Journal of Airport Engineering Technology (JAET)
https://e-journal.poltekbangplg.ac.id/index.php/jaet

Volume: 5, No. 2. June, 2025: pp. 135-149
E-ISSN; P-ISSN: 2774-9622; 2775-4871
DOI: 10.52989/jaet.v5i2.205
Submitted: 2025-02-16; Revised: 2025-04-07; Accepted: 2025-06-07

MICROCONTROLLER-BASED BIRD REPELLENT DEVICE AT THE AIRPORT: DESIGN, SENSOR, AND POWER SUPPLY

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Abstract

The development of electronic technology as a control system has progressed rapidly in the era of society 5.0. Various facilities at the airport have implemented microcontrollers, especially bird repellent devices, to realize the concept of a smart airport. Bird repellent devices are designed to automatically and efficiently repel birds. This is because birds pose a threat to increasing the risk of bird strikes, which can cause damage to aircraft engines and trigger flight accidents. When designing bird repellent devices, researchers must consider the design, sensors, and power supply to enhance the effectiveness of the tool when applied in the field. This article will review the factors that influence the effectiveness of bird repellent devices, namely: design, sensors, and power supply, in a literature review. The purpose of this writing is to build a hypothesis of the influence of the design, sensor, and power supply used in the design of bird repellent devices so that it can be used as a reference in further research. The results of this literature review article are: 1) the design affects the bird repellent; 2) the sensor affects the bird repellent; and 3) the power supply affects the bird repellent.

Keywords: *bird repellent device, design, sensor, power supply*

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Introduction

The development of science in the field of electronics and control systems has progressed rapidly in the era of society 5.0. Various electronic facilities appear as a solution to simplify human work. One of these facilities is a microcontroller system. A microcontroller is a computer device packaged in the form of an Integrated Circuit (IC) that performs system control operations, such as receiving input, processing, and output according to the program provided to the microcontroller. Microcontroller devices are quite efficient in tool control systems at an affordable price (Zanofa et al., 2020). Microcontrollers have several examples, including Arduino, ESP32-CAM, DEV-3 Mini, and others. Microcontrollers are used for equipment automation. This technology has been applied in various industrial sectors, including the airport. The primary purpose of automation at the airport is to enhance operational efficiency, streamline processes, minimize manual labor, enhance the passenger experience, and ensure flight safety and security. Some facilities at the airport that have implemented microcontrollers are automatic alarm and fire extinguishing systems, self-check-in systems, CCTV, and many more (Kustori, 2017).

According to the Law of the Republic of Indonesia Number 1 of 2009 concerning Aviation states that an area on land and/or waters with certain boundaries used as a place for aircraft to land and take off, up and down passengers, loading and unloading goods and a place for intra and intermodal transportation movements equipped with aviation safety and security facilities, as well as basic and other supporting facilities is referred to as an airport. Based on the Regulation of the Minister of Transportation of the Republic of Indonesia Number PM 36 of 2021 concerning Standardization of Airport Facilities states that the airport has several areas which are divided into three parts, including land side (land side facilities), air side (air side facilities) and aviation safety and security facilities. The landside area is designed to accommodate the movement of land vehicles, cargo transportation, and passengers at the airport. The land-side facilities include: airport terminals, crubs, parking, and vehicles (Ramadhan et al., 2023). Meanwhile, airside facilities are where aircraft take off and land at the airport. Please note that the runway area, taxiway, apron, Air Traffic Control (ATC) building, and other facilities are examples of airside infrastructure (Seno & Ahyudanari, 2015). Then, flight safety and security facilities are facilities designed to maintain flight safety and security during flight operations.

Some facilities, such as drainage systems, electrical power supply systems, airfield lighting systems, Aviation Accident Relief-Fire Fighting (PKP-PK) buildings, and others, are examples of aviation safety and security facilities (Bendi et al., 2023). Among several areas at the airport, the airside area is vital because it is directly related to aircraft movement and operations. Therefore, the level of security in this area is crucial. In the airside area, there are often several airport operational disruptions that cause delays to flight accidents. This will certainly interfere with the comfort and trust of passengers as users of aviation services (Indriani et al., 2023). Various operational disturbances, such as the entry of wild animals, bird disturbances, and the presence of hazardous objects on the airside, are collectively referred to as Foreign Object Debris (FOD). The entry of various animals onto the airside is typically caused by abundant food sources and objects that can serve as nests and playgrounds for these animals (Simanjuntak & Sutarwati, 2023).

Wild animals will feel at home in airside areas if there is no regular maintenance of grass, trees, and other facilities. To prevent this, maintenance can be performed by cutting grass, inspecting facilities, and repairing any damage. The goal is to prevent wild animals that interact in the airside area from becoming FOD. FOD is any form of object, such as: garbage, rocks, wood, animal carcasses and plastics in the airside area that are harmful to aircraft operations if sucked in by aircraft engines (Prihantono, 2023). Among the several disturbances in the airside area, the emergence of wild animals, especially birds, warrants further review. This is because the

bird population has recently increased and will become a threat if preventive measures are not taken at the airport. According to Ross et al (2024), in their research report, there is an increased risk of bird strike, which can cause damage to the aircraft, thus threatening flight safety. Bird strike is a collision event between an airplane and birds or other animals during flight (Nursani & Arifianto, 2024). Aircraft flying in the air can have the opportunity to be hit by birds or other animals flying on the flight path. This can be a serious problem as collisions with birds or animals can cause damage to the aircraft and its engines.

Based on Bird Strike Information System (IBIS) data obtained from ICAO reports in the period 2008 to 2015, there were 97,751 reports of wild animal strikes (Oktaviani et al., 2019). This number has increased rapidly compared to the previous period from 2001 to 2007, where there were 42,508 cases of wild animal strikes. These reports came from 91 countries out of a total of 105 listed countries. The effects of wild animal strikes on aviation have been reported in 12,227 cases (Mafaza & Haryati, 2022). Of these reports, 2,550 bird strike cases with clear indications of effects on aviation were identified. The impact of bird strikes has also been observed in Indonesia, as seen at Juanda Airport in Surabaya. Launching from Detik Jatim news in 2022, it was reported that Lion Air JT-800, operating on the Surabaya-Makassar route, experienced a bird strike while preparing to start the engine on the apron. About 15 minutes into the flight, an engine jet indicator in the cockpit displayed an incorrect indication, signaling potential damage to the aircraft's engine. This obstructs airport operational activities, causing inconvenience to passengers.

In addressing bird strikes, several efforts have been made, one of which is the application of bird repellent tools to cars. Although this tool is still lacking, both in terms of the number of car units used and the effectiveness of the sound produced to repel birds (Palupi & Basuki, 2020). A research conducted by Adis Prasetyo in year 2019 makes a sound generator with direct output using an electrically powered speaker, the range of sound emitted by the speaker to have a sound pressure above 75 dB and be able to reach an area of + 256 meters is to apply the use of Horn TOA type speakers with a capacity of 80.6 dB and Tweeter Piezoelectric type speakers with a capacity of 76.4 Db (Kusni et al., 2010). The coverage area of +256 meters is sufficient to reach the area around the runway of Juanda Airport Surabaya, provided the device is installed as far as 100 meters from the side of the runway (Kusni et al., 2010). However, the device's output needs to be tested again on birds other than sparrows and blekoks, which are commonly found in the airside area of Juanda Airport, Surabaya.

Bird repellents at airports often utilize sound devices powered by sources such as batteries or electricity. However, these solutions often incur high operational costs and can have negative environmental impacts due to the inefficient use of energy resources. Coupled with seeing the number of bird strikes at airports that interfere with operational activities (Suripto & Oktarinaria, 2020), researchers want to study a bird repellent tool based on SKEP/42/III/2010 concerning Guidelines and Procedures for Civil Aviation Safety Regulations Part 139-03 Management of Wild Animal Hazards at Airports. An effective bird repellent tool can apply a microcontroller as a processor to realize the smart airport concept. This concept involves automating airport equipment to enhance flight safety and security. Additionally, according to the instruction of the Director General of Air Transportation, as stated in letter number AU. 105/1/4/DRJU-212 airports are required to implement the concept of an eco airport. This concept is important as a contribution to reducing carbon emissions worldwide by utilizing renewable energy in airport equipment, particularly bird repellent devices.

This study aims to investigate the effect of applying design, sensors, and power supply to bird repellent devices in order to repel birds at airports throughout Indonesia effectively. This research was conducted by searching for supporting articles through academic databases, including Scopus, Web of Science,

and Google Scholar, from 2014 to 2024, on the application of bird repellent devices at airports. Based on the above background, problems can be formulated that will be discussed to build hypotheses for further research, namely: (1) Does the design of the bird repellent tool affect its effectiveness? (2) Does the sensor affect the bird repellent? (3) Does the power supply affect the bird repellent? This article aims to strengthen the research theory by examining the relationship between device design, sensors, and the effective application of power supply in bird repellent devices, as a form of literature review study in the field of auditing.

Methods

This study employs a qualitative-descriptive approach, utilizing a literature review method, to identify and analyze the technical factors that influence the effectiveness of microcontroller-based bird repellent devices in airport environments. The literature review was conducted to establish a conceptual basis and framework for developing tools in future research. Literature sources were collected through scientific databases, including Scopus, Web of Science, Google Scholar, and DOAJ, using the following keywords: "bird repellent device", "microcontroller bird scarer", "ultrasonic bird control", "airport bird strike prevention", and "solar-powered bird deterrent". Inclusion criteria for the literature sources are articles published between 2019 and 2024, focusing on the design, sensors, or power systems of bird repellent devices. Published in reputable peer-reviewed journals or scientific proceedings. The exclusion criteria for this research are articles that only discuss bird repellents in agricultural areas and articles with population or ecological studies that lack a technical approach.

From the initial search results (n=96), 47 articles were selected that met the criteria and analyzed thematically based on three main variables: 1) device design and functional dimensions, 2) type and effectiveness of sensors (PIR, microwave, ultrasonic), and 3) Power supply system (PLN, battery, hybrid, solar power). One of the primary reasons for conducting qualitative research is that it is exploratory in nature (Nurliyanti et al., 2022).

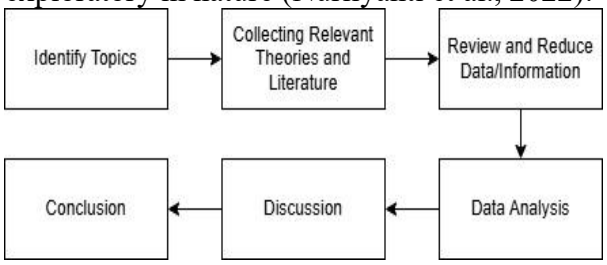

Figure 1. Stages of Research

The analysis process was conducted through a thematic narrative synthesis and content analysis of comparable results. The results of the study were then presented in a comparison table and discussed to form an initial framework for the hypothesis.

Results And Discussions

Bird repellent is a device used to deter birds from entering specific areas by utilizing auditory techniques as a means of repulsion. Bird repellent devices are currently designed to automatically support the smart airport concept by incorporating microcontrollers (Palupi & Basuki, 2020). This tool was tested directly at Ahmad Yani Semarang International Airport, with an effective frequency range of 800 Hz to 5 kHz and a sound pressure level of 85 dB. This frequency is generated by the transmitter and received by the receiver. Then, it is processed by the signal processing circuit to produce distance information from the object. The frequency produced does not overlap with the frequency range of airplanes, specifically 63 Hz to 250 Hz, so it will not interfere with flight operations (Palupi & Basuki, 2020).

Bird repellent is an automated device that minimizes bird strikes in an area using acoustic methods (Kusni et al., 2010). The bird repellent device is designed using an Arduino microcontroller for automation. This test was conducted in the airside area of Juanda Airport Surabaya. According to this study, the placement of bird repellent devices and the type of sound are very influential on the effectiveness of bird repellent in the field. The ideal frequency range for square and sawtooth waves is 5 kHz to 9 kHz, while the frequency modulation sound range is 2 kHz to 7 kHz. Additionally, artificial predator sounds

are applied with a sound pressure of 75 dB (Kusni et al., 2010). This frequency is influenced by the design and sensor of the tool, with the application of a buzzer as a sound-producing medium that can be adjusted by the user as needed.

Bird repellent is a tool developed to prevent, monitor, and control bird disturbances at airport locations (Alfaris & Sonhaji, 2024). This tool employs an acoustic method that utilizes sound with a specific frequency level to repel birds. The effectiveness of the device in repelling birds is influenced by effective design, sensor application, and power supply selection. This tool is used at Hang Nadim International Airport, Batam, to manage wildlife hazards within the airport environment. In addition to utilizing bird repellent devices, all airport stakeholders need to work together to conduct intensive and continuous monitoring and maintenance. This aims to improve flight safety and security at the airport (Alfaris & Sonhaji, 2024). This bird repellent tool has been widely studied by previous researchers including (Amri et al., 2024; Muddin et al., 2023; Noer et al., 2020). ***Design*** is a creative process that involves planning and creating a system or tool as a form of solution to a particular problem. Design plays a crucial role in tool innovation, as it encompasses various aspects that ensure the tool not only functions properly but is also effective, efficient, and novel, thereby appealing to users. In research on the design of bird repellent tools, a good design is as minimalist and portable as possible while maintaining the quality necessary for effective bird repellency in the field. The bird repellent design features a height of 1.5 meters and includes a control panel measuring 35 cm x 35 cm. On this panel, there is a set of bird repellent control systems, including a microprocessor, a battery, a motor, a servo, and so on. The solar panel will then be positioned above the control panel to facilitate the conversion of solar energy into electrical energy, which will be stored in the battery. This bird repellent tool utilizes the Arduino IDE software as a programming application and Blynk as a control application, accessible via the user's smartphone.

Design is the process of planning the creation of an object, system, or structure to meet the needs of its users. In presenting the design of the bird repellent tool, the aim is to control and prevent birds from entering a certain area, thereby minimizing the disturbance caused by them. The bird repellent tool used in research (Jalaludin & Laksmiati, 2023) has physical dimensions of 30 cm x 30 cm x 15 cm, with an ultrasonic sensor positioned at a height of 30 cm and a Passive Infrared Receiver (PIR) sensor positioned 20 cm above ground level. Considering the size of this bird repellent tool, it has been designed to be portable, allowing the user to move it easily. The design of this tool effectively integrates hardware and software components. Hardware components are arranged by assembling ESP-32Cam components, servo motors, ultrasonic sensors, PIR sensors, and buzzers. The software supporting the bird repellent tool is made using the Arduino IDE application (Jalaludin & Laksmiati, 2023).

Design is a stage in the development process that lays the foundation for creating the system. The system will be broken down into several components, including flowcharts, interface designs, and data flow diagrams that will integrate seamlessly into the system. With this implementation, the system can be built more structurally and efficiently. In the study by Hanif Yuhdi et al. (2023), a bird repellent tool design was described that can be arranged in a portable manner while maintaining the tool's functionality. This system consists of several hardware and software components to support the tool. Hardware components play a crucial role in supporting, protecting, and operating the tool, ensuring it functions properly. Hardware components include solar panels, cases, batteries, buzzers, servos, and many other components. Then, the software component plays a role in creating, instructing, and remotely controlling the tool, allowing users to carry out activities beyond monitoring birds. Some examples of software include: Arduino IDE, XY Remote Web Platform, and XY Arduino Control Remote

Application. By designing a mature design concept, this tool can function as planned (Hanif Yuhdi et al., 2023).

The design and indicators that influence the implementation of bird repellent devices have been studied by many previous researchers including (Oklanri et al., 2023), (Syahminan, 2017) and (Alfriadi et al., 2018).

Sensors are electronic devices that can detect and measure phenomena or conditions in the field. Sensors have many types, such as: ultrasonic sensors, Passive Infrared Receiver (PIR) sensors, and motion sensors. In bird repellent devices, sensors serve as electronic components to detect and repel birds in the field (Jalaludin & Laksmiati, 2023). The sensor used in this research is an ultrasonic sensor. An ultrasonic sensor is a sensor that converts physical quantities (sound) from electrical energy and vice versa. This sensor can interpret the distance of objects programmed with a certain frequency. The sensor sensitivity indicator has been tested 5 times, and this sensor can detect birds at a distance of 200 cm from the device. As a sensor driver, the device applies a DC motor, a battery, and a solar cell power supply. The ultrasonic sensor is integrated into an IoT system, allowing users to monitor their devices through software installed on their smartphones (Jalaludin & Laksmiati, 2023).

Sensors are devices that detect and measure environmental conditions by converting physical signals into electronic signals. In research (Saputra & Nasirudin, 2022), a bird pest repellent device has been designed using a Passive Infrared Receiver (PIR) sensor to detect and expel birds. The PIR sensor is a pyroelectric sensor that detects interference from objects entering the sensor area through radiation emitted by objects and living things. The effective range of the PIR sensor is 3-5 meters. During a 2-minute test using both living and inanimate objects, this sensor can detect only the movement of living things, with a response delay of 1.4 seconds. This is because the responsive heat generated by living things is more effective in affecting the sensor's sensitivity compared to inanimate objects. Thus, the PIR sensor is quite effective when applied in the field as a bird repellent device that continuously detects objects and repels them. As a power source, PIR sensors utilize solar cells and batteries as energy storage media (Saputra & Nasirudin, 2022).

Sensors are devices used to detect changes in the physical environment by converting them into signals that observers and tools can read. In research (Khumaidi & Hikmah, 2021) on bird repellent tools using microwave RCWL motion sensors. The RCWL motion sensor is a sensor that utilizes microwaves and Doppler radar technology to detect the movement of living things. Researchers use this sensor because it has a better level of accuracy than Passive Infrared Receiver (PIR) sensors and ultrasonic sensors. This is shown in sensor testing where at a distance of 1-10 meters with the movement of waving hands can be read well on the system on an ongoing basis, this sensor can also detect the movement of birds in groups with a range of > 5 birds, but if < 5 birds the sensor is difficult to detect properly. As the power supply of the sensor device, researchers have used solar panels because they are more efficient and environmentally friendly (Khumaidi & Hikmah, 2021). The types of sensors and testing their accuracy in the implementation of bird repellent devices have been studied by many previous researchers, including (Zulfikri et al., 2022), (Herida et al.,2022), and (Andi Taufiq et al.,2022).

A power supply is a device that provides electrical power for certain electronic devices. The power supply consists of several types, including batteries, solar cells, and so on. Research (Hadi et al., 2017) suggests that solar panels are an effective power source for use in bird repellent tools. Solar panels are a set of modules to convert electrical energy through solar thermal power through photovoltaic cells. The electricity generated through this process is DC electricity, so it can be stored in batteries. The optimal time for solar panels to charge energy is between 08:00 AM and 05:00 PM, with a voltage that fluctuates according to weather conditions and sunlight intensity. In this study, the average voltage of the solar panels produced was 12.50 Volts, and the current was 0.7 amperes. With a large current, the battery charging

process can run quickly, allowing the bird repellent device to fulfill its operational power (Hadi et al., 2017).

A power supply is a device that functions as a source of energy for other devices. Some examples of power supplies include batteries, generators, PLN electricity, solar panels, and many more. In a bird repellent tool study (Oktivira, 2017), a hybrid power supply is utilized. A hybrid power supply is an energy storage and distribution system that utilizes two sources of electricity in order to maintain the efficiency level of the electricity supply. This tool utilizes batteries as the main power supply, while PLN electricity as an energy source that will be transmitted to the battery. This bird repellent tool utilizes the battery when the voltage reaches 7 Volts and will automatically switch to use the PLN power supply when the remaining battery voltage is 3 Volts. In terms of tool reliability, the application of hybrid power supplies is highly effective in increasing the efficiency and flexibility of electrical energy. It can reduce the impact of power outages when the tool is in operation (Oktivira, 2017).

A power supply is an auxiliary device that provides energy for other devices to function properly. Power supplies come in various types, but research (Hamdani & Ramadhan, 2020) has found that solar panels are commonly used as the primary power source for bird repellent tools. This is a form of protecting the environment from the impact of carbon gas emissions worldwide, as well as the application of eco-friendly airport practices. It should be noted that the solar cell power supply is the conversion of sunlight into electricity, either directly using photovoltaic cells or indirectly with concentrated solar power. In this study, we used 2 5-Volt solar panels assembled in series. The results of this study obtained an effective voltage functionality of 8.9 Volts when the solar cell is exposed to sunlight. Weather conditions and sunlight intensity certainly influence these results. The application of solar cells as a power supply for bird repellent devices is very effective for the sustainable use of renewable energy at airports (Hamdani & Ramadhan, 2020).

Research on the application of power supply in bird repellent devices has been researched (Hardian, 2020; Arifandi et al., 2021; Hidayatullah & Sulistiyanto, 2022).

Table 1. Relevant Previous Research

No	Author (year)	Results of previous research	Similarities with this article	Differences with this article
1	Andi taufiq et al., (2022)	The bird repellent device incorporates IoT by integrating hardware and software devices into its design. Evaluation of the effectiveness of sensors and IoT in repelling birds. The application of solar cells to reduce emissions caused by devices in the environment. The results of this research indicate that the design, sensors, and power supply used in the device have a significant impact on the effectiveness of the bird repellent device.	Focuses on the application of technology to increase the effectiveness of bird repellent in the field. The design, sensors, and power supply all affect the bird repellent device.	The location of application in this research serves as a differentiator, as previous research was conducted in a rice field environment, whereas this research was conducted at the airport.
2	Jalaludin & Laksmiati,	The designed system integrates a bird repellent	The tool has integrated technology to make it easier	The previous researcher's test location was located on

	(2023)	device with an automatic irrigation system. This tool features a minimalist design, utilizing software and hardware programmed to run the process. This tool has utilized sensors and a PLN electricity power supply. This research illustrates that the suitability of the design, sensor, and power supply has a positive effect on the sustainability of the bird repellent.	for users to do bird repellent in the field. The design, sensor, and power supply all affect the bird repellent tool.	agricultural land, while the researcher will apply the effectiveness of the tool at the airport.
3	Saputra & Nasirudin, (2022)	The bird repellent system is designed to use a PIR sensor to detect the presence of birds, with Arduino serving as the main control. The device has implemented a solar panel to save electrical power generated by the user and the integration of software and hardware devices. The results of research on design, sensors and power supply have a positive effect on the sustainability of bird repellent devices.	The device features a sophisticated design incorporating sensors and a solar cell power supply to enhance the effectiveness of bird repelling in the field. So that the design factor, sensor, and power supply are very influential on the bird repellent tool.	The researcher will implement it at the airport, while the previous research conducted experiments on agricultural land.
4	Khumaidi & Hikmah, (2021)	Implement RCWL Microwave motion sensors with IoT integration in bird repellent devices so that users can monitor and expel bird pests remotely. The design of the tool and sensor design has a very positive and significant effect on the design of the bird repellent tool.	The tool implements sensors in bird detection by utilizing the latest design and technology to increase effectiveness. So that design and sensors become influential factors in the design of bird repellent devices.	The researcher focused on implementation in the airport environment, while the previous researcher focused on implementation on agricultural land.
5	Hadi et al., (2017)	The device has implemented solar panels as a power supply and utilizes hardware components such as PIR sensors and microcontrollers as automatic bird detection devices in the field. The design components, sensors and the	The designed tool has the same purpose as a bird repellent tool by utilizing the latest technology in increasing effectiveness. Both design, sensors and power supply are very influential on bird repellent tools.	The previous research focused on testing on farmland for bird repelling, while the current research focuses on airports.

		implementation of solar cell power supply have a significant effect on the bird repellent device.		
6	Oktivira, (2017)	The bird repellent device uses a hybrid power supply (solar cell and battery) to increase the flexibility and energy efficiency of the device to perform effective bird repellent work. This device has integrated sensors and is based on IoT as a medium for monitoring birds in the field. Components such as design, sensors and power supply are very influential for the sustainability of bird repellent devices.	The tool has the aim of carrying out bird repellent by implementing technology and power efficiency with renewable energy. So that both design, sensors and power supply are very effective in designing bird repellent devices.	The previous study conducted trials on agricultural land, while this study will focus on the effectiveness of use at airports.

Based on theoretical studies and relevant previous research, the discussion of this literature review article in the concentration of electronic and digital engineering. Design is the initial design stage in making tools to ensure success when operating. The goal is to have higher novelty and effectiveness in optimizing the tool. In this research, design has a very significant influence on bird repellent tools. There are several indicators that affect the design of this bird repellent tool, including: dimensions, aesthetics, type of material, durability, constituent components, and tool functionality (Laksono & Zahidi, 2017). The dimensions of the tool must be in accordance with the needs and aesthetics in the field, but to increase flexibility, the design can be designed as portable as possible so that it can be moved according to user needs. In addition, aesthetics also plays an important role as beauty and visual appeal can influence user acceptance and integration with the environment. This needs to be considered so that the tool can perform its work function well. Then, the selection of the appropriate type of material ensures the strength, durability and longevity of the tool. Tool durability is also a crucial factor because the tool must be able to withstand various situations and weather conditions as well as repeated use without experiencing significant damage. In addition, the selection of tool components must be considered, especially in the integration of IoT systems or other automation concepts to support the smart airport concept. In selecting components, make sure the hardware and software systems can be integrated and controlled so that users can monitor in real-time without having to go directly to the field. Then, the functionality of the tool is the main indicator to assess how well the tool performs its main function, namely effective and efficient bird removal.

Several design indicators greatly affect the indicators of bird repellent including: effectiveness, durability and user satisfaction. The effectiveness indicator of the tool is seen from how well the tool is able to repel birds. A well-designed tool with an effective mechanism can perform its main function efficiently. Then, durability reflects the service life of the tool before requiring maintenance or repair. The selection of the right materials and components as well as the design that eats will increase the durability of the tool in the long run. Furthermore, user satisfaction is influenced by aesthetic design, easy to use and effective will increase user satisfaction with bird repellent tools (Afif et al., 2023).

In order to increase the effectiveness of the bird repellent, the designer must optimize

aesthetics by creating a visually appealing design. Then strengthen the durability and function of the design by choosing materials that are resistant to extreme weather in the field. In addition, improving the design function of the tool by developing contemporary features to monitor the performance of the engine and control system in ensuring the effectiveness of bird repelling in the field. This step is very important where researchers can ensure that bird repellents can operate effectively and with high quality (Oktivira, 2017).

Design affects bird repellent tools, if the design is perceived well by customers or consumers, this will be able to improve the quality and effectiveness of bird repellent tools. This can increase user satisfaction and the success of the tool in repelling birds (Andi taufiq et al., 2022). Design affects bird repellent tools, this is in line with research conducted by: (Laksono & Zahidi, 2017), (Herida et al., 2022), and (Hanif Yuhdi et al., 2023).

It should be noted that sensors are electronic devices that function to detect and measure a phenomenon against objects measured in the field. In this study, sensors have a significant effect on the effectiveness of bird repellent devices, where sensor indicators such as: sensor type, sensitivity, accuracy and responsiveness affect the indicators of bird repellent devices (Zulfikri et al., 2022). In the application of sensor types in the field, such as: ultrasonic sensors, PIR sensors and motion sensors, it is very necessary to make adjustments to components and situations in the field. This is because the type of sensor chosen determines the effective way of working on the tool in carrying out bird repelling. Then, sensor sensitivity is the ability of the sensor to detect birds at a certain distance and condition. Good sensor sensitivity allows the tool to detect birds more quickly and accurately. In addition, accuracy is the precision of the sensor in detecting the presence of birds. High accuracy ensures that the sensor can distinguish between birds and other objects correctly. Furthermore, responsiveness is the speed of the sensor in responding to the presence of birds. High responsiveness ensures that the device can immediately repel birds as soon as they are detected. Bird repellent indicators, such as: effectiveness, durability and user satisfaction that have been described previously are closely related and mutually influential on the tool's sensor indicators (Herida et al., 2022).

In increasing the effectiveness of bird repellent devices, the designer must choose the right type of sensor. This is so that the device can work effectively by detecting and expelling the targeted bird species. Then increase the sensitivity of the sensor by performing regular calibration and maintenance so that the sensor is able to detect birds better even in less than ideal conditions. In addition, increasing the accuracy of the expulsion by adjusting the type of frequency or sound pressure produced by the buzzer after the sensor detects the bird object. And accelerate the responsiveness of the sensor in detecting the object so as to increase the effectiveness of the eviction. This procedure is very important where researchers can ensure the effectiveness of the tool sensor can operate effectively and efficiently in carrying out bird expulsion.

Sensors affect bird repellent tools, if sensors are perceived well by customers or consumers, it can improve the quality and effectiveness of bird repellent tools. This can increase user satisfaction and the success of the tool in repelling birds (Julisma et al., 2023). Sensors affect bird repellent devices, this is in line with research conducted by: (Jalaludin & Laksmiati, 2023), (Saputra & Nasirudin, 2022), and (Khumaidi & Hikmah, 2021).

It should be noted that a power supply is a device that provides electrical power to certain electronic devices. In this literature, the power supply has a significant influence on bird repellent devices. In this case, dimensional indicators such as: type of power supply, power capacity, efficiency, power stability and portability affect the indicators of bird repellent devices. In the type of power supply use, such as: batteries or batteries, PLN electricity, solar cells and hybrid systems determine the availability and sustainability of power from bird repellent devices. By

selecting an effective power supply on the tool, it is able to maximize the performance process of the tool, so that it can operate optimally. Then, the power capacity is the amount of energy provided by the power supply during a certain period. A larger power capacity allows the tool to operate longer without the need for recharging. Furthermore, high energy efficiency can reduce energy waste and increase the operational duration of the tool. Then, power stability encompasses the consistency of voltage and current provided by the power supply. Good stability ensures that the device can function optimally without any interruptions. Next, portability or the ease of carrying and installing the power supply in various locations. Portable power supplies are able to increase the flexibility of using bird repellent tools. Based on the power supply indicators above, it is very influential on the indicators of bird repellent tools, such as effectiveness, durability and user satisfaction that have been described previously. These indicators are interrelated with each other to improve the performance of the bird repellent (Hidayatullah & Sulistiyanto, 2022).

In improving the bird repellent tool can pay attention to the power supply, so what the designer must do is choose the right type of power supply. The selection of the type of power supply is adjusted to the energy needs and operational environment of the tool. However, in supporting the concept of eco airport and smart airport, designers can apply the hybrid concept (solar cell and PLN electricity) alternately according to the power needs of the tool or they can use solar cells as a whole. Then the designer should also increase the power capacity to extend the operating time of the device. In addition to improving energy efficiency, we can use a continuous power supply to reduce energy waste. To prevent operational disturbances, the bird repellent tool can utilize a power supply that provides a stable current and voltage, ensuring the tool is not easily damaged. Researchers should also select an effective power supply that can be easily carried and installed to enhance the device's flexibility. This is very important, where researchers can ensure that bird repellents can operate effectively and with high quality (Arifandi et al., 2021).

The power supply affects the bird repellent if it is perceived well by customers or consumers. A positive customer perception of the tool's power supply performance can enhance the quality and effectiveness of the bird repellent. This can increase user satisfaction and the tool's success in repelling birds automatically (Hardian, 2020). Power supply affects bird repellent tools, this is in line with research conducted by: (Hadi et al., 2017), (Oktivira, 2017), and (Hamdani & Ramadhan, 2020).

Based on the formulation of the problem, theoretical studies, relevant previous research and discussion of the influence between variables, the thinking framework of this article is as below.

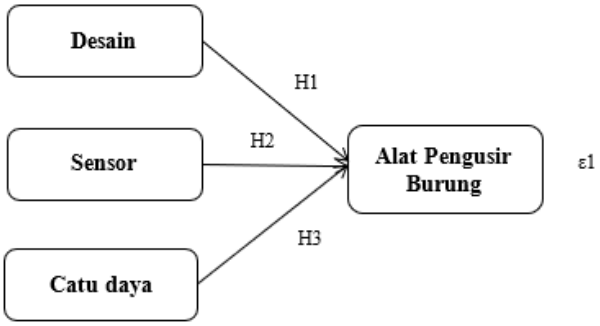

Figure 2. Conceptual Framework

Based on the conceptual framework above, the design, sensor and power supply affect the bird repellent. Apart from these three exogenous variables that affect bird repellent devices, there are still many other variables that affect them including: (1) Placement location: (Jalaludin & Laksmiati, 2023), (Kusni et al., 2010), and (Khumaidi & Hikmah, 2021). The effectiveness of microcontroller-based bird repellent devices in airport environments is greatly influenced by three main components, namely design, sensors, and power supply systems. A good design includes indicators such as dimensions, materials, aesthetics, portability, and integration with IoT systems, which directly impact effectiveness, durability, and user satisfaction (Laksono & Zahidi, 2017; Hanif Yuhdi et al., 2023). A compact and portable design facilitates the installation and

movement of the device as needed in the field, as well as enhancing its resistance to extreme weather conditions (Oktivira, 2017; Afif et al., 2023). Meanwhile, the selection of sensor types such as ultrasonic, PIR (Passive Infrared Receiver), or microwave determines the level of sensitivity, accuracy, and response speed of the device in detecting the presence of birds. PIR sensors can distinguish the movement of living creatures based on heat radiation, while RCWL microwave sensors have the advantage of detecting the movement of groups of birds more accurately (Saputra & Nasirudin, 2022; Khumaidi & Hikmah, 2021; Jalaludin & Laksmiati, 2023). The accuracy of sensor selection will determine the success of early detection and the effectiveness of bird deterrence in critical areas. Additionally, the power supply system is a crucial factor in ensuring the operational sustainability of the device, whether through the use of environmentally friendly solar panels (Hadi et al., 2017; Hamdani & Ramadhan, 2020) or a hybrid system combining batteries and grid electricity to enhance energy flexibility (Oktivira, 2017; Arifandi et al., 2021). Power efficiency, energy storage capacity, voltage stability, and portability are key indicators determining how effectively the equipment can function optimally in supporting aviation safety and security in line with the concepts of smart airports and eco-airports (Suripto & Oktarinaria, 2020; Hidayatullah & Sulistiyanto, 2022).

Conclusion

Based on the review of theoretical frameworks, relevant previous studies, and the overall discussion presented in this paper, it can be concluded that the design, type of sensor used, and the power supply system are key components that influence the effectiveness of microcontroller-based bird repellent devices at airports. These three factors determine how well the device can detect and deter birds from critical airport areas. Nevertheless, the findings of this literature review also suggest that these components are not the only factors affecting the device's performance. Other aspects, such as the positioning or distance of the device from the targeted area, environmental conditions, bird species behavior, and even integration with other airport safety systems may also contribute to the success or failure of such devices. As such, further research is strongly recommended to identify and analyze additional variables that were not covered in this review but may play a significant role in optimizing bird control strategies at airports. A more comprehensive understanding of these factors will be essential for developing more effective, reliable, and adaptable bird repellent technologies in the future.

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