

Consumer Counting System in Stores Based on Internet of Things (IoT) With ESP 32 Microcontroller and Ultrasonic Distance Sensor

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ABSTRACT

In the era of modern technology, efficiency and accuracy in store management have become very important. This research aims to develop an Internet of Things (IoT) based consumer counting system using an ESP32 microcontroller and an ultrasonic distance sensor. This system is designed to help shop owners monitor the number of consumers who come so they can improve stock management and services. The research method used is a prototype, starting from needs analysis, system design, and prototyping to implementation and testing. The research results show that this system is able to detect consumers with high accuracy; the 1% error that researchers got was because the ultrasonic sensor was delayed and displayed the number of consumers on the I2C LCD screen as well as the Blynk IoT application. This system is expected to provide practical solutions for shop owners to optimize shop operations.

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1. Introduction

In this modern era, technological advancements have made many things more accessible. As technology continues to develop, numerous innovations keep emerging, making it essential to monitor technological advancements closely. In modern stores, knowing the number of customers visiting the store daily is crucial information for store owners. This information helps in stock planning, customer behaviour analysis, and improving service quality. For this purpose, an IoT-based system with the ESP32 microcontroller and ultrasonic distance sensors has been developed to automatically and in real-time count the number of customers. This research discusses an Internet of Things (IoT) based system used to count the number of customers at Toko Dian Mukti, utilizing the ESP32 microcontroller and ultrasonic distance sensors [1].

Nowadays, microcontroller devices are often used to facilitate work in this digital era. Therefore, this system will help store owners efficiently track the number of customers without consuming much time. In this customer counting system, the device will be placed at the cashier to ensure accurate counting and optimal functionality. This system is also capable of storing the number of customers through the Blynk IoT application to help store owners know the daily number of customers. Store owners need not worry about potential malfunctions because this system is meticulously built to avoid errors or breakdowns [2].

A new problem arises in crowded places, such as stores, where it becomes difficult to ascertain whether the number of customers visiting the store has increased compared to the previous day. To address this issue, researchers have developed a system to count the number of customers queuing at the cashier. This system is designed to provide accurate data on the number of customers visiting the store and queuing at the cashier. This data is crucial for store owners to make strategic decisions in stock management [3].

In this paper, researchers apply the prototype method to design a system intended for use in stores. The prototype method itself is an approach in system development where an initial model of the system

(prototype) is created, tested, and iteratively improved based on user feedback and test results, with the hope that this customer counting system can function without errors [4].

2. Methods

The method used by the researchers to create this journal involves data collection and the use of the prototype method [5]. The stages are as follows:

- a. Literature Review: In the literature review stage, the researchers collected data from various sources such as theses, scientific journals, and the internet. This process aims to refer to and draw from the information available in related literature. By investigating these various sources, the researchers can gain a more comprehensive understanding of the topic being studied. This step is crucial in building a strong knowledge base and ensuring that the resulting journal has a solid theoretical foundation and is relevant to the research context [6].
- b. System Analysis: The analysis aims to provide direction and determine the subsequent stages of work in terms of policy determination [7]. The stages in system analysis include:
 - i. Problem Analysis: This stage aims to identify the problems occurring in the existing or ongoing system [8].
 - ii. Requirement Analysis: This stage is conducted to determine the hardware and software requirements to be used [9].
 - iii. Feasibility Analysis: Based on the requirement analysis, this stage aims to evaluate whether the planned system is feasible to proceed with in terms of technology and operations [10].
 - iv. Current System Analysis: This stage is conducted to understand the current system or processes in place [11].
- c. System Prototype Development: In the system prototype development stage, a series of processes are carried out, including designing, building, coding, and testing the system from the initial to the final stages. This process aims to produce a prototype that is not only functional but also can be effectively implemented at Toko Dian Mukti. The steps involved include selecting components, assembling the device, testing functionality, and making adjustments so that the device can operate optimally in the actual store environment. Therefore, this stage is key in ensuring that the resulting prototype is ready to be used to monitor the number of customers entering the store accurately and efficiently [12].

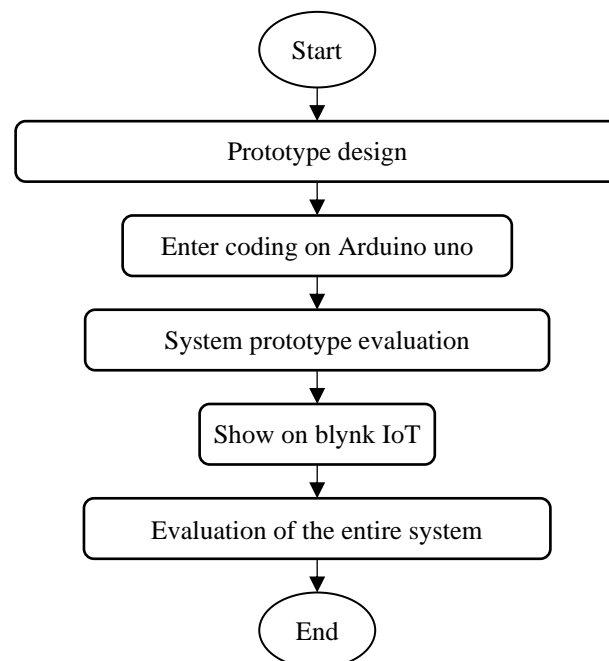


Figure 1. Research Implementation Flowchart

Figure 1 is a flowchart of the research implementation flow. This flowchart is created to facilitate researchers in conducting the research implementation flow[13].

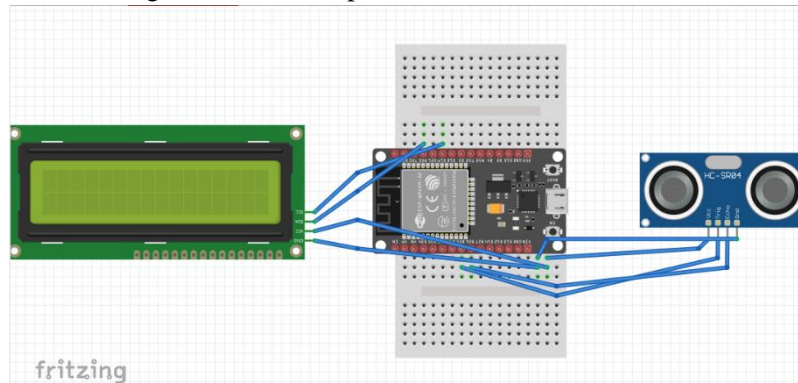


Figure 2. Customer Counting System Design

Figure 2 is the design of the customer counting system. The researchers used Fritzing to create the design, as shown above [14].

- d. System Implementation: In this stage, the results of the customer counting system are presented, and the system is tested by comparing it with systems created by others. Subsequently, the results of these tests will be evaluated [15].

3. Results and Discussions

This research aims to create a technology-based solution utilizing the Internet of Things (IoT) to enhance store management efficiency. The focus is on developing a customer counting system using the ESP32 microcontroller and ultrasonic distance sensors. The research results show that this system can help store owners, such as Toko Dian Mukti, to monitor the number of customers more easily. This allows for faster and more accurate decision-making in managing their stores.

The customer counting system is built using several main components: an ESP32 microcontroller, ultrasonic sensors, and an I2C LCD as the output device to display the number of detected customers. This system is installed in the cashier area and designed to detect every movement of a person passing by the ultrasonic sensor. Subsequently, the customer count data will be displayed on the LCD screen. Below is an image of the system created by the researchers, along with a list of components used to ensure accuracy and optimal performance.

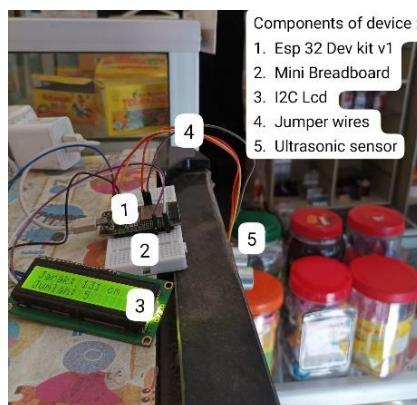


Figure 3. System Placement at Toko Dian Mukti

Figure 3 shows the placement of the system, with the research conducted at Toko Dian Mukti located in Sawahan Ngemplak Boyolali. The research was carried out routinely over four days to determine the number of customers, and this data is included in the results and discussion section. The customer counting system is placed at the cashier to ensure that the ultrasonic sensor can accurately

count the number of customers. The researchers monitored the customer counting system results via Blynk IoT.



Figure 4. I2C LCD Output Display

Figure 4 shows the output display of the I2C LCD. This system uses a 16x2 I2C LCD to display the customer count. The 16x2 I2C LCD itself is a display module commonly used in various IoT or electronics projects, especially those involving microcontrollers such as the Arduino Uno and ESP32. This module combines an LCD screen with an I2C (Inter-Integrated Circuit) interface module, simplifying the connection and control of the display. The I2C LCD connected to the ESP32 and the ultrasonic sensor will display the detected customer count. To connect the I2C LCD to the ESP32 and the ultrasonic sensor, the researchers used the following pin connections: VCC: 5V, GND: GND, SDA: I2C SDA pin (default on ESP32: pin 21), SCL: I2C SCL pin (default on ESP32: pin 22).

Overall, the 16x2 I2C LCD is a very popular choice among the maker and electronics development community due to a combination of various factors that make it very efficient and practical to use. Its ease of use makes it an ideal tool for both beginners and experts, as it can be easily integrated into various projects with minimal setup. Additionally, the flexibility offered by the 16x2 I2C LCD allows users to display a wide range of information, from simple text to complex sensor data, with excellent clarity. Its capacity to display information clearly and easily readable on two lines with sixteen characters per line makes it very suitable for applications that require concise yet informative data displays. With all these advantages, it is no surprise that the 16x2 I2C LCD is a preferred component for many electronic and IoT projects worldwide, whether for smart home applications, monitoring systems, or various other innovative projects.

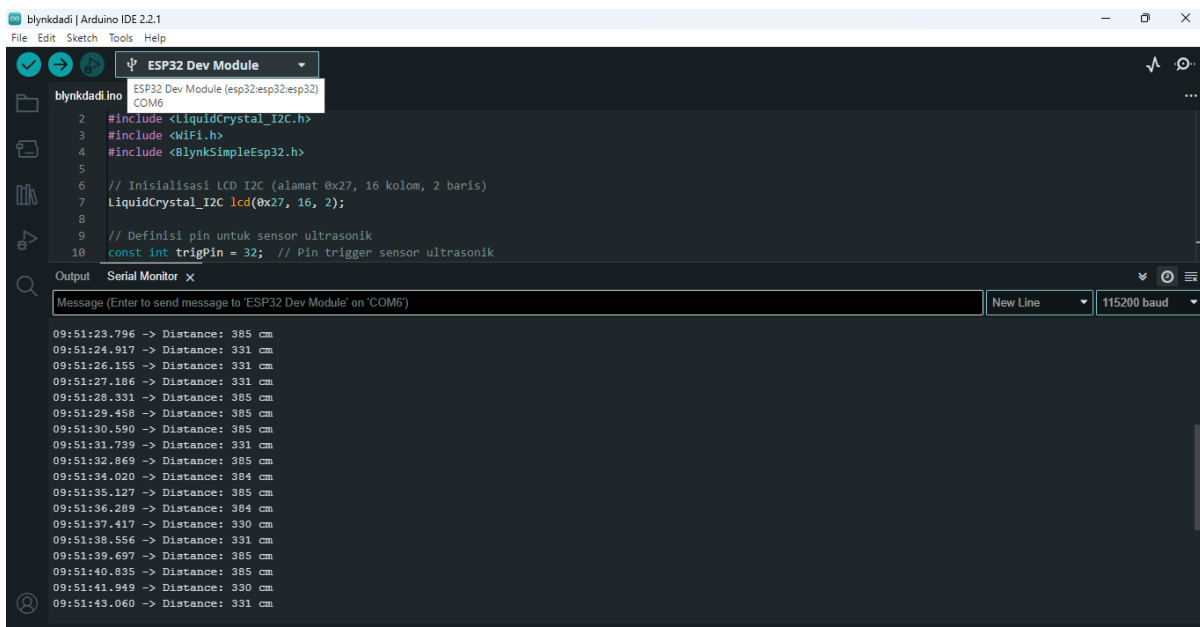


Figure 5. System Accuracy Data

Figure 5 shows the system accuracy data on the Arduino IDE. Data accuracy in the Arduino IDE system is crucial to ensure that the system functions correctly and reliably. Several factors affect data accuracy, and there are several ways to optimize it, including sensor type and calibration. The type of sensor used in a system greatly influences the accuracy of the data produced. More expensive and precise

sensors are usually able to provide more accurate data compared to cheaper and less precise sensors. Therefore, selecting the right sensor is essential to achieve optimal results. Moreover, proper calibration is also a crucial aspect of ensuring sensor reading accuracy. The calibration process involves adjusting the sensor against known reference values so that the sensor can provide output that matches the correct values. For example, for ultrasonic sensors, calibration can be done by measuring the distance to an object with a known distance and then adjusting the sensor output to match the correct value. Thus, proper calibration can enhance the reliability and accuracy of the data produced by the sensor.

Figure 6 shows the Blynk IoT display. Blynk IoT is an Internet of Things (IoT) platform that simplifies IoT application development by providing tools to control hardware through a smartphone app. In the context of counting visitors, Blynk IoT allows users to monitor real-time data from sensors connected to microcontrollers like ESP32. The Blynk IoT application is available for Android and iOS, providing a customizable user interface with widgets like graphs, labels, buttons, and more to display sensor data and control devices. Blynk can store or process data from the ESP32 microcontroller, but it requires an upgrade to the paid mode for advanced features.



Figure 6. Blynk IoT Display

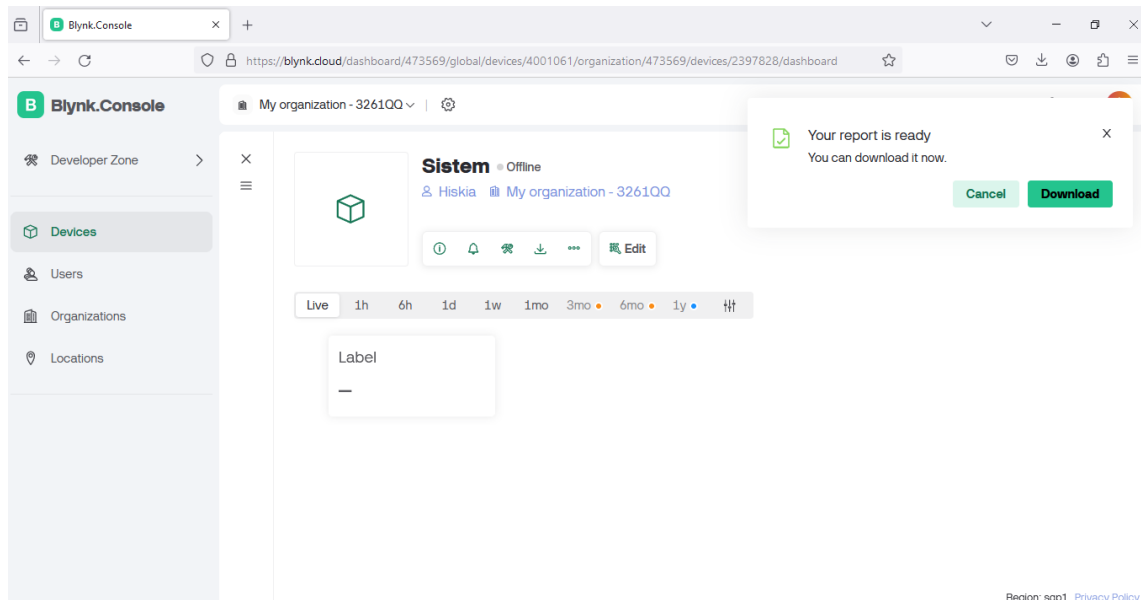


Figure 7. Blynk IoT Data Saving

Figure 7 shows the Blynk cloud data download on a PC. This download can be performed when upgraded to the paid version. Blynk Cloud is a cloud platform used by Blynk to store and manage data from connected IoT devices. With Blynk Cloud, users can access, monitor, and download data collected by their devices, such as visitor count data from ultrasonic sensors connected to the ESP32 microcontroller.

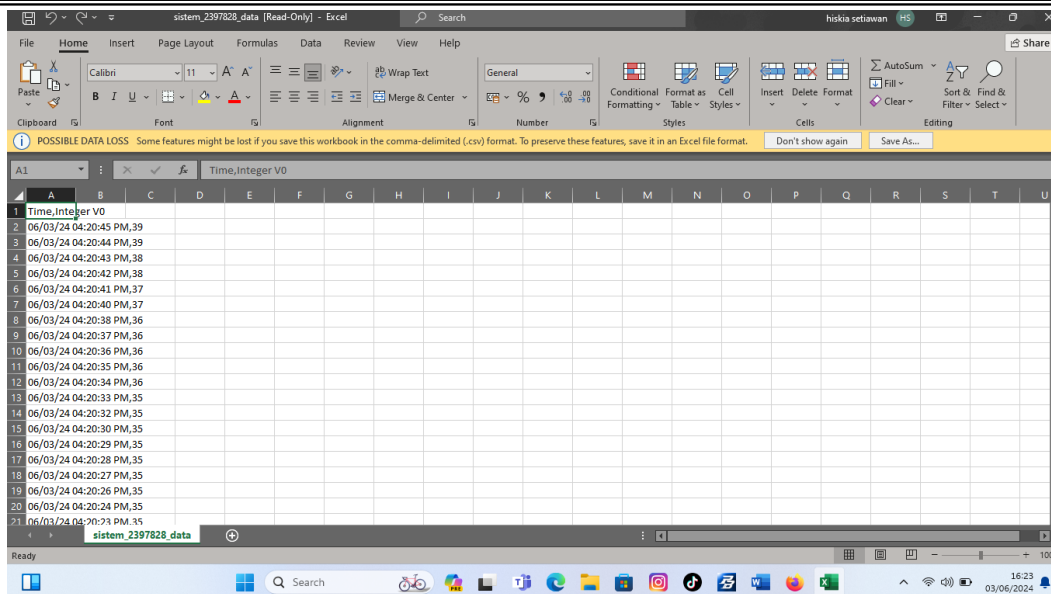



Figure 8. Downloaded Data Result

Figure 8 shows the result of downloaded saved data from Blynk IoT. When the data collected from IoT devices using Blynk Cloud is downloaded, it is often packaged in a ZIP file format. The ZIP format is used to compress and combine multiple files, making data distribution and storage easier.

After selecting the time range and downloading data from Blynk Cloud, the downloaded file usually has a .zip extension. The steps to download the data are: Log in to the Blynk web dashboard, navigate to the relevant project and find the option to download data, select the time range, click the button to download the data, and the ZIP file will be downloaded to the device's file explorer.

This system testing aims to determine the number of customers detected by the ultrasonic sensor and then displayed on the integrated I2C LCD. The testing process is conducted to ensure the system's reliability and accuracy in counting the number of customers entering the store. This testing was carried out for four consecutive days, starting from Monday, June 3, 2024, to Thursday, June 6, 2024. Data was collected continuously each day to ensure that the system could operate well under various operational conditions, including variations in the number of customers and their arrival times. During the testing period, several important parameters were recorded, such as the total number of customers detected each day, peak arrival times, and the accuracy of sensor detection under different environmental conditions. The purpose of this testing is to ensure that the system can provide accurate and reliable data that can be used for further analysis and store operational planning. The results of this testing are summarized in the table below, which provides a comprehensive overview of the performance of the customer counting system during the testing period. This table includes details of the number of customers detected per day, as well as an analysis of any anomalies or inconsistencies that may have arisen during the testing. Thus, this testing provides a solid foundation for the evaluation and further development of the IoT-based customer counting system.

Table 1. Customer Counting System Testing

Day Testing	Input number of consumers	I2C lcd display
Day 1	39	


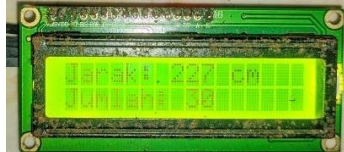
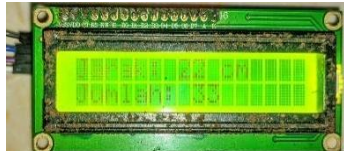
Day Testing	Input number of consumers	I2C lcd display
Day 2	41	
Day 3	30	
Day 4	33	

Table 1 shows the results of the system testing. After a thorough testing process at Toko Dian Mukti, the designed and developed system successfully demonstrated a satisfactory level of accuracy, as shown in Figure 5, in counting the number of customers entering the store. Additionally, data related to the number of customers entering is automatically recorded and stored in the Blynk IoT application. Integration with the Blynk IoT platform provides additional benefits by enabling real-time monitoring. This way, the system not only facilitates store management but also provides valuable insights for more strategic and effective decision-making in managing the business.

After testing the developed system, the researcher conducted a comparison with the system created by Lilik Suhery, Noviardi, and Yessa Marlisa, titled "Design of Visitor Counting System Using Arduino Uno and Ultrasonic Sensor." The differences between the researcher's system and the one made by Lilik Suhery, Noviardi, and Yessa Marlisa are the absence of an I2C LCD in their system and the use of different microcontrollers: ESP32 in the researcher's system and Arduino Uno in theirs. The ESP32 is more efficient than the Arduino Uno. The ESP32 is more efficient because it has a dual-core processor that runs at 240 MHz, while the Arduino Uno has an 8-bit processor running at 16 MHz. Additionally, the ESP32 is equipped with Wi-Fi and Bluetooth, making it easier to connect to networks without requiring additional modules, whereas the Arduino Uno needs external modules for connectivity.

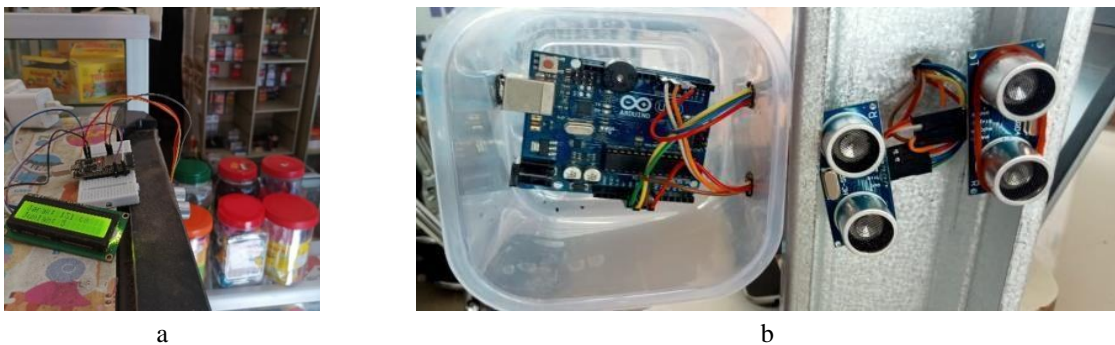


Figure 10. Researcher's System (a) and System by Lilik Suhery, Noviardi, Yessa Marlisa (b)

Figures 10a and 10b show the comparison. The components used by the researcher include the ESP32 Dev Kit V1, a mini breadboard, jumper wires, an I2C LCD, and an ultrasonic sensor. In contrast, the components used by Lilik Suhery, Noviardi, and Yessa Marlisa include the Arduino Uno, jumper wires, a buzzer, and an ultrasonic sensor.

A comparison of the systems built by the researcher and by Lilik Suhery, Noviardi, and Yessa Marlisa reveals key differences: the systems use different microcontrollers (ESP32 vs. Arduino Uno), and the system by Lilik Suhery, Noviardi, and Yessa Marlisa does not include an I2C LCD, which is used to display the number of visitors passing the ultrasonic sensor. On the other hand, the researcher's system does not use a buzzer, so no sound is produced when someone passes by the sensor.

4. Conclusion

This research successfully developed an Internet of Things (IoT)-based customer counting system at Toko Dian Mukti. The system is designed to help store owners monitor the number of customers visiting the store more efficiently and accurately. Through the implementation of this system at Toko Dian Mukti, the test results show that the system is capable of detecting customer movements with a high level of accuracy and displaying the customer count data in real-time on an I2C LCD screen as well as the Blynk IoT application.

The success of this system not only facilitates store management but also has the potential to improve stock management and the quality of customer service. With more accurate monitoring, store owners can make more precise and quicker decisions in various operational aspects. An example of store inventory management is using customer count data to adjust stock levels.

Overall, the use of IoT technology in this customer counting system demonstrates that the integration of modern technology can provide significant benefits in retail business management, particularly in terms of operational accuracy. This research also opens opportunities for more comprehensive future development, such as integration with data analytics to gain deeper insights into customer behaviour and enhancing sensor capabilities to ensure higher reliability and accuracy of the data. Thus, the implementation of this technology not only enhances the current system's performance but also provides a solid foundation for continuous innovation in the future.

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