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DESIGN OF AN IOT-BASED LONG-DISTANCE CONTROL SYSTEM MODEL FOR ESCALATORS AT AIRPORT

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Abstract
The current manual system at Sultan Mahmud Badaruddin II Airport presents significant challenges in the real-time monitoring and control of escalators, resulting in inefficiencies and delays in addressing operational issues. These limitations can result in prolonged downtime, increased maintenance costs, and potential safety risks for passengers. To address these issues, this study proposes an IoT-based control system model designed to enhance the operational efficiency and safety of escalators. This research employs the Research and Development (R&D) method, utilizing the Borg and Gall model, to design, develop, and evaluate the system. The system integrates ultrasonic sensors to detect passenger movement and transmits data via an ESP32 microcontroller to a central control center for real-time analysis. This approach enables continuous monitoring, immediate detection of system anomalies, and prompt responses to technical issues. Additionally, the IoT system reduces downtime by providing technicians with real-time data, thereby ensuring a faster resolution of escalator problems. Testing results indicate that the system performs well under various conditions, including high passenger traffic, making it a reliable solution for the airport. By implementing this IoT-based control system, escalator operations at the airport are expected to become more efficient, safe, and reliable, ultimately improving the overall passenger experience while reducing maintenance costs and downtime.
Keywords: *Internet of Things, Escalator, ESP 32*

Introduction

The significant role of internet usage today has expanded into all aspects of societal needs (Wibowo, S., & Kurniawan, 2018), then humans are required to be able to carry out various activities in a relatively short period of time. The advancement of technological knowledge has also extended into various sectors and has been particularly implemented in the aviation industry (Karaman et al., 2018) . The development of technology in aviation has led to an increase in the number of passengers. This is evidenced by data from the Central Bureau of Statistics (BPS), which shows a sharp rise in passenger movement at Sultan Mahmud Badaruddin (SMB) II Airport in Palembang from year to year (Purwanto & Sunandar, 2019), as illustrated in Figure 1.

Figure 1. SMB II Palembang Passenger Number Graph
(Source: Badan Pusat Statistika, 2023)

The increasing mobility of air traffic passengers demands that aviation sector workers further optimize operational efficiency (Supardam & Raza, 2023). Therefore, the government, through PM 24 of 2019 on the Organization and Work Procedures of Palembang Aviation Polytechnic, has established the Applied Bachelor's Program in Airport Engineering Technology with a vocational education system to prepare professionals who are ready to apply, develop, and disseminate optimal knowledge and technology in the transportation sector (Wijaya, 2021).

In the current era of globalization, automatic control systems in technology have been rapidly advancing (Sanaris & Suharjo, 2020). Sultan Mahmud Badaruddin II (SMB II) Airport in Palembang has made significant progress in its operational management by implementing a Building Automation System (BAS) for remote control. The implementation of BAS at SMB II Airport offers advantages, including integration with various terminal systems such as lighting, temperature control, security, and other facilities. This greatly enhances energy efficiency, reduces operational costs, and creates a more comfortable environment for passengers. The central control provided by BAS also enables more effective and efficient management of various operational aspects within the airport terminal (Prianto & Lisdawati, 2021). The condition of the BAS control desk at SMB II Airport can be seen in Figure 2.

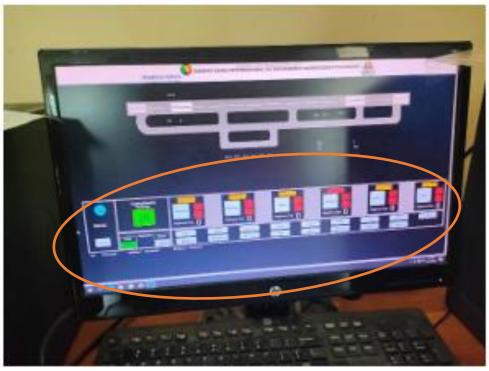

Figure 2. Bas Control Desk
(Source: Author documentation, 2023)

Despite its success, the BAS at SMB II Airport in Palembang has several limitations that need to be taken into consideration. One of its main limitations is its flexibility, as it relies on cables as the primary transmission medium (Moraes et al., 2024). These cables restrict network expansion and make it difficult to adapt to potential changes. Due to these limitations, the BAS cannot be applied to mechanical devices such as escalators, which require highly responsive monitoring systems to support passenger movement within the airport terminal.

Escalators, as supporting infrastructure in airport terminals, are devices that transport passengers between floors (Janaldi et al., 2018). At SMB II Airport in Palembang, escalators are still operated manually. Given the large area of the SMB II Airport, the high workload of technicians and field operators, and the limited number of available technicians (only 2–3 personnel), manual operation of escalators requires significant time and effort. Therefore, transitioning to an automation system for remote control of escalators is necessary. Table 1 presents data on the total number of manually operated escalators at SMB II Airport in Palembang.

Table 1. SMB II Palembang Airport Escalator Data Classification

Jumlah	Merek	Location
1 Unit	Hyundai	Domestic Arrival Terminal
1 Unit	Hyundai	International Arrival Terminal
1 Unit	Hyundai	Departure Terminal
3 Unit	Hyundai	Waiting Room
1 Unit	Guangri	Terminal Office
2 Unit	Hyundai	Sky Bridge to LRT Station

Considering the workload of technicians in manually operating escalators, the author sees potential in developing a control system based on IoT. The Internet of Things (IoT) is a system that transfers data over the internet and can operate autonomously. IoT enables physical objects to interact with the internet and share data with other devices (Hidayat & Sari, 2021). A previous IoT implementation was conducted by (Faizah et al., 2021), who applied IoT to the lighting control system in the Terminal Room at Aji Pangeran Tumenggung Pranoto Airport. This research successfully assisted field technicians by eliminating the need for manual access to the lighting control points. The study's results demonstrated that IoT implementation can enhance operational efficiency at airports.

Building on the success of previous research, this study investigates how the integration of IoT into the system can improve operational efficiency and security. Additionally, this system can help reduce operational costs and improve service quality (Mayangsari & Yuhendri, 2023). It is hoped that this study can be implemented on escalator devices at SMB II Airport in Palembang, assisting field technicians in operating the equipment more effectively and efficiently.

Methods

The author employs the Research and Development (R&D) method, which is a process or set of steps used to develop a new product or refine an existing one. According to (Fujiwara, 2024) R&D is a research method to develop and test products that will later be used in education. Various kinds of research models like borg & gall can be used as a reference in this Research and Development research (Delamare et al., 2024). R&D is a research and development process aimed at creating, understanding, and advancing new products, technologies, or techniques. The R&D process includes activities such as researching new technologies, experimenting with new materials, and developing product prototypes (Rumetna et al., 2020).

The development of this system is carried out using the Research and Development (R&D) method, adapting the model from (Pata et al., 2024). As explained, this study follows the Borg & Gall development model, where a needs analysis is conducted to ensure the creation of a suitable product. The R&D method employed in this product development represents the culmination of the research. The Borg & Gall model, based on research (Husni, 2023),The Borg & Gall model consists of ten (10) steps for developing a model or product. However, due to the limitations of this study, it has been summarized into six (6) development stages of the Borg & Gall model. The following are the research stages:

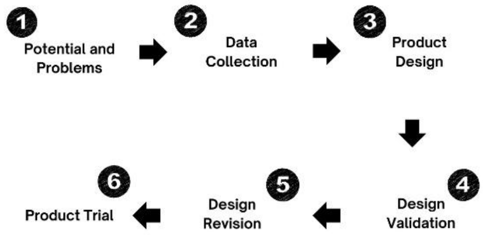

Figure 3. Bas Control Desk
(Source: Author documentation, 2023)

In this study, the author adopts the Borg & Gall development research model from (Rabiah & Widodo, 2023), which consists of 10 stages. However, by adjusting to the research problem formulation and limitations, the author implements only 6 stages of the Borg & Gall model. A similar approach was also applied by (Amalia et al., 2022), who adapted the Borg & Gall model into 3 stages to accommodate a more streamlined and flexible methodology aligned with their research approach. The author limits the use of the Borg & Gall method up to the 6th stage due to time constraints in completing this study. These limitations arise from several factors, including a tight research schedule and limited resources. Therefore, the author chooses to focus on the first six stages of the Borg & Gall model, which are considered the most relevant and capable of making a significant contribution to achieving the research objectives.

Results And Discussions

Based on research into the design of an IoT-based control system (Carli et al., 2020) for escalators to support more efficient and effective device operation by technicians, the study employs an R&D research design. In the Borg & Gall development model, there are ten (10) stages required to ensure that the designed product meets feasibility standards based on research (Rahayu et al., 2022). However, in this study, the process is summarized into six (6) stages, considering time and budget constraints.

The initial stage in developing this model involved conducting a needs analysis through an initial observation with the mechanical maintenance unit at SMB II Airport, Palembang, from October to December 2023. This analysis aimed to understand the actual conditions and needs in the field, ensuring that the designed model aligns with existing operational requirements. The development of this control system model focuses on the operational activities of escalator devices, which mechanical technicians carry out. During the observation, the researcher identified that current operations still rely on manual methods, as well as TQM devices, including escalators (Alawag et al., 2023). This manual method is considered ineffective and inefficient for several reasons. The vast airport area requires technicians to physically move from one location to another for monitoring and troubleshooting escalators, which consumes a significant amount of time and energy.

The heavy workload of technicians and field operators often overburdens them, especially given the limited number of personnel, which typically consists of only 2–3 people. This condition forces technicians and operators to work extra hard to ensure that all equipment functions properly. Based on the explanation above, the manual method not only requires more time and effort but also hinders the technicians' ability to respond quickly in emergencies. If a sudden malfunction or emergency occurs with the escalator, technicians cannot respond immediately, as they first need to locate the device. This delay increases safety risks for airport users and disrupts overall airport operations.

Currently, SMB II Airport Palembang has implemented a Building Automation System (BAS) to enhance its services. This integrated Building Automation System (BAS) is connected to various systems, including lighting, temperature control, and security. The centralized control provided by BAS enables more effective and efficient management, while also reducing energy consumption and operational costs. However, despite its significant benefits, BAS has limitations when applied to TQM devices such as escalators, which interact directly with passengers. This is because BAS is not designed to monitor device conditions in real-time, which is essential for escalator operations. **Figure 3** illustrates the manual operation still being carried out at the SMB II Airport in Palembang.

Figure 4. Manual Operation of Escalator
(Source: Author documentation, 2024)

The limitations of manual operations highlight the need to develop a control system capable of real-time monitoring of escalator conditions. With this system, technicians can supervise and control escalators remotely via a smartphone, eliminating the need for physical movement. This system will enable early detection of issues, generate automatic alerts in the event of malfunctions, and facilitate quick intervention by technicians.

Considering the current challenges, the author sees potential in the development and implementation of a control system for escalators using IoT technology. The obstacles in manual escalator operations, such as limited technician availability, slow response times, and the need for physical monitoring in a large area, highlight the urgent need for an integrated solution.

This research focuses on the development of an IoT-based Remote Control System Model for Escalators. The model is designed to enable real-time monitoring and control of escalators from a central control system (Osipov et al., 2022), eliminating the need for technicians to be physically present at each location. With IoT implementation, the ESP32 module connected to the device will continuously transmit data to the system, enabling early detection of issues, predictive maintenance, and prompt intervention in the event of malfunctions (Hercog et al., 2023).

The main objective of developing this model is to enhance efficiency, effectiveness, and safety in SMB II Airport Palembang operations. With this system, technicians can monitor escalator conditions at any time and from anywhere, significantly reducing the time and effort required for manual operations. Additionally, the system will provide automatic alerts and periodic condition reports, enabling management to take preventive actions before issues become more serious.

The author collected data related to the operation of escalator systems at SMB II Palembang during the On-the-Job Training (OJT) program. During the OJT, the author conducted observations alongside the mechanical technician team to gain an in-depth understanding of how the escalators operate and to identify areas that needed improvement or development. These observations included direct monitoring of escalator performance, maintenance activities, and user interactions with the system under various operational conditions.

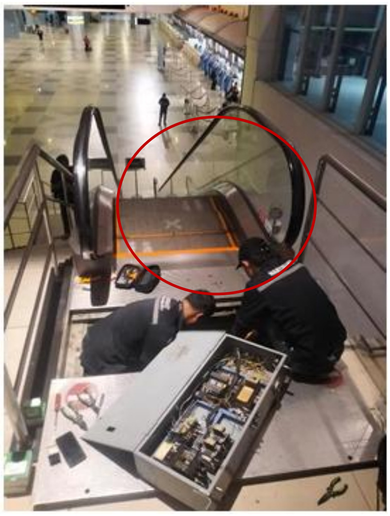

Figure 5. Escalator Observation
(Source: Author documentation, 2024)

After conducting observations with the mechanical technician team at SMB II Airport Palembang, the author gained valuable insights to gather information and plan the research to develop a more effective and efficient operational system. Subsequently, the author conducted interviews with the mechanical team, and based on the agreed-upon findings, a plan was formulated to design an IoT-based remote control system for escalators that allows technicians to monitor and control the system remotely.

The design of the IoT-based remote control system model for escalators at SMB II Palembang Airport is tailored to match the characteristics of the original escalator's shape and function. This is done to ensure that the developed control system can integrate seamlessly with its mechanism and structure. Below is a model design illustration that depicts the concept of the control system:

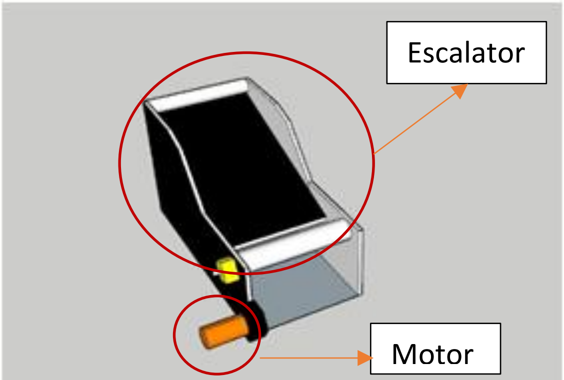

Figure 6. Model Design
(Source: Author documentation, 2024)

The workflow of the product begins with the installation of the ESP32 microcontroller on the escalator to monitor its operational status. The ESP32 microcontroller then transmits real-time data to the IoT communication module via a website using an IP address connected to the internet. The IoT communication module acts as a bridge between the ESP32 microcontroller and the website, ensuring that the collected data can be accessed and monitored remotely. The website, integrated with the IoT platform, receives data from the ESP32 microcontroller and analyzes it to detect the operational condition of the escalator.

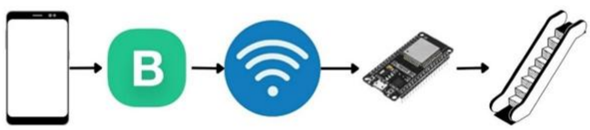

Figure 7. Workflow Design
(Source: Author documentation, 2024)

The design and workflow of the product above utilize electrical wiring to operate the IoT-based remote control system. This wiring includes the placement of cables connecting the proximity sensor, motor driver, ESP32 microcontroller, and power supply. Below are the detailed wiring specifications for the product design.

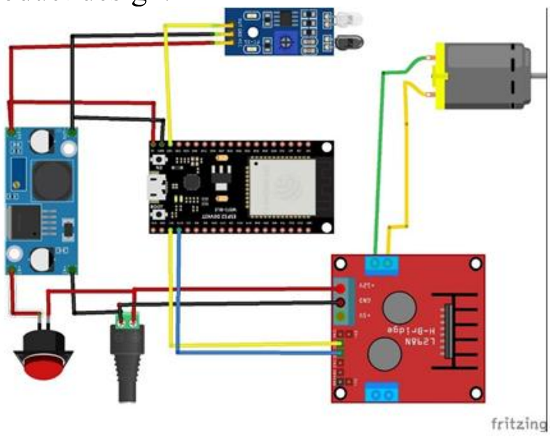

Figure 8. Product Wiring Design
(Source: Author documentation, 2024)

After assembling the electrical wiring, the next step is to program (code) the ESP32 microcontroller for the IoT-based remote control system on the escalator. Below are the programming details for the product design.

Figure 9. Product Program
(Source: Author documentation, 2024)

The design was validated through a Focus Group Discussion (FGD) conducted during the final on-the-job training (OJT) evaluation in February 2024. The purpose of this focus group discussion (FGD) was to validate the design and gather feedback for revisions and product trials. Assistant Managers of Maintenance attended the discussion forum at SMB II Palembang Airport, along with OJT students from Palembang Aviation Polytechnic. The discussion took place on January 16, 2024, under the theme "Smart Airport for Passenger Comfort." This FGD provided valuable input and revisions to help students complete their OJT reports and gather the necessary data for their final projects. The outcomes of this discussion are expected to enhance the quality of student reports and research while offering deeper insights into the implementation of the Smart Airport concept at SMB II Palembang Airport. Table 2 presents the list of FGD participants involved in discussions with experts.

Table 2. FGD Participant Attendance List

Participant's Name	Position
Barkah Susianto, S.T (Airport Infrastructure Expert)	Assistant Manager Infrastructure facility
Almuzani, S.T (Mechanical & Electrical Expert)	Assistant Manager Electrical & Mechanical
Harry Novriadi, S.T (Building Maintenance Expert)	Assistant Manager Maintenance Building
Fikri, S.T (Electronics Expert)	Assistant Manager Electronics & IT Facility
Defri Syahputra, S.T (Airport Mechanical Expert)	Supervisor Mechanical facility

During the implementation of the FGD, validation results were obtained and will be used in the design revision stage. This validation encompasses both technical and functional aspects, taking into account input from discussion participants. The revision process will ensure that the final design meets the required efficiency for implementation at SMB II Palembang Airport. Below is the list of revisions from experts regarding the IoT-based remote control system model for escalators:

Supervisor of Electronics & IT Facility: “Ensure that the system does not rely on external hosting, such as additional applications or similar services. It would be preferable if the system could operate through local hosting on built-in devices to ensure security against unauthorized access. This approach is similar to the BAS designed by the Electrical Maintenance Team at SMB II Palembang Airport, which has been proven to be secure and effective for remote control using a local host system”.

Assistant Manager of Electrical & Mechanical: “The system should provide real-time information on the device’s on or off status. This is crucial to ensure that the control system for the escalator functions properly and remains reliable. With accurate and real-time status information, escalator maintenance and operation will become more efficient and safer”.

Supervisor of Mechanical: “Ensure that the model includes a contingency plan by providing an emergency button for manually shutting down the device. This emergency button is crucial for ensuring passenger safety in case of emergencies or system failures. With this feature, operators can immediately stop the escalator’s operation to prevent injuries or further damage”.

Figure 10. FGD Documentation
(Source: Author documentation, 2024)

The design revision stage involves validating or assessing the control system model for escalators, which has been conducted through a Focus Group Discussion (FGD) with personnel from SMB II Palembang Airport to identify any existing deficiencies or weaknesses. Based on findings from airport personnel, relevant improvements or additions were made to address the concerns raised by experts. This process ensures that the escalator control system operates optimally by the required safety and performance standards. The conclusions drawn from the FGD with experts are presented in the workflow flowchart below.

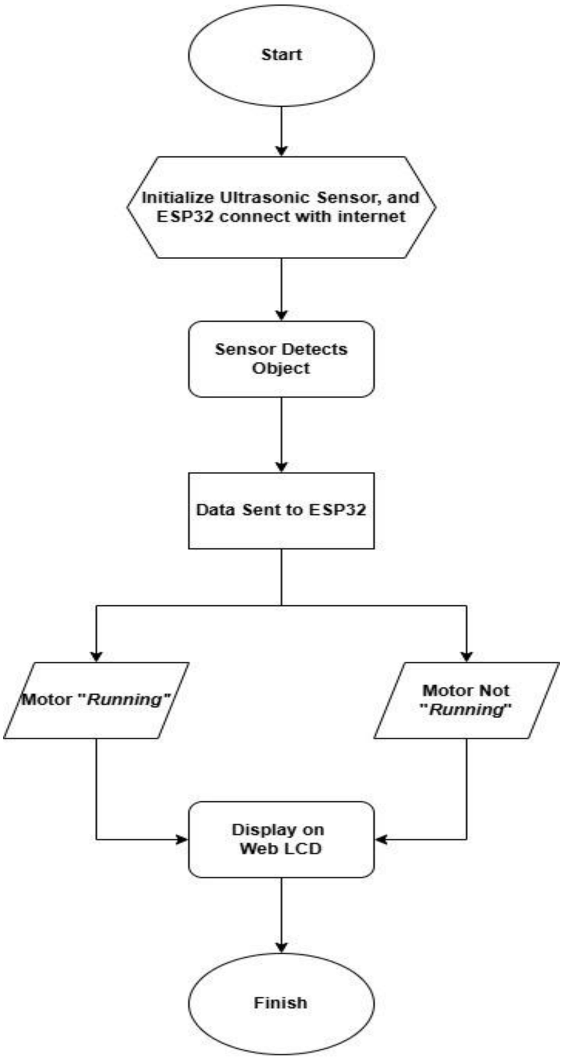

Figure 11. Flowchart Workflow Model
(Source: Author documentation, 2024)

The flowchart above illustrates the workflow of the IoT-based remote control system model for escalator devices using a validated IP address. After planning the product workflow, the author assembled the product by adjusting the design according to the revisions. The following image shows the research product results, which align with the product design and expert feedback revisions.

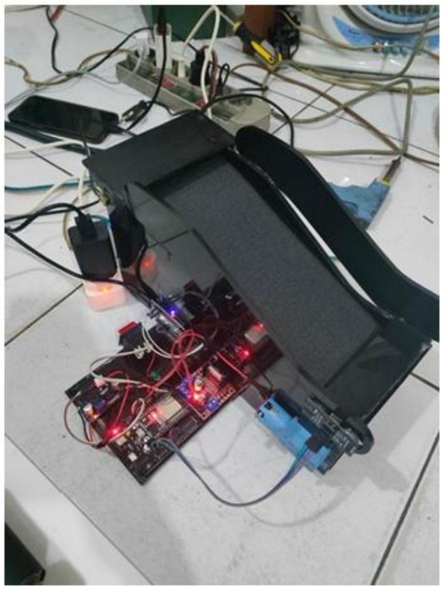

Figure 12. Product Results
(Source: Author documentation, 2024)

The product above utilizes electrical wiring to operate the system. This wiring includes the placement of cables connecting two ESP32 microcontrollers—one functioning as a transmitter that sends data to the SSR relay for device control, and the other as a receiver that collects data from an ultrasonic sensor used for real-time remote monitoring of the device. Below are the wiring details of the final product.

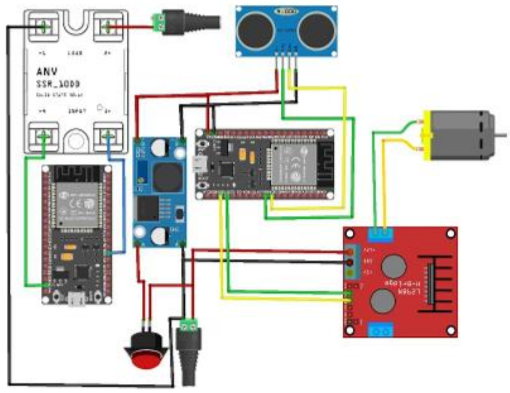

Figure 13. Wiring Product Results
(Source: Author documentation, 2024)

To operate the electrical wiring above, programming must be uploaded to each ESP32 microcontroller. This programming includes pin configuration, data processing from components, data transmission to the IoT server, as well as receiving and executing commands from the user interface. Each component connected to the ESP32 microcontroller is properly configured, with input pins on the ESP32 used to read data from the components. The code is written to initialize sensors, periodically read data, and process it before sending it to the server via a Wi-Fi connection. Below are the programming details of the product design:

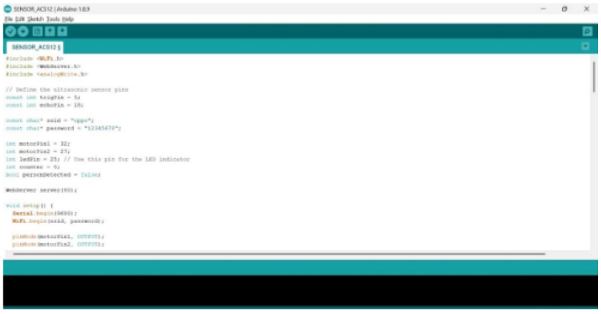

Figure 14. Program Product Results
(Source: Author documentation, 2024)

The IoT-based remote control system for the escalator consists of several key components that ensure its operation. Below is a table detailing each component:

Table 3. Component Model (Source: Author documentation, 2024)

Tool	Total	Unit
ESP 32	2	Unit
Motor DC 12V	1	Unit
Sensor Proximity	1	Unit
Converter	1	Unit
Motor Drive	1	Unit
Switch	1	Unit
Handphone	1	Unit
Relay SSR	1	Unit
Adaptor	1	Unit
Akrilik	40x40	Cm
Pipa	1	Meter
Bearing	4	Unit
Kain	1	Meter
Kabel Jumper	40	Unit

A. Product Trial

After undergoing the revision and validation stages, the refined product was tested on a small scale to represent its real-world performance in this development research. At this stage, the system was tested to simulate actual operational conditions in the airport environment. The objective was to assess the effectiveness, reliability, and usability of the IoT-based remote control system before its full implementation across all escalators at SMB II Palembang Airport. The researcher prepared evaluation instruments such as questionnaires for technicians and operators and airport users, which can be found in the appendix. Additionally, realistic usage scenarios were developed to simulate various potential operational conditions.

The results of this small-scale trial provided valuable insights for researchers to make further revisions and refinements. Researchers were able to identify and address weaknesses or shortcomings in the system before large-scale implementation. Thus, this small-scale trial ensures that the system is truly ready for widespread use and can function optimally in various operational scenarios at SMB II Palembang Airport. Success at this stage is a crucial step toward a full-scale implementation that is safe, efficient, and reliable for all escalators in the airport. The product trial results can be accessed via the link below or the barcode provided in the appendix. Uji Coba Rancangan Model Sistem Kontrol Jarak Jauh Berbasis IoT - M. Agrist P. Ramadhan - YouTube

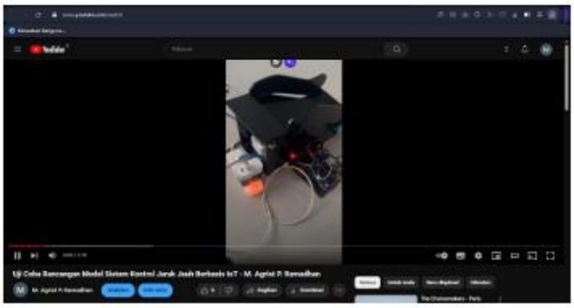

Figure 15. Product Trial Video
(Source: Author documentation, 2024)

Discussion

This study's development of an IoT-based remote control system for escalators directly addresses the goal of improving operational efficiency and safety through real-time monitoring. The system enables remote operation via Wi-Fi and ESP32, offering continuous updates and quick responses—features essential for airport environments.

Compared to previous research, such as (Sihombing, 2023) which focused solely on monitoring, this study adds remote control using low-latency internet protocols, improving responsiveness and accessibility.

It also enhances earlier models through better hardware and web dashboard integration, and proves effective under simulated high-traffic conditions, supporting its relevance to airport operations.

Overall, the proposed system advances and expands the functionality of existing IoT-based escalator control solutions.

Conclusion

This study aimed to develop an IoT-based remote control system model for escalators using an ESP32 microcontroller and integrated internet connectivity to enhance operational efficiency and safety at Sultan Mahmud Badaruddin II Airport. The resulting system enables operators to monitor and control escalators remotely in real-time, including turning devices on or off and performing system resets during emergencies. The system provides timely information through Wi-Fi-based data transmission, allowing for improved decision-making and faster responses to technical issues.

However, this study was limited to prototype-scale implementation and testing in a controlled environment, without deployment in a fully operational airport setting. Therefore, the scalability, long-term reliability, and cybersecurity aspects of the system remain to be validated.

Future research should focus on conducting large-scale trials in actual airport environments, optimizing data security protocols, and integrating predictive maintenance features. Additionally, practical implementation could be expanded to other public facilities that rely heavily on escalator systems, such as shopping malls and train stations.

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