Design and build IoT-based noise *monitoring and analysis tools* in hangars Aviation Polytechnic

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ABSTRACT

Noise in aircraft hangars is a crucial problem in the aviation industry that can threaten the health, safety, and productivity of workers. The Surabaya Aviation Polytechnic hangar, especially the Diploma 3 Aircraft Engineering program, produces high noise levels due to aircraft engine maintenance and testing activities that have the potential to endanger students, technicians, and instructors. This research aims to design and build an Internet of Things (IoT)-based noise monitoring system that is able to detect, monitor, and analyze noise levels in real-time at the AMTO 147D-10 Hangar of the Surabaya Aviation Polytechnic. The research method used an experimental approach with prototype development that integrated the FC-04 sound sensor, ESP32 microcontroller, 128x64 pixel OLED display, and a web-based monitoring platform using Node.js. The system is designed with portable dimensions of 21.5 x 14.5 x 8.5 cm and utilizes Wi-Fi, HTTP, and WebSocket communication protocols for data transmission to cloud servers. The test was carried out at three measurement points with a distance of 1 meter, 3 meters, and 5 meters from the noise source in the form of a grinding machine, then the results were compared with the standard Sound Level Meter of the Blue Gizmo BG325 brand. The results showed that the system had very high accuracy with an accuracy percentage of 99.293%-99.882% at a distance of 1 meter with an error rate of 0.118%-0.707%, an accuracy of 98.583%-99.527% with an error of 0.473%-1.417% at a distance of 3 meters, and an accuracy of 95.970%-96.786% with an error of 3.214%-4.030% at a distance of 5 meters. The measured noise level ranges from 81.17-84.43 dB which is close to the safe threshold of 85 dB according to OSHA standards and the Minister of Manpower Regulation No. 5 of 2018. The system provides an effective solution for continuous noise monitoring with early warning features, real-time data visualization, and historical data storage that support strategic decision-making in occupational safety and health management in aviation vocational education environments.

Keywords*:* *Internet of Things*, Noise Monitoring, Aircraft Hangar

1. INTRODUCTION

Noise in aircraft hangars is a crucial problem in the aviation industry that requires serious attention, especially in aircraft maintenance and repair environments. Hangar environments often produce very high noise levels due to various sources such as aircraft engine noise, maintenance equipment, and other operational activities that take place simultaneously. According to the standards set by *the Occupational Safety and Health Administration* (OSHA), exposure to noise exceeding 85 dB over a long period of time can result in permanent hearing loss and various other health problems in workers. The impact of excessive noise is not limited to physical health aspects alone, but also significantly affects occupational safety and productivity. Hearing loss due to noise exposure can lead to miscommunication between technicians, potentially increasing the risk of fatal errors in the aircraft maintenance process. In addition, high noise levels can trigger stress, mental fatigue, and decreased concentration which have a direct impact on operational efficiency and safety in hangars.

The Surabaya Aviation Polytechnic, especially the Diploma 3 Aircraft Engineering program, has hangar facilities as a means of supporting education to develop science and technology in the field of aviation. The hangar used for aircraft maintenance and repair activities generates high noise, especially during the engine testing process or intensive maintenance activities. High noise levels have the potential to endanger the health, safety, and productivity of technicians, instructors, and students who are active in it. As a vocational educational institution in the aviation sector, compliance with noise safety standards is a fundamental aspect to protect the health, comfort, and safety of the entire academic community, while improving the quality of learning about noise management in the aviation industry.

The development of *Internet of Things* (IoT) technology opens up new opportunities in more accurate and real-time noise monitoring. Although there have been several studies related to IoT-based noise monitoring, most of them have focused on the general industrial and commercial environment, while the implementation of this technology for vocational education in the aviation sector is still very limited. IoT-based noise monitoring systems offer an effective solution by enabling continuous noise level measurement, providing early warning when noise levels exceed predefined safe limits, and storing historical data that can be used for in-depth analysis and strategic decision-making. The use of this technology not only supports efforts to improve occupational safety and health, but is also in line with international regulations related to noise management in the aviation industry environment. The implementation of this monitoring system is expected to double function as a noise monitoring tool to maintain the safety and comfort of students in the practice area, as well as an effective learning medium about the importance of noise management in the aviation industry.

Based on this background, this study is focused on the problem of how to compare noise measurement levels using tools designed with standard sound level meter measuring instruments. This research was conducted in the hangar of the Surabaya Aviation Polytechnic with a focus on the noise generated by aircraft engine maintenance and testing activities, using IoT-based sound sensors with data processing through cloud or local platforms, specifically designed for use by students, technicians, and instructors as an integral part of the learning process and occupational safety management.

This research aims to design and build an IoT system that is able to comprehensively detect, monitor, and analyze noise in aircraft hangars, as well as provide noise level measurement results that can be compared with standard *sound level* meter measuring tools to validate the accuracy of the developed system. The system is designed to provide *real-time* monitoring data and noise level analysis, as well as automatic alerts if noise levels exceed specified thresholds, thus supporting efforts to create safer work environments and increase technician productivity.

The benefits of this study are multidimensional, covering a wide range of stakeholders. For the Surabaya Aviation Polytechnic as an educational institution, this research improves the quality of vocational education by providing modern technology-based learning tools and supporting work safety programs in the hangar environment. For students, the system improves understanding of noise hazards and the importance of safety management in the work environment, while also introducing IoT technology as a practical solution in the aviation industry. For the aviation industry more broadly, this study can serve as a reference for the development of similar systems in other hangars and provide relevant noise data to support occupational health and safety policies. Meanwhile, for other researchers, this research contributes to the development of IoT-based research in the field of aviation and occupational safety, and can be the basis for further development such as integration with wearable devices or other more advanced automated systems.

2. METHODS

This study uses an experimental method with a prototype development approach to design and build an *Internet of Things* (IoT)-based noise monitoring system. The research stage began with the identification of problems in the hangar environment of the Surabaya Aviation Polytechnic which had a noise level exceeding the threshold recommended by *the Occupational Safety and Health Administration* (OSHA), which was 85 dB for a working duration of 8 hours. Excessive noise generated from aircraft engines, heavy equipment, and other operational activities can trigger stress, disrupt communication, and increase the risk of work accidents. The lack of a noise monitoring system based on IoT technology and the absence of a special mitigation program make efforts to protect occupational health and safety less optimal. After the identification of the problem, references are collected from various sources such as scientific journals, books, and relevant previous research to obtain supporting information as a reference in designing the system. The theoretical foundation is compiled based on the references that have been collected, including the principles of IoT, the hardware and software used, as well as other supporting theories.

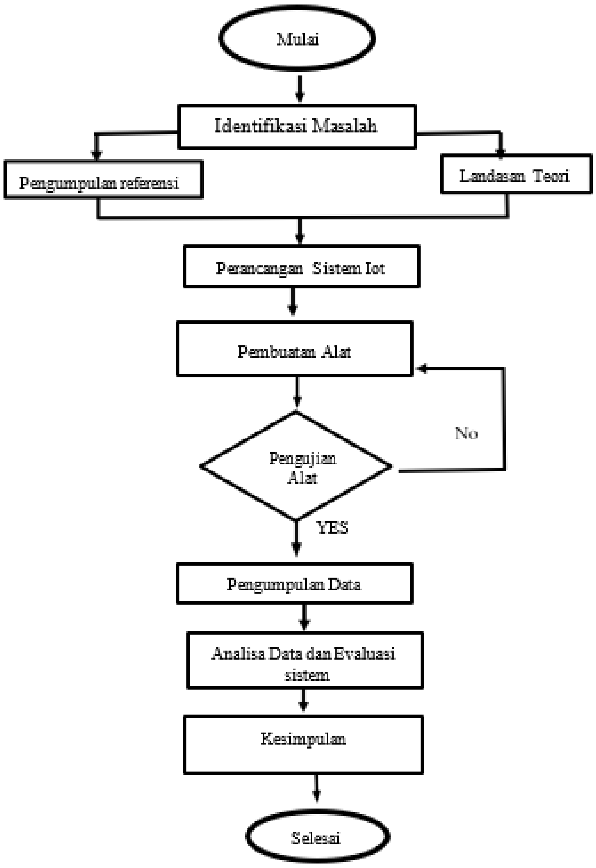


Figure 1. Researcher Method Flow Diagram

The design of the noise monitoring system uses a modular approach that involves four main components, namely sensors, microcontrollers, IoT systems, and computers as user interfaces. FC-04 sound sensor with operating voltage specification of 3.3-5V and PCB size of 3.4 x 1.6 cm was selected as the noise level detector component in the hangar environment. The sensor is connected to an ESP32U WROOM microcontroller operating on the 802.11 b/g/n protocol with a frequency of 2.4 GHz to 2.5 GHz and an operating voltage of 5V. The ESP32 serves as a processing center that reads analog data from the sensor using the analogRead() function, then processes the data to determine the noise level. IoT systems are designed using MQTT, HTTP, or Websocket communication protocols with platforms such as ThingsBoard, Firebase, or Node-RED to send data from microcontrollers to cloud servers for remote monitoring. The measurement data is displayed in real-time on a 128 x 64 pixel OLED display connected via an I2C interface, and visualized on a computer using HTML, CSS, JavaScript, and Node.js web technologies with MySQL databases. All components are housed in a black plastic box measuring 21.5 x 14.5 x 8.5 cm equipped with a power supply, an ON/OFF button, and a 20 mm diameter lens indicator light.

The system works starting from the power supply that provides power to all components, then the device is activated via the ON/OFF button. When the device is on, the sound sensor begins to detect ambient noise by measuring the intensity of the sound received. Data from the sensor is forwarded to the ESP32 which serves as a processing center to process the sound data and send the measurement results to the OLED for real-time display, while also sending the data to the server via a Wi-Fi connection for remote monitoring. The system also comes with a feature of exporting data in Excel format using the xlsx library which allows users to save noise data for further analysis. The connection between the components uses a 20 cm female to female jumper cable, and the device is mounted on the box using 2 mm bolts to ensure the stability of the components.

The tool test was carried out at the AMTO 147D-10 Hangar of the Surabaya Aviation Polytechnic by placing the device at three different measurement points, namely at a distance of 1 meter, 3 meters, and 5 meters from the noise source in the form of a grinding machine. The data obtained from the design tool is compared with the readings of the Blue Gizmo BG325 brand standard Sound Level Meter which has an accuracy specification of ±1.5 dB, a measurement range of 35-130 dB, a frequency of 31.5 Hz – 8 kHz, A & C weighting, a resolution of 0.1 dB, and an electric condenser microphone type. This test method aims to assess the reliability and validity of the design tool in measuring noise levels as well as identify possible deviations in the measurement results.

Data analysis was carried out by calculating the error value and measurement accuracy using the equation proposed by Lia Wilani et al. (2023). The error value is calculated with the formula: Error = |(Tool Data - Standard Value) / Standard Value| x 100%, where the tool data is a design sensor reading (dB) and the standard value is a Sound Level Meter (dB) reading. According to Fajrin et al. (2020), the results of inaccurate readings or acceptable errors have a maximum value of 5%. The accuracy value is then calculated using the equation: Accuracy = 100% - Error. This research was carried out from November 2024 to August 2025 with stages including title submission, title evaluation, proposal proposal and examiner, proposal preparation, proposal seminar, proposal revision, guidance and preparation of final project, research result hearing, final project revision, and final project report collection. The measurement data will be presented in a table that compares the measurement results of the device design, the standard Sound Level Meter measurement, the error percentage, and the accuracy percentage for each measurement point.

3. RESULTS AND DISCUSSION

This research produced a prototype of an IoT-based noise monitoring and analysis tool that was designed in an integrated manner with box dimensions measuring

21.5 cm long, 14.5 cm wide, and 8.5 cm high. The system consists of several main components that are interconnected, namely ESP32 as the main microcontroller, FC-04 sound sensor as a noise intensity detector, 128x64 pixel LCD to display local information, and indicator light as a visual marker of measurement status. The ESP32 component was chosen for its ability to process sensor data and transmit information in real-time via Wi-Fi, HTTP, and WebSocket communication protocols to a cloud server located at IP address 103.16.117.242 with port 3000.

The hardware configuration is designed with power consumption efficiency and ease of integration between components in mind. The FC-04 sound sensor is connected to the ESP32 via GPIO pin 33 as the sound signal data input line, with a 5V power supply connected to the VCC pin and ground connected to the GND pin ESP32. The indicator light is connected to the GPIO 5 pin, while the LCD module uses I2C communication with the SCL pin connected to the GPIO 22 and the SDA pin connected to the GPIO 21. This pin configuration ensures that there are no conflicts in the data readings and allows the system to operate simultaneously without signal interference. The exterior design shows the components neatly arranged with a power supply port, LCD, FC-04 sound sensor, and lens light integrated in one portable container, while the interior shows the ESP32 as a data processing center connected to all supporting components.

On the software side, the system is programmed using an Arduino IDE with a C++ programming language optimized for the ESP32 microcontroller. The program utilizes several important libraries, including WiFi.h for wireless network connections, WebSocketsClient.h for *real-time* communication with servers, ArduinoJson.h for data processing in JSON format, and Adafruit_GFX.h and Adafruit_SSD1306.h for

control the display on the OLED screen. The selection of this library is based on the need for the system to transmit data efficiently and display information in a responsive manner to users. The web-based monitoring system was developed to facilitate remote monitoring by using Node.js as a backend server running on port 3000. Access to the web application is done through a http://noisemot.my.id:3000/ address that allows users to monitor noise levels in real-time from any location. The use of port 3000 was chosen because of its compatibility with Node.js-based applications and data monitoring frameworks such as Grafana, in contrast to standard web services that generally use port 80 for HTTP or 443 for HTTPS.

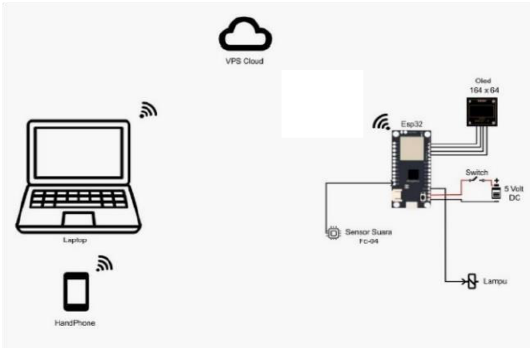


Figure 2. IoT Simulator Scheme

The system test was carried out at the AMTO 147D-10 Hangar of the Surabaya Aviation Polytechnic with variations in measurement distances to evaluate the accuracy and consistency of the tools. The testing process begins by connecting the 5V power supply to the design of the appliance, connecting the ESP32 to a hotspot, placing the appliance in a predetermined position, and then observing the measurement results generated by the sound sensor. The working principle of the system is that when the sound sensor receives the sound wave signal, the ESP32 will receive and process the data from the sensor to then activate the lens light and display the measurement results on the LCD in real-time. Based on the World Health Organization (WHO) standards, noise is classified into three levels, namely low and safe level (≤ 30 dB), medium level (35-75 dB), and high level (more than 85 dB).

The results of the 1-hour test at a distance of 1 meter showed good noise level consistency with an average value of 84.43 dB. The measurement data is compared to the Sound Level Meter as a standard benchmark to calculate the error rate and accuracy of the designed system. In Table 1, it can be seen that the measurement accuracy ranges from 99.293% to 99.882% with a very low error rate ranging from 0.118% to 0.707%. These results show that the designed system has a high level of precision in detecting noise at close ranges. Data collection was carried out at intervals of 5 minutes to obtain an accurate representation of noise fluctuations during the test period

Table 1. Noise Monitoring Distance 1 Meter

No	Information	Design Measurement Results	Sound Level Meter Measurement	Error (%)	Accuracy (%)
1	Tall	84.4 dB	84.7 dB	0,354	99,946
2	Tall	84.4 dB	84.6 dB	0,236	99,764
3	Tall	84.4 dB	85.0 dB	0,706	99,294
4	Tall	84.4 dB	84.7 dB	0,354	99,646
5	Tall	84.5 dB	84.9 dB	0,471	99,529
6	Tall	84.4 dB	84.7 dB	0,354	99,646
7	Tall	84.5 dB	85.0 dB	0,588	99,412
8	Tall	84.3 dB	84.9 dB	0,707	99,293
9	Tall	84.3 dB	84.6 dB	0,355	99,645
10	Tall	84.4 dB	84.7 dB	0,354	99,646
11	Tall	84.6 dB	84.7 dB	0,118	99,882
12	Tall	84.6 dB	85.0 dB	0,471	99,529

From the results of the measurement, the noise level at a distance of 1 meter is close to the safe threshold of 85 dB, prolonged exposure without ear protection risks causing hearing loss. It is still relatively safe at a distance of 3 meters if the duration of exposure does not exceed the standard working time limit, but it is still recommended to use ear protection if exposed regularly.

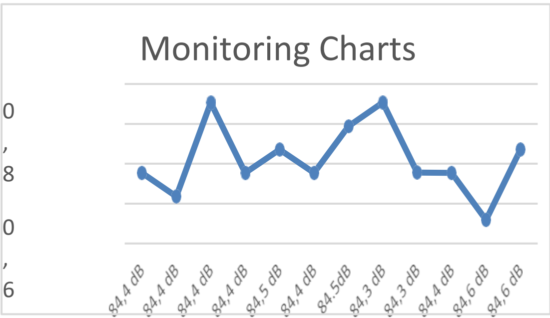


Figure 3. 1 meter distance noise monitoring chart

Data analysis showed a negative correlation between the measurement distance and the detected noise level, in accordance with the principle of sound wave propagation which is attenuated as the distance from the source increases. Based on the Regulation of the Minister of Manpower No. 5 of 2018 and the recommendations of the World Health Organization (WHO), the safe noise threshold for workers is 85 dB for a maximum working duration of 8 hours per day. The measurement results at a distance of 1 meter with a value of 84.43 dB are close to the safe threshold, so prolonged exposure without wearing ear protection has the potential to cause hearing loss. At a distance of 3 meters with a value of 83.90 dB, the condition is still relatively safe if the duration of exposure does not exceed the standard working time limit, but the use of ear protection is still recommended, especially for workers who are regularly exposed. Measurements at a distance of 5 meters showed a value of 81.17 dB which was below the threshold, but long-term exposure can still have an impact on auditory health, especially in individuals who have high sensitivity to noise.

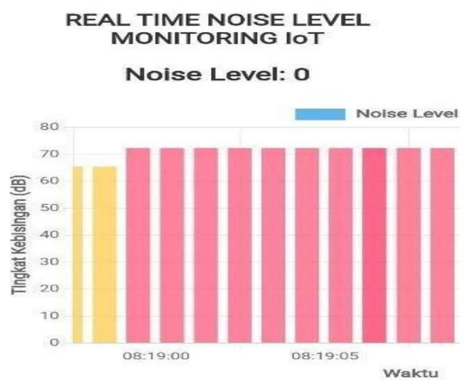


Figure 4. Noise Monitoring WEB Display

Table 2. Noise Monitoring Distance 3 Meters

No	Information	Measurement Results Design	Measurement *Sound Level Meter*	*Error* (…%)	Accuracy *(…%)*
1	Tall	84.0 dB	84.6 dB	0,709	99,291
2	Tall	83.7 dB	84.4 dB	0,829	99,171
3	Tall	83.6 dB	84.5 dB	1,065	98,935
4	Tall	83.9 dB	84.5 dB	0,710	99,290
5	Tall	84.0 dB	84.6 dB	0,709	99,291
6	Tall	83.7 dB	84.3 dB	0,712	99,288
7	Tall	83.6 dB	84.6 dB	1,182	98,818
8	Tall	83.5 dB	84.7 dB	1,417	98,583
9	Tall	83.9 dB	84.7 dB	0,945	99,055
10	Tall	84.0 dB	84.6 dB	0,709	99,291
11	Tall	84.0 dB	84.6 dB	0,709	99,291
12	Tall	84.9 dB	84.5 dB	0,473	99,527

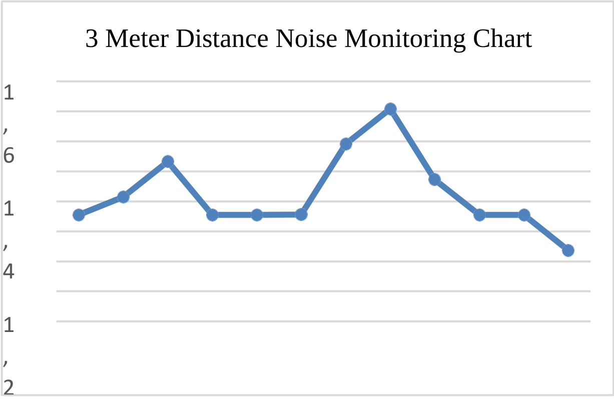


Figure 5. 3 Meter Distance Noise Monitoring Chart

Tests at a distance of 3 meters showed an average noise value of 83.90 dB with a high accuracy ranging from 98.583% to 99.527%, although there was a slight decrease in accuracy compared to the 1 meter distance measurement. The error rate at this distance ranges from 0.473% to 1.417%, which indicates that the increase in distance affects the sensitivity of the sensor but is still within acceptable tolerance limits. Meanwhile, testing at a distance of 5 meters yielded an average noise value of 81.17 dB with an accuracy ranging from 95.970% to 96.786% and an error rate ranging from 3.214% to 4.030%. A more significant decrease in accuracy at a distance of 5 meters indicates that the FC-04 sensor has optimal sensitivity at near to medium distances, and performance begins to decline as the distance of the sound source increases.

Table 3. Noise Monitoring at a Distance of 5 Meters

No	**Information**	**Measurement Results Design**	**Measuremen t** ***Sound Level Meter***	***Error*** **(…%)**	**Accuracy** ***(…%)***
1	Tall	81.4 dB	84.2 dB	3,327	96,673
2	Tall	81.1 dB	84.3 dB	3,800	96,200
3	Tall	81.3 dB	84.4 dB	3,674	96,326
4	Tall	80.9 dB	84.2 dB	3,917	96,083
5	Tall	81.2 dB	84.2 dB	3,562	96,438
6	Tall	81.5 dB	84.0 dB	3,214	96,786
7	Tall	81.4 dB	84.1 dB	3,214	96,786
8	Tall	81.0 dB	84.2 dB	3,802	96,198
9	Tall	80.8 dB	84.3 dB	4,030	95,970
10	Tall	81.0 dB	84.3 dB	3,911	96,089
11	Tall	81.1 dB	84.2 dB	3,683	96,317
12	Tall	81.3 dB	84.1 dB	3,327	96,673

Figure 6. 5 Meter Distance Noise Monitoring Chart

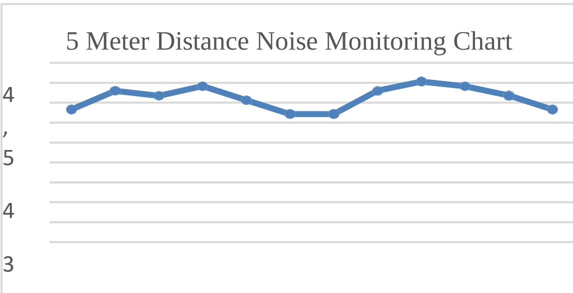
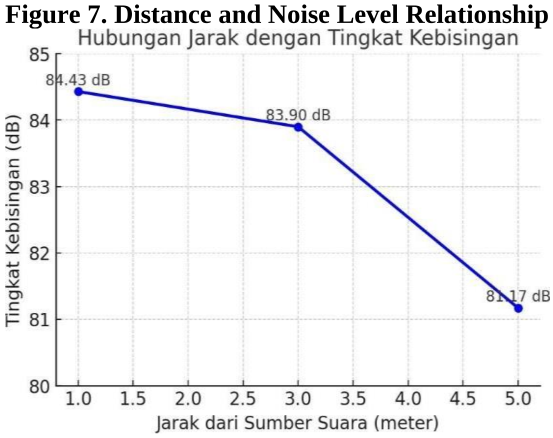


Figure 7. Distance and Noise Level Relationship



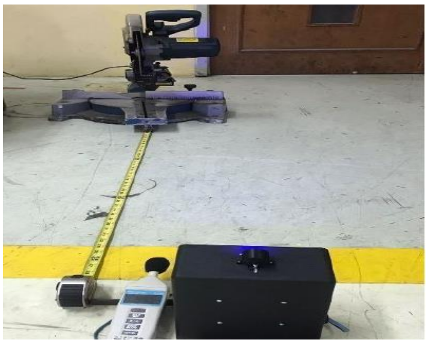


Figure 8. Measurement Distance

The web-based monitoring system developed features an informative interface with several key features, including real-time display of noise values, data visualization in the form of time-series graphs, time and date measurement information, and historical data download features according to the user's desired period. The integration between hardware and software allows the system to operate autonomously with minimal manual intervention, so that monitoring can be carried out continuously without the presence of an operator on site. The advantages of the designed system include a portable and flexible design that allows it to be easily moved to various measurement locations, as well as a simple and easy-to-understand design for users with various levels of technical expertise.

However, this system also has some limitations, namely a relatively slow sound detection interval with a period of 5 seconds between measurements, as well as a graph display that does not show the entire time span comprehensively, so that for more detailed historical data analysis requires an offline data download and processing process.

4. CONCLUSION

This research has successfully designed and built an Internet of Things (IoT)-based noise monitoring system that is able to detect and analyze the noise level in the AMTO 147D-10 Hangar of the Surabaya Aviation Polytechnic in real-time with a high level of accuracy. The system integrating the FC-04 sound sensor, ESP32 microcontroller, and web-based monitoring platform showed excellent performance with measurement accuracy reaching 99.293% to 99.882% at a distance of 1 meter, 98.583% to 99.527% at a distance of 3 meters, and 95.970% to 96.786% at a distance of 5 meters, with a maximum error rate of 4.030% which is still below the 5% tolerance limit according to the standard of Fajrin et al (2020). The measurement results showed that the noise level in the hangar ranged from 81.17 dB to 84.43 dB depending on the measurement distance, which is close to the safe threshold of 85 dB set by OSHA and the Minister of Manpower Regulation No. 5 of 2018, so it requires serious attention to the duration of exposure and use of ear protection for students, technicians, and instructors who are active in it. The system not only makes a practical contribution to improving occupational safety and health in aviation vocational education environments, but also serves as an effective learning medium on the importance of noise management, although further development is still needed regarding the optimization of detection intervals and visualization of historical data to improve responsiveness and ease of long-term analysis.

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