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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 smart airport. Bird repellent devices are designed to expel birds automatically and efficiently. This is because birds are a threat in increasing the risk of bird strikes that cause damage to aircraft engines and will trigger flight accidents. In designing bird repellent devices, researchers need to consider the design, sensors and power supply used in order to increase 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 and Power Supply*

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 in fulfilling the desire 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) to perform system control operations, such as: receiving input, processing and output according to the program given 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, ESP 32 CAM, DEV 3 Mini and so on. The application of microcontrollers is carried out for equipment automation. This technology has been applied in various industrial sectors, one of which is the airport. The purpose of automation at the airport is to improve operational efficiency, simplify processes, reduce manual labor, improve 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 land side 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 landing at the airport. Please note that the runway area, taxiway, apron, Air Traffic Control (ATC) building, and others are some examples of airside facilities (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 a vital area because it is directly related to aircraft movement and operations. So the level of security of this area is very important. 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 appearance of dangerous objects on the airside known as Foreign Object Debris (FOD). The entry of various animals on the airside is usually caused by abundant food sources and objects that can be used 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. In preventing this, maintenance can be done by cutting grass, inspecting and repairing facilities if there is 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 his 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 occurred in Indonesia, one of which is at Djuanda Airport Surabaya. Launching from Detik Jatim news in 2022 informs that Lion Air JT-800 with the Surabaya-Makassar route experienced a bird strike when it was about to start the engine on the apron. About 15 minutes into the flight, there was an engine jet indicator in the cockpit with an inappropriate indication and signaled damage to the engine of the aircraft. This causes obstruction of airport operational activities that can cause passenger inconvenience.

In handling bird strikes, there have been several efforts, one of which is the application of bird repellent tools with cars as vehicles. 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 output of the device needs to be tested again on birds other than sparrows and blekok which are commonly found in the airside area of Juanda Airport Surabaya.

Bird repellents at airports often involve the use of sound devices that are operated by power sources, such as: batteries or electricity. However, these solutions often require high operational costs and can cause negative impacts on the environment 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 is a form of airport equipment automation so that flight safety and security can be better guaranteed. In addition, according to the instruction of the Director General of Air Transportation in letter number AU. 105/1/4/DRJU-212 airports are required to implement the concept of eco airport. This concept is important as a form of contribution to the world in reducing carbon emissions by utilizing renewable energy in airport equipment, especially bird repellent devices.

This study aims to see the effect of the application of design, sensors and power supply on bird repellent devices in order to carry out bird repellent effectively at airports

throughout Indonesia. This research was conducted by searching for several supporting articles through academic databases, such as: Scopus, Web of Science and Google Scholar in the period 2014-2024 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 affect the bird repellent tool? (2) Does the sensor affect the bird repellent? (3) Does the power supply affect the bird repellent? This article is needed to strengthen the theory of the research in examining the relationship or influence of device design, sensors and effective power supply application on bird repellent devices as a form of literature review study in the field of auditing.

Methods

This study uses a qualitative-descriptive approach with a literature review method that aims to identify and analyze technical factors that influence the effectiveness of microcontroller-based bird repellent devices in airport environments. The literature review was conducted to develop a conceptual basis and framework for tool development in further research. Literature sources were collected through scientific databases such as Scopus, Web of Science, Google Scholar, and DOAJ, with keywords: "bird repellent device", "microcontroller bird scarer", "ultrasonic bird control", "airport bird strike prevention", "solar-powered bird deterrent". Inclusion criteria for the literature sources are articles published between 2019–2024, focus 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 repellent in agricultural areas, articles with population/ecological studies without 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 main reasons for conducting qualitative research is that the research is exploratory (Nurliyanti et al., 2022).

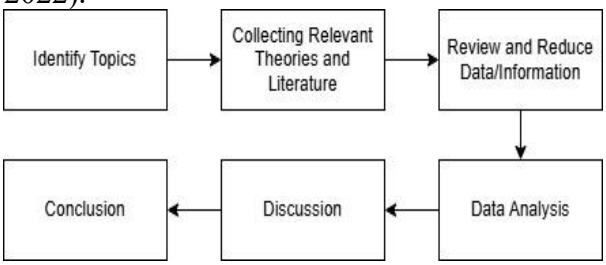

Figure 1. Stages of Research

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

Results And Discussions

Bird repellent is a device used to prevent birds from entering certain areas by utilizing auditory techniques as a medium for 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 is very influential on the effectiveness of bird repellent in the field. The

ideal frequency range in the form of square and sawtooth waves is 5 kHz - 9 kHz, frequency modulation sound in the range of 2 kHz - 7 kHz and the application of artificial predator sounds with 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 set appropriately by the user.

Bird repellent is a tool developed to prevent, monitor and control bird disturbances at airport locations (Alfaris & Sonhaji, 2024). This tool uses an acoustic method that utilizes sound with a certain frequency level to expel birds. The effectiveness of the device in repelling birds is influenced by effective design, sensor application and power supply selection. This tool is applied at Hang Nadim International Airport Batam to handle wildlife hazard in 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) and (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 an important role in making tool innovation because it covers various aspects that help ensure that the tool not only functions properly but is also effective, efficient and has novelty so that it can appeal to users. In research on the design of bird repellent tools, a good design is a design that is made as minimalist and portable as possible while maintaining quality as a bird repellent tool in the field. The bird repellent design is made with a height of 1.5 meters and there is a control panel with dimensions of 35 cm x 35 cm. On this panel there is a set of bird repellent control systems, including: microprocessor, battery, motor, servo and so on. Then the position of the solar panel will be placed above the control panel to facilitate the conversion of solar energy into electrical energy that will be stored in the battery. This bird repellent tool uses Arduino IDE software as a tool programming application and Blynk as a tool control application that can be accessed via the user's smartphone.

Design is the process of planning the creation of an object, system or structure with the aim of meeting user needs. In presenting the design of the bird repellent tool, it aims to control and prevent birds from being in a certain area to minimize the disturbance caused by birds. The bird repellent tool in research (Jalaludin & Laksmiati, 2023) has physical dimensions of 30 cm x 30 cm x 15 cm with an ultrasonic sensor placed at a height of 30 cm and a Passive Infrared Receiver (PIR) sensor placed at a height of 20 cm above ground level. Looking at the size of this bird repellent tool, it has been designed to be portable which allows the tool to be moved by the user easily. The design of this tool has integrated hardware and software components as effectively as possible. Hardware components are arranged by assembling ESP-32Cam components, servo motors, ultrasonic sensors, PIR sensors and buzzers. While the software supporting the bird repellent tool is made using the Arduino IDE application (Jalaludin & Laksmiati, 2023).

Design is a design stage that is the basis for making the system. The system will be broken down into several parts which include making flowcharts, interface designs, and data flow designs that will flow into the system. With this implementation, the system can be built more structurally and efficiently. In the (Hanif Yuhdi et al., 2023) which designed a bird repellent tool design described that a good design can be arranged portable while maintaining the functionality of the tool. This system consists of several hardware and software components to support the tool. Hardware components play an important role to support, protect and operate the tool so that it can work properly. Hardware components include: solar panels, cases, batteries, buzzers, servos and many more. Then the software component plays a role in creating, instructing, and remotely controlling the tool so that users can carry out other activities besides 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 are able to 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 function as electronic devices to detect and expel birds in the field (Jalaludin & Laksmiati, 2023). The sensor used in this research is an ultrasonic sensor. Ultrasonic sensor is a sensor to convert 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 with 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 can detect and measure conditions in the environment 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 is able to detect interference from objects that enter the sensor area through radiation emitted by objects and living things. The effective range of the PIR sensor is 3-5 meters. In a testing time of 2 minutes using objects of living and inanimate objects, this sensor is able to 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. RCWL motion sensor is a sensor that applies microwaves with Doppler radar technology to detect the movement of living things. This sensor is used by researchers 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 that 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 solar panels produced was 12.50 Volts and a current of 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, such as: batteries, batteries, generators, PLN electricity, solar panels and many more. In a bird repellent tool in research (Oktivira, 2017) using a hybrid power supply. Hybrid power supply is an energy storage and distribution system that utilizes two sources of electricity in order to maintain the efficiency level of 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 very effective for increasing the efficiency and flexibility of electrical energy and can reduce the impact of power outages when the tool is operating (Oktivira, 2017).

A power supply is an auxiliary device to provide energy for other devices to function properly. Power supplies have various types, but in research (Hamdani & Ramadhan, 2020) using solar panels as the main power supply for bird repellent tools. This is a form of protecting the environment from the impact of carbon gas emissions in the world and the application of eco airports at airports. It should be noted that the solar cell power supply is the conversion of sunlight into electricity either directly using photovoltaic or indirectly with concentrated solar power. In this study using 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. These results certainly adjust to weather conditions and sunlight intensity. 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 by many previous researchers including (Hardian, 2020), (Arifandi et al., 2021) and (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 implements IoT with the integration of hardware and software devices in the design. Evaluation of the effectiveness of sensors and IoT in repelling birds. Application of solar cells to reduce emissions caused by devices in the environment. The results of this research found that the design, sensors and power supply used in the device significantly affect the effective bird repellent device.	Focuses on the application of technology to increase the effectiveness of bird repelling in the field. So that the design, sensors and power supply affect the bird repellent device.	The location of application in this research is a differentiator where the previous research was applied in a rice field environment, while this research was applied at the airport.

2	Jalaludin & Laksmiati, (2023)	The designed system utilizes the integration of a bird repellent device with an automatic irrigation system. This tool is made with a minimalist design by utilizing software and hardware that is programmed to run the process. This tool has utilized sensors and 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.	The tool has integrated technology to make it easier for users to do bird repelling in the field. So that the design, sensor and power supply affect the bird repellent tool.	The previous researcher's test location was located on 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 using a PIR sensor to detect the presence of birds with Arduino as the main control. The device has implemented a solar panel to save electrical power issued 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 has implemented a sophisticated design with the application of sensors and solar cell power supply to increase 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 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.

		The design components, sensors and the 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 M 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.

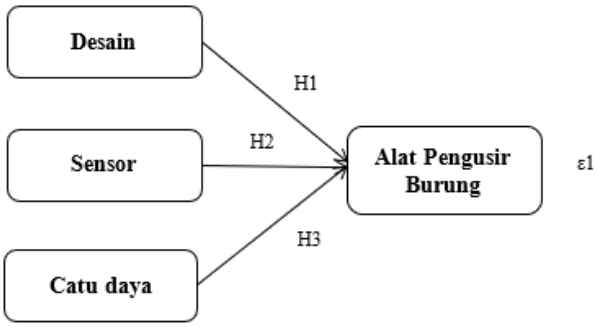

Figure 2. Conceptual Framework

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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