is included. If there is waste that is colored and does not contain metal, whether it's organic or inorganic, it will be considered as organic waste. For the criteria of inorganic waste, it encompasses non-colored/invisible inorganic waste, such as examples like plastic bottles, glass bottles, acrylic, and other transparent waste. If inorganic waste has color, it will be categorized as organic waste. The criteria for metal waste include all types of waste containing metal, whether coated with paper, plastic, or not.

Based on these detection results, logic can be developed to identify the type of waste, enabling the sorting of waste according to its type using the waste sorting logic presented in Table 2.

Table 2. Logic for waste type.

Type of Waste	Proximity Sensor		
	Infrared	Inductive	Capacitive
Organic	1	0	1
Anorganic	1	0	0
Metal	1	1	1

2.2 Diagram block system

Figure 1 is the block diagram of the waste sorting system, where the PLC M221 serves as the controller. Infrared sensor, inductive proximity sensor, and capacitive proximity sensor, along with limit switch, function as inputs. Meanwhile, DC motor-1 and DC motor-2 play the role of outputs. The status of whether the waste bins are full or not will be monitored using an HMI through a smartphone.

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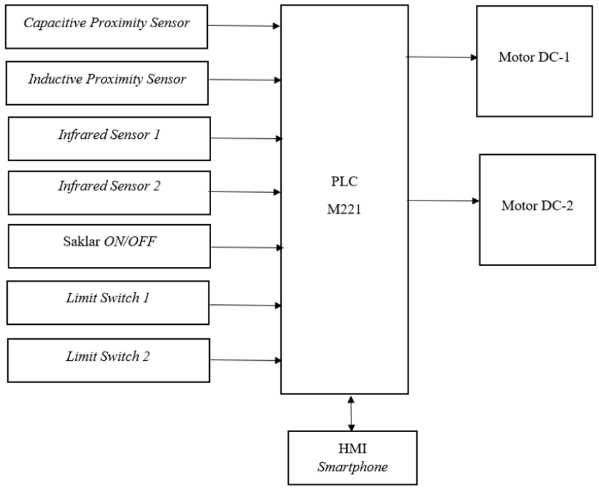

Fig. 1. Diagram block system.

The system will operate when the switch has been turned on, then the sensors detect the presence of waste. After the sensors detect the presence and type of waste, DC motor-2 will rotate and move the final collection plate. The motor will rotate and stop according to the type of waste detected by the sensors. When the limit switch triggers the final waste collection plate, DC motor-2 will stop, and DC motor-1 will rotate in a counterclockwise (CCW) direction, opening the initial waste collection plate. Once the waste has entered the final waste container, DC motor-1 will rotate clockwise (CW) again.

The infrared sensor will operate when it detects the presence of waste, indicating that the waste container is full. In this design, the HMI used is a smartphone-accessible HMI application called Modbus, which can be downloaded from the Play Store. The HMI in the Modbus application on the smartphone will provide a warning when the waste is fully filled. The warning will come in the form of an alarm to notify that the waste container is full.

2.3 Flowchart system

The main flowchart in Figure 2 illustrates the process of the waste sorting system. The system initiates when the waste enters, and the three sensors detect the type of waste. After determining the waste type based on the sensor input data and waste types in Table 2, the waste will be sorted according to the designated final collection bins, as indicated in the flowchart for each process in Figure 3. Once the waste is inside the final collection bins, the infrared sensor will determine whether the bins are full or not. When the infrared sensor detects the presence of waste, a warning will appear on the HMI.

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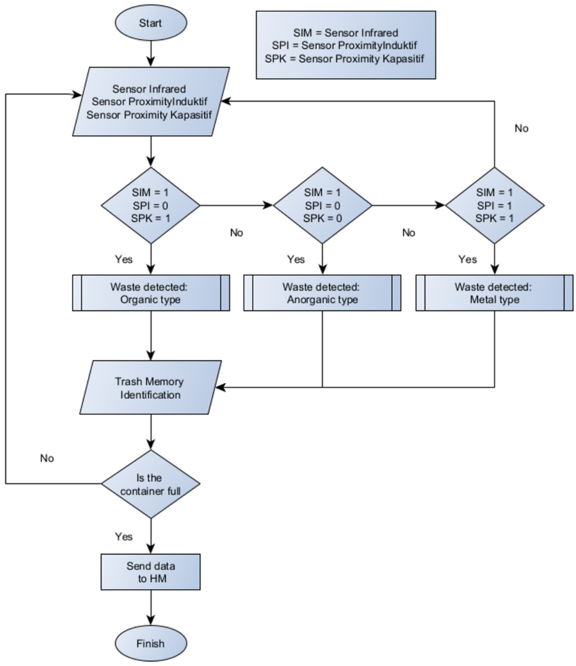

Fig. 2. Main flowchart.

Figure 3 illustrates the flowchart of the waste sorting process. The waste will be sorted into three categories: organic waste, inorganic waste, and metal waste. Essentially, waste sorting is achieved by identifying the type of waste by initializing waste into memory word forms. The rotation of the waste containers is also performed by adjusting the waste identification process upon detection. This determination will dictate whether the motor rotates clockwise (CW), counterclockwise (CCW), or doesn't rotate at all. The initial or default position, as shown in Figure 4, must be established. Once the position is set to default, the waste sorting system can operate without using a home base. This default position also applies to memory words with addresses %MW7, %MW8, and %MW9, which determine the motor rotation.

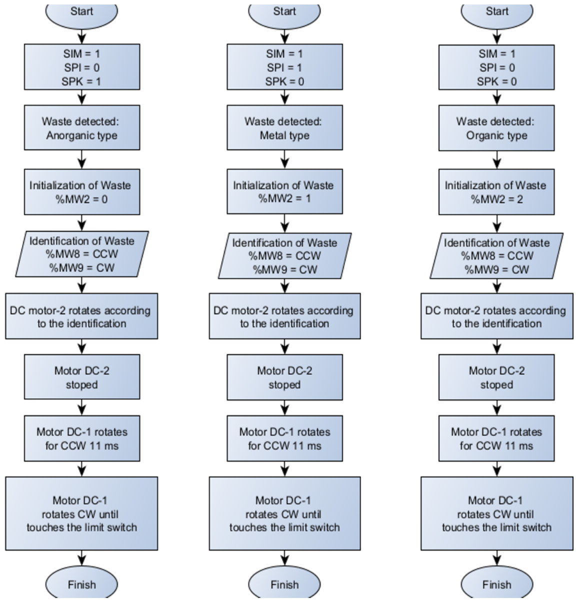

Fig. 3. Flowchart of the waste sorting process.

The sorting system begins when the waste type is detected. Once the waste type is detected, the waste will be initialized into memory word form. For inorganic waste, it's assigned a value of 0; metal waste is assigned a value of 1, and organic waste is assigned a value of 2. DC Motor-2 will rotate in either a clockwise (CW) or counterclockwise (CCW) direction after the motor identifies the value from the initial waste initialization. If the initialization value is 0, DC Motor-2 won't rotate. If the initialization value is 1, DC Motor-2 will rotate in a counterclockwise direction (CCW), and if the initialization value is 2, DC Motor-2 will rotate in a clockwise direction (CW).

When the identified value in the final waste receptacle corresponds to the value in %MW8, the motor will rotate clockwise (CW). If the identified value corresponds to the value in %MW9, the motor will rotate counterclockwise (CCW). If the identified value corresponds to the value in %MW7, the motor will not rotate. The motor will continue to rotate until it comes to a stop when the platform of the final waste receptacle touches the next limit switch.

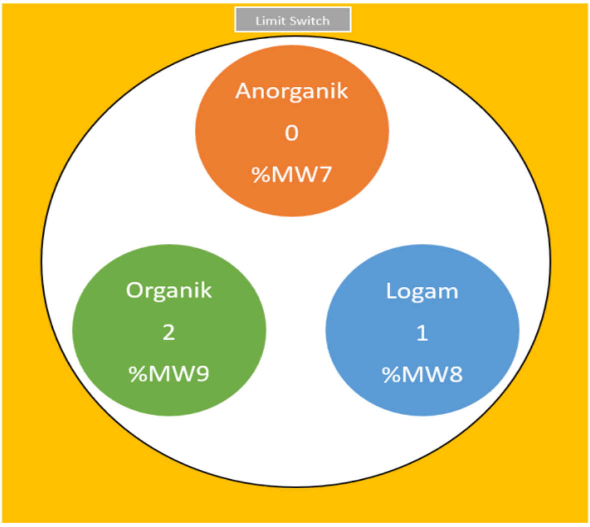

Fig. 4. The default position of waste segregation.

2.4 Hardware plan

Hardware design and implementation involve finding the most efficient model for all the systems created, considering problem factors and the required components' needs. This system is divided into two parts, namely the initial waste receptacle and the final waste receptacle. The initial waste receptacle serves as the point of entry for the waste to be identified by its type. In this section, there are three sensors for detecting the type of waste, placed on the platform of the initial waste receptacle, along with a DC motor. The final waste receptacle consists of three compartments with different names corresponding to the sorting of the waste: organic, inorganic, and metal. These three final waste receptacles are positioned on the platform of the final waste receptacle, which can be rotated by a motor.

When the trash is full, the infrared sensor located above the waste bin will detect the presence of waste and send data information to the HMI via the Modbus Android application on a smartphone. The HMI will issue a warning indicating that the trash is full. It is assumed that an operator will then dispose of the waste, and the final waste container will be empty. The overall device design is depicted in Figure 5.

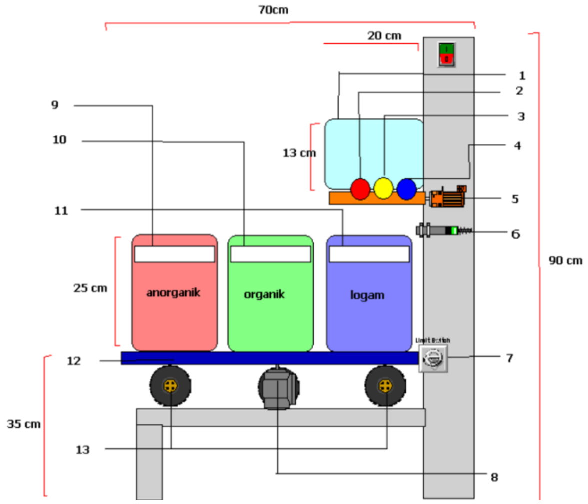

Fig. 5. Hardware planing system

The explanation of the components in Figure 5 of the waste sorting system based on PLC can be found in Table 3.

Table 3. Description of the figure 5.

No	Description	Function
1	Initial Waste Receptacle	Initial container and waste type detector
2	Infrared Sensor	Detects organic waste type
3	Inductive Proximity Sensor	Detects metal waste type
4	Capacitive Proximity Sensor	Detects inorganic waste type
5	DC Motor-1	Acts as a valve and waste stopper
6	Infrared Sensor (for waste level)	Detects waste presence (full/empty)
7	Limit Switch	Detects the container
8	DC Motor-2	Functions as the waste container plate driver
9	Final Waste Receptacle-1	Collects inorganic waste
10	Final Waste Receptacle-2	Collects organic waste
11	Final Waste Receptacle-3	Collects metal waste
12	Waste Container Plate	Serves as the base for the final receptacles
13	3 Support Wheels	Supports the load of waste

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2.5 The HMI display on android

In this design, the HMI display functions to monitor the status of the waste receptacle using an application on an Android smartphone called Modbus. This design presents two conditions, where the first condition is depicted in Figure 3 (left), the initial view on Modbus when the waste receptacle is not yet fully filled. When the final waste receptacle is fully filled, the HMI display will differ from before, as shown in Figure 6 (right). In this HMI scenario, when the waste has reached full capacity, the display will change, a red-colored light will illuminate, and the alert will transform to 'Trash Bin Full, Please Dispose of Trash Immediately!'.

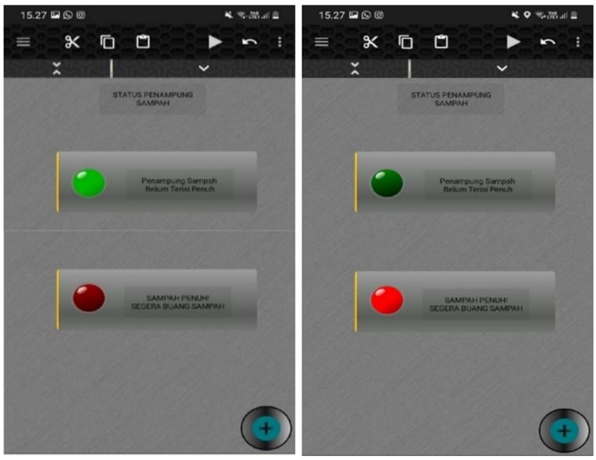


Fig. 6. Initial HMI display (left) and final display (right)

3 Results

The hardware implementation of the waste sorting system based on PLC consists of DC motors, limit switches, proximity sensors, waste receptacle platforms, waste receptacles, and the waste sorting electrical circuit. The hardware setup of the waste sorting system based on PLC can be seen in the figure 5.

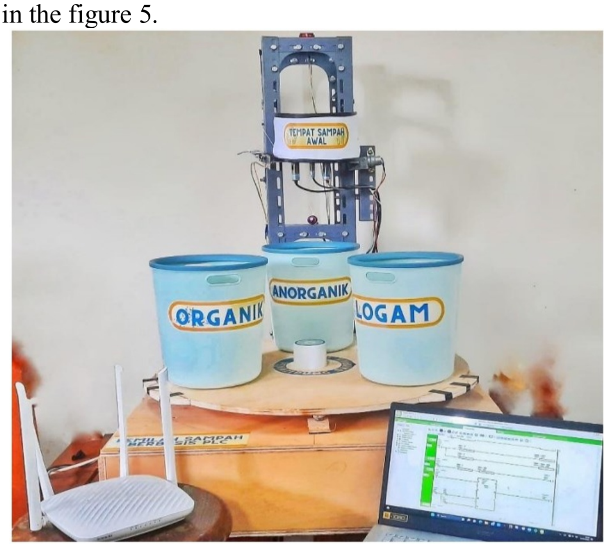


Fig. 5. The hardware implementation results of the Waste Sorting System.

3.1 Observation results of waste type detection sensor

Initial Condition in the System through PLC as shown in Figure 6. All sensors have not detected any waste, and the logic is adjusted according to Table 2. The capacitive proximity sensor uses a normally closed input configuration, where the initial state when no waste is detected is active, so the input needs to be configured as normally closed for the normal condition. However, the logic of using normally closed and normally open configurations in the PLC system is adapted according to the Table 2. SI is for Infrared Proximity Sensor, SIN is for Inductive Proximity Sensor, and SIC is for Capacitive Proximity Sensor.

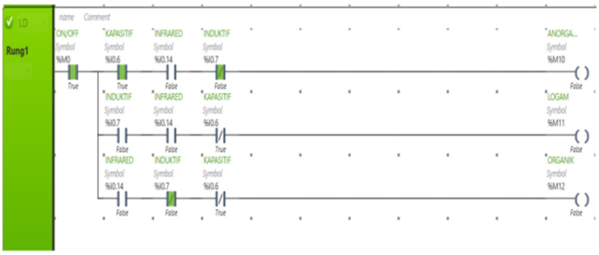


Fig. 6. Initial condition of waste type detection sensor.

3.1.1 Observation data of metal waste

Table 5 represents the data results for metal waste. The experiment was conducted multiple times with various shapes and colors of waste to ensure diverse data outcomes.

Table 5. Observation data of metal waste detection sensor.

Form of Waste	Sensors			Results
	SI	SIN	SIC	
Beverage Can 1	1	1	1	Success
Beverage Can 2	1	1	1	Success
Beverage Can 3	1	1	1	Success
Beverage Can 4	1	1	1	Success
Candy Tin	1	1	1	Success
Metal Lid	1	1	1	Success
Spoon	1	1	1	Success
Metal Waste 1	1	0	1	Unsuccesful
Metal Waste 2	1	1	1	Success
Bolt	1	0	1	Unsuccesful

In the data presented in Table 5, the critical role is the inductive proximity sensor for detecting various shapes, colors, and types of metal waste. The PLC system's response when detecting metal waste can be seen in Figure 7. During the data collection process, errors were encountered, particularly with the bolt and metal waste 1. This was due to the fact that the waste didn't make successful contact with the inductive proximity sensor. Iron waste 1 was too large in size, and the bolt was too small. Based on the observations from the data above, it can be concluded that for accurate detection, the waste needs to make contact with all the sensors, especially the inductive proximity sensor. Additionally, the waste should fit within the initial waste receptacle. The success rate of the metal waste detection sensor is 80%.

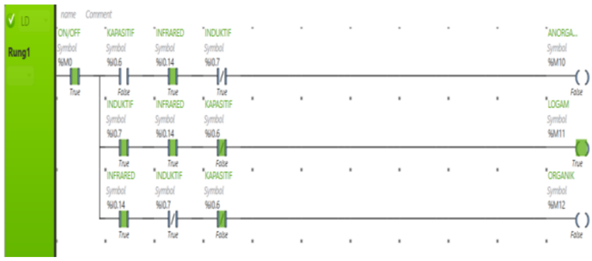
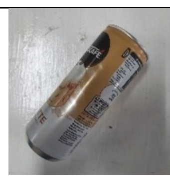


Fig. 7. System when metal waste is detected.

In Table 6, there is an overview of the objects used in Table 5. Each type of waste has different criteria, such as shape, color, and size. This is done to generate a diverse set of data.

Table 6. The object from Table 5.

		
Beverage Can 1	Beverage Can 2	Beverage Can 3
		
Beverage Can 4	Candy Tin	Metal Lid
		
Spoon	Metal Waste 1	Metal Waste 2
		
Bolt		

3.1.2 Observation data of organic waste

Table 7 represents the data results for organic waste. The experiment was conducted multiple times with various shapes and colors of waste to ensure diverse data outcomes.

Table 7. Observation data of organic waste detection sensor.

Form of Waste	Sensors			Results
	SI	SIN	SIC	
Beverage Box	1	1	1	Unsuccessful
Banana Peel	1	0	1	Success
Milk Carton	1	0	0	Unsuccessful
Shampo Box	1	0	1	Success
Colored Paper	1	0	1	Success
Cardboard 1	1	0	1	Success
Cardboard 2	1	0	1	Success
Leaf 1	1	0	1	Success
Leaf 2	1	0	0	Unsuccessful
Plywood	1	0	1	Success
Tissue	1	0	1	Success
Bond Paper	1	0	1	Success

In the data presented in Table 7, the capacitive proximity sensor plays a crucial role in detecting various shapes, colors, and types of organic waste. The PLC system's response when detecting organic waste can be seen in Figure 8. During the data collection process, errors were encountered, particularly with the beverage can, milk carton, and leaf 2. In the case of the beverage can, the error was caused by the presence of aluminum content, allowing the inductive proximity sensor to detect the waste even though the predominant material was paper. For the milk carton and leaf, errors occurred due to the objects being too large, preventing the waste from making proper contact with the capacitive proximity sensor. Based on the observations from the data above, it can be concluded that for accurate detection, the waste needs to make contact with all the sensors, especially the capacitive proximity sensor. Additionally, the waste should fit within the initial waste receptacle. The success rate of the organic waste detection sensor is 75%.

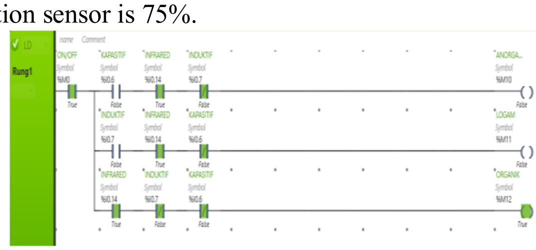
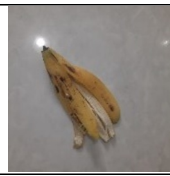
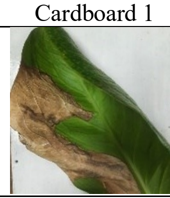
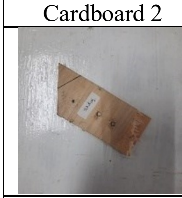


Fig. 8. System when organic waste is detected.

In Table 8, there is an overview of the objects used in Table 7. Each type of waste has different criteria, such as shape, color, and size. This is done to generate a diverse set of data.

Table 8. Object from Table 7.

		
Beverage Box	Banana Peel	Milk Carton
		
Shampo Box	Colored Paper	Cardboard 1
		
Cardboard 2	Leaf 1	Leaf 2
		
Plywood	Bond Paper	Tissue

3.1.3 Observation data of anorganic waste

Table 9 represents the data results for anorganic waste. The experiment was conducted multiple times with various shapes and colors of waste to ensure diverse data outcomes.

Table 9. Observation data of anorganic waste detection sensor.

Form of Waste	Sensors			Results
	SI	SIN	SIC	
Clear Bottle Plastic 1	1	0	0	Success
Clear Bottle Plastic 2	1	0	0	Success
Clear Bottle Plastic 3	1	0	0	Success
Colored Bottle Plastic 1	1	0	1	Unsuccessful
Colored Bottle Plastic 2	1	0	1	Unsuccessful
Clear Glass Bottle 1	1	0	0	Success

 https://doi.org/10.1051/e3sconf/202447505004

Colored Glass Bottle 1	1	0	1	Unsuccessful
Colored Glass Bottle 2	1	0	1	Unsuccessful
Plastic Waste 1	1	0	1	Unsuccessful
Plastic Waste 2	1	0	1	Unsuccessful
Plastic Waste 3	1	0	1	Unsuccessful
Plastic Waste 4	1	0	1	Unsuccessful

In the data presented in Table 9, the important role is played by the infrared sensor in detecting various shapes, colors, and types of inorganic waste, The PLC system's response when detecting inorganic waste can be seen in Figure 9. During the data collection process, there were several errors, such as with glass bottles, beverage bottles, and plastic waste. These errors occurred because the waste was also detected by the capacitive proximity sensor. Errors also arose due to objects being too large or too small, preventing the waste from properly contacting the infrared sensor. Based on the observations from the data above, it can be concluded that for accurate detection, the waste needs to make contact with all the sensors, especially the infrared sensor. Additionally, the waste should fit within the initial waste receptacle. anorganic waste that can be successfully detected includes transparent anorganic (not colored waste include white and black color/only clear color waste) waste like plastic bottles (clear color), glass bottles (clear color), and acrylic (clear color). The success rate of the inorganic waste detection sensor is 33.33%.

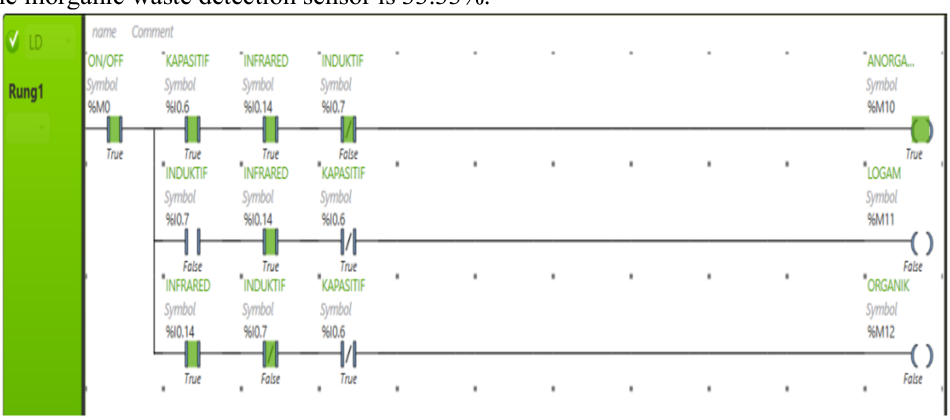


Fig. 9. System when anorganic waste is detected.

In Table 10, there is an overview of the objects used in Table 9. Each type of waste has different criteria, such as shape, color, and size. This is done to generate a diverse set of data.

Table 10. Object from Table 9.

		
Clear Bottle Plastic 1	Clear Bottle Plastic 2	Clear Bottle Plastic 3
		
Colored Bottle Plastic 1	Colored Bottle Plastic 2	Clear Glass Bottle 1
		
Colored Glass Bottle 2	Colored Glass Bottle 1	Plastic Waste 1
		
Plastic Waste 2	Plastic Waste 3	Plastic Waste 4

Based on observations of the waste detection process using 3 proximity sensors, each type of waste exhibits various errors, primarily stemming from objects being either too large or too small. This necessitates adjusting the waste to ensure contact with all sensors. Consequently, in some cases, waste might not be accurately detected because it doesn't touch all three sensors. Waste must make complete contact with all three sensors for the logic in the PLC program to align with Table 2. Failure to make contact with all three sensors can lead to incorrect waste type detection, causing waste to be sorted improperly.

In the case of anorganic waste, there are also numerous errors. In Table 9, the Proximity Capacitive Sensor in the system often detects waste, which leads the system's logic to indicate organic waste. To differentiate between organic and inorganic waste, in accordance with the experiments using the Proximity Capacitive Sensor in Table 1, specific criteria need to be applied to anorganic waste to enable the system to distinguish between the two types. Therefore, the criteria for identifying inorganic waste, ensuring proper system performance, involve it not being colored or transparent, as indicated in Table 9 with the "successful" label. If the capacitive sensor detects an object, the system processes it as metal waste if the inductive sensor detects something or as organic waste if it doesn't.

Meanwhile, the most accurate detection occurs with metal waste. The inductive proximity sensor can discern a narrower range of materials, specifically metals, making it highly accurate. The inductive proximity sensor can even detect metal objects obstructed by paper stickers as long as they remain within its detection range.

3.2 Waste sorting data results from motor rotation

Waste sorting is carried out by rotating the final waste receptacle plate according to the type of waste initially detected. Data collection for waste sorting is aligned with Table 3.5. The position of the initial and final waste receptacles is in a single line, representing the inorganic waste type (default condition). Waste disposal is done randomly to demonstrate the operation of the DC-2 motor rotating either in a clockwise (CW) or counterclockwise (CCW) direction, confirming the proper rotation of the waste sorter without returning to the home base, as shown in Table 11.

Table 11. Process of DC-2 motor sorting waste.

Form of Waste	Type of Waste	Motor Rotation		Result
		CW	CCW	
Papper	Organic	1	0	Success
Glass Bottle	Anor	0	1	Success
Cardboard	Organic	1	0	Success
Beverage Can 1	Metal	1	0	Success
Beverage Can 2	Metal	0	0	Success
Leaf	Organic	0	1	Success
Banana Peel	Organic	0	0	Success
Beverage Can 3	Metal	1	0	Success
Plastic Bottle 1	An-or	1	0	Success
Plastic Bottle 2	An-or	0	0	Success
Plastic Bottle 2	An-or	0	0	Success

From this data, the waste sorting process through DC Motor-2 is carried out by rotating the final waste container plate. The final waste container plate, which holds 3 compartments for the final waste collection, rotates both clockwise (CW) and counterclockwise (CCW), according to the detected waste type.

3.3 Limit switch data as input to PLC

In the waste sorting process using DC Motor-2, the input data to the PLC program is essential, and this is achieved using a limit switch. This is crucial because, during some trials, the limit switch might not make proper contact. The input data from the limit switch will be stored in memory and used to determine whether the motor will rotate clockwise (CW) or counterclockwise (CCW). The data in Table 12 represents the input data from the limit switch, starting from 0 after waste is re-detected and the motor rotates. The limit switch also serves the purpose of stopping the rotation of the final waste container plate.

Looking at the data generated in Table 12. The observation of the input data count from the limit switch shows a 100% success rate in the input received by the PLC program. As a result, DC Motor-2 can rotate both clockwise (CW) and counterclockwise (CCW) as needed, stopping according to the waste sorting type.

Table 12. Limit switch data as input to PLC.

Form of Waste	Type of Waste	CW/ CCW	input	Result
Paper	Organic	CW	1	Success
Glass Bottle	An-or	CCW	1	Success
Cardboard	Organic	CW	1	Success
Beverage Can 1	Metal	CW	1	Success
Beverage Can 2	Metal	-	0	Success
Leaf	Organic	CCW	1	Success
Banana Peel	Organic	-	0	Success
Beverage Can 3	Metal	CW	1	Success
Plastic Bottle 1	An-or	CW	1	Success
Plastic Bottle 2	An-or	-	0	Success

3.4 Observation results of waste full/empty status data

This success is based on the detection of the infrared sensor. The infrared sensor will detect if an object is in front of it at a distance of approximately 0-30 cm. When an object is detected, as shown in Figure 11, a red LED indicator will light up. In this system, this detection is used as input when the waste is full. When the waste container is full and exceeds its capacity, or when the infrared sensor detects an object in front of it, the infrared sensor will provide an input that is then sent to the HMI to trigger a notification indicating that the waste is full.

Fig. 11. Waste when the storage full.

The system operation relies on the information provided by each infrared sensor when detecting the presence of waste. If an infrared sensor detects the presence of waste, the HMI will issue a warning. The initial condition displayed on the HMI when no waste is detected is that the LED indicator is off, and the condition of detection can be observed figure 12.

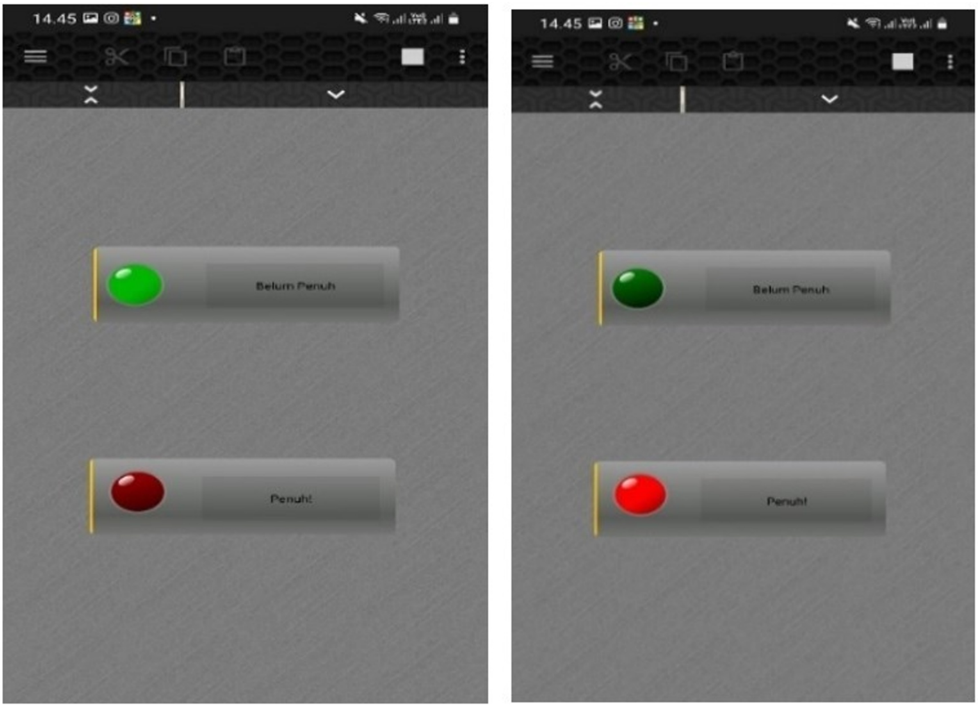


Fig. 12. HMI when no waste is detected (Left) and when waste is detected (Right).

4 Conclusions

From the design and testing results of the "PLC-Based Waste Sorting System," several conclusions can be drawn, including:

1. The PLC-based waste sorting system has a success rate of 90.37% when it comes to anorganic waste selection according to the set criteria. Various types of waste have criteria to ensure proper sorting:
   a. Waste must come into contact with all type-detection sensors for accurate sorting.
   b. In the case of anorganic waste, the system successfully detects clear-colored waste.
2. The system effectively sorts waste, achieving proper rotation of the DC-2 motor in both clockwise (CW) and counterclockwise (CCW) directions. The motor halts accurately based on its designated position by interacting with the limit switches, allowing waste to be deposited correctly into the final waste receptacle.
3. Remote monitoring using an Android smartphone was successful. Communication between the M221 PLC and the HMI application using Modbus on the smartphone operated smoothly, resulting in effective SCADA system performance.

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