IDENTIFICATION OF WILD BOAR (WILDLIFE HAZARD) AND THE HAZARD CONTROL FOR AIR TRANSPORT SAFETY USING BOW-TIE ANALYSIS

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Abstract

One of the threats that is rarely studied but has a major impact on safety is the presence of wild boars on the airside. This study aims to analyze the constraints of wild boar pest control and formulate risk mitigation strategies that are in accordance with aviation safety standards. The study was conducted using a descriptive qualitative approach, combining field observation methods, in-depth interviews, and documentation. Data were analyzed using a gap analysis approach to identify gaps between actual conditions and ideal conditions based on regulations, and bowtie analysis to visually map the relationship between hazards, top events, threats, consequences, and barriers. The results of the study indicate that wild boar disturbances are triggered by damaged perimeter fences, unmanaged tall vegetation, and the absence of an early warning system. Current handling is still reactive, through manual patrols and deterrence, without detection tools or integrated handling protocols. The results of the bowtie analysis provide an overview of the main threats that have not been anticipated through adequate preventive barriers and recovery barriers. In addition, escalation factors such as CCTV damage and minimal cross-unit coordination increase the potential for runway incursions that lead to flight accidents. This study recommends that the approach to controlling wild boar pests shift from an emergency response system to an integrated proactive control system. Strengthening infrastructure such as fence repair, habitat management, and the use of surveillance technology and early warning systems are urgent needs to prevent potential bigger accidents in the future.
Keyword: *Air Transport safety, Bowtie analysis, Gap analysis, Wild boar pest, Wildlife hazard.*

1. INTRODUCTION

Aviation safety and security is the main priority in the implementation of air transportation (Xiong et al., 2024). One of the primary responsibilities of airport management is to ensure passenger safety. All aviation service providers, particularly airport management, are required to prioritize safety and security in all operational

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activities. In this context, aviation safety is a condition in which all provisions relating to the use of airspace, aircraft operations, airports, air transportation services, flight navigation and other supporting facilities have been fulfilled in accordance with applicable standards (Renaldo & Sunendar, 2017). To support this, facilities and infrastructure that meet safety standards are required, including the existence of an Aviation Accident Assistance and Fire Fighting Unit (ARFF) which has a crucial role in protecting lives and assets from the possibility of incidents or accidents in the airport environment (Hutapea & Martanti, 2023).

ICAO, through Document 9859 Safety Management Manual (SMM), emphasizes that safety risk management must be carried out proactively, by identifying hazards, assessing risks, and establishing appropriate controls to prevent accidents or incidents (International Civil Aviation Organization Doc 9859, 2013). One of the serious threats to aviation safety is wildlife hazard, namely the presence of wild animals in airport operational areas that can disrupt or pose a potential danger to aircraft operations.

According to the Regulation of the Directorate General of Civil Aviation Number: Skep/42/III/2010 concerning Guidelines and Procedures for Civil Aviation Safety Regulations Part 139–03, wildlife hazard management is a series of activities to control the airport's attractiveness to wildlife, including birds and mammals (Dirjen Perhubungan Udara, 2010). One incident that attracted attention occurred on December 29, 2024, when a Jeju Air plane was struck by a bird, causing a fatal accident and killing dozens of passengers and crew (Detik.com, 2024). This incident emphasized that wildlife hazard control is crucial in ensuring flight safety.

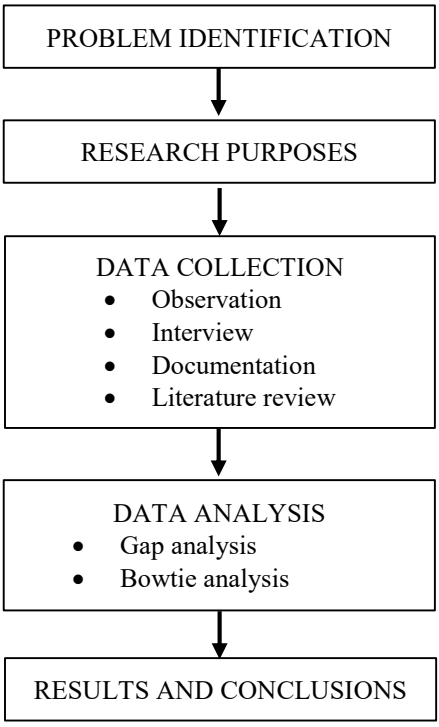
Fatmawati Soekarno Airport in Bengkulu City is a Class I airport with a runway measuring 2,250 x 45 meters and managed by the Directorate General of Civil Aviation. The airport is surrounded by tropical forest, home to a variety of wildlife. Observations indicate that wild boars are frequently found around the airport perimeter, particularly along the access road, runway, apron, and taxiway. One significant incident occurred on October 15, 2024, when a Super Air Jet pilot reported to the Airport Safety, Risk, Quality, and Performance unit that a herd of wild boars had crossed the runway while the aircraft was in the take-off phase. This incident demonstrates the importance of mitigating risks to wildlife on airport airsides. The discovery of wildlife on operational routes also directly impacts the performance of ARFF units, particularly in terms of emergency response time, which depends on visibility and infrastructure conditions. Unfortunately, the current condition of airside vegetation is still suboptimal, with tall weeds and a lack of maintenance, increasing the risk of interactions between aircraft and wildlife.

Research on wildlife hazards has generally focused on bird strikes, using technical approaches (Lian et al., 2021; M et al., 2023; Micaelo et al., 2023; Pahuja & Kumar, 2021; Yang et al., 2020). However, few studies have specifically analyzed disturbances from mammals such as wild boar using a systematic approach. In this context, the use of bowtie analysis is considered relevant because it can provide a comprehensive (helicopter view) of the relationship between causes, risk events, and their consequences in a structured and easy-to-understand visual format (Faturachman et al., 2023). Based on this background, this study aims to analyze wild boar pest control (wildlife hazard) at Fatmawati Soekarno Airport in Bengkulu to support flight operational safety. The results are expected to contribute to efforts to reduce the wild

boar population in the airport area and minimize the potential for accidents caused by wild animals.

2. METHODOLOGY

Research design is a plan and steps in implementing research that includes decision making, starting from general assumptions to the selection of detailed, logical, and systematic data collection and analysis methods. The research method used in this study is a qualitative method (Engelbertink et al., 2020; Kiger & Varpio, 2020). Qualitative research methods are an approach to research that aims to describe, elaborate, and analyze a phenomenon or event in detail and comprehensively. To describe a phenomenon, the researcher in this study employed qualitative descriptive research. This research focuses on understanding the context, meaning, and experiences of the research participants from their own perspectives (Döringer, 2021). The following are the stages of qualitative research conducted by the researcher.



The research problem and objectives will guide the researcher's steps, including the development of a research plan (Döringer, 2021). The first step is to formulate the research problem by identifying and analyzing the existing phenomena. After formulating the problem, the researcher must determine the research objectives to ensure a more focused study. Next, the researcher collects data by selecting and defining the research object, namely the wildlife hazards found around Fatmawati Soekarno Airport, particularly in the airside area. Researchers collect data through field

observations, namely by directly observing the phenomena that occur and the conditions at the research location, conducting interviews with sources regarding problems in the field, and conducting documentation as concrete evidence that the phenomenon or problem does exist in the field, as well as conducting literature studies on the problems raised (Döringer, 2021; Rosenthal, 2016).

The collected data was then analyzed using gap analysis, comparing the gap between actual conditions in the field and the expected conditions according to regulatory standards. Bowtie analysis was also used, a diagram that visualizes the risks faced in a single, easy-to-understand image. This diagram resembles a bow tie, creating a clear distinction between proactive and reactive risk management. In short, this diagram provides a simple visual explanation of risks that would be much more difficult to explain otherwise. After all this, the final step is for researchers to determine the results and draw conclusions from the data obtained.

3. DISCUSSION

Based on the data collection conducted, we arranged the gap analysis, which draws the current condition in Fatmawati Sukarno Bengkulu Airport. By comparing it with the regulation standards, it helps us to know the best recommended practice we should propose in order to overcome the situation. The result of Gap Analysis shown on Table 1 below described six critical condition which strongly related to the wild-boar pest, which are: Potential hazard identification, understanding habitat, open trash can, vegetation and drainage management, perimeter fence, and control equipment.

TABLE 1. GAP ANALYSIS

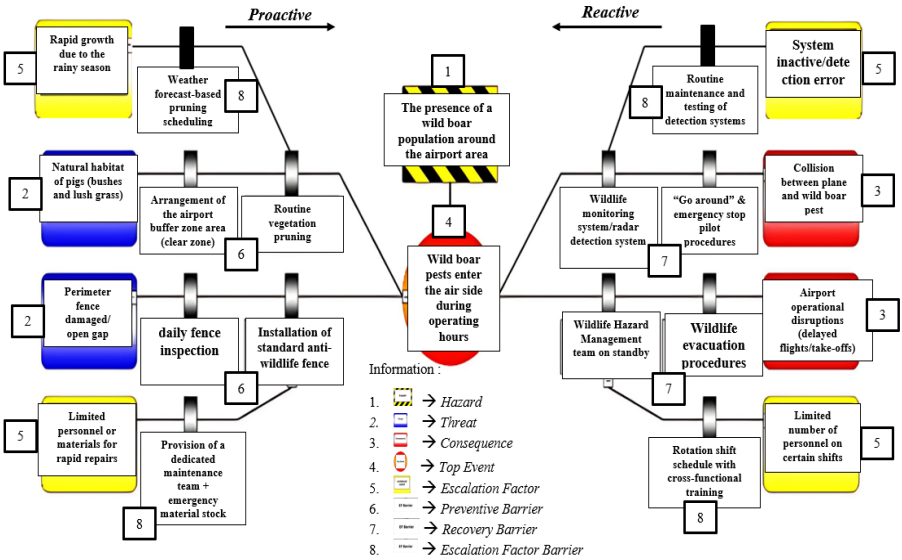
No	Current State	Standard SKEP/42/III/2010	Gap	Recomendation
Potential Hazard Identification				
1	Routine identification of wild boar occurrences throughout the perimeter has not been carried out.	Article 3.a: Identify as early as possible potential dangers due to disturbance by wild animals.	Lack of early detection of wild boar movements.	Establish a daily routine inspection schedule, as well as create a fast reporting system to ARFF.
Understanding Habitat				
2	Areas of tall vegetation, swamps, and bushes are allowed to	Article 3.b: Understanding the habitat of wild animals that endanger flight safety.	Wild boar habitat mapping in the airside area is not yet optimal.	Conduct habitat mapping and determine vulnerable zones as patrol priorities.

	grow without management.			
Open Trash Can				
3	The landfill at Fatmawati Soekarno airport is still open.	Article 3.b: Understanding the habitat of wild animals that endanger flight safety.	The presence of open trash bins around operational areas or outside the airport perimeter provides a potential food source that can attract wildlife from their natural habitat to approach and enter the airside area.	To mitigate this risk, waste management must be an integral part of airport habitat management programs. Waste receptacles should be tightly sealed, animal-proof, and located away from perimeters or vulnerable areas.
Vegetation and Drainage Management				
4	Grass is >30 cm tall, water channels are open and stagnant.	Article 3.c: Clearing undergrowth, limiting grass height, closing drainage.	Wild boar habitat is not reduced, open water access remains available.	Regular pruning, herbicide spraying, and drainage blocking.
Perimeter Fence				
5	The fence is damaged in several places and there are gaps, making it easier for animals to enter.	Article 3.c and Article 5.1: Eliminate the causes of the entry of feral animals; provide prevention equipment.	The gap in the fence has not been addressed and is not equipped with a countermeasure.	Complete fence repair, installing barbed wire, and installing sounds on the fence from cans filled with rocks.
Control Equipment				
6	There are no visual tools or predatory animals available to ward off wild animals.	Article 5.2: Devices may be visual, acoustic, lethal, or predatory.	There is no detection technology or deterrent animals.	Provide spotlights, rattling cans on the fence, and special weapons if necessary.

Source: Research Result.

From the results of the gap analysis, six forms of discrepancy (gap) were identified between the standards set out in the regulations and the real situation in the field at Fatmawati Soekarno Airport, which include several important aspects, including:

a. Lack of early detection of wild boar movements.
b. Mapping of wild boar habitat in the airside area is not yet optimal.
c. The presence of open trash bins around operational areas or outside the airport perimeter provides a potential food source that can attract wildlife from their natural habitat to approach and enter the airside area.
d. Wild boar habitat is not reduced, open water access remains available.
e. The gap in the fence has not been addressed and is not equipped with a countermeasure.
f. There is no detection technology or deterrent animals.



Source: Research Result.

Figure 1. Bowtie Analysis

In the context of risk assessment using the *Bowtie Analysis* approach, several key elements were identified. The **threats (2)** that may trigger potential disruptions include damage to the perimeter fence or open gaps, as well as the natural habitat of wild boars, such as bushes and lush grass surrounding the airport area. These threats could lead to **consequences (3)** in the form of airport operational disruptions, including delayed departures and landings, and even collisions between aircraft and wild boar pests.

The primary **hazard (1)** underlying this risk is the presence of a wild boar population in the vicinity of the airport. This hazard can escalate into the **top event (4)**, namely the intrusion of wild boars into the airside during operational hours. Such an event may be exacerbated by several **escalation factors (5)**, including limited personnel

or materials for rapid repairs, rapid vegetation growth during the rainy season, insufficient staffing during certain shifts, and inactive or faulty detection systems.

To prevent these threats from developing into a top event, several **preventive barriers (6)** are required, such as daily perimeter fence inspections, installation of standard anti-wildlife fencing, arrangement of the airport buffer zone (*clear zone*), and routine vegetation pruning. In the event that the top event does occur, **recovery barriers (7)** can serve as mitigation measures. These include the availability of a Wildlife Hazard Management team on standby, established wildlife evacuation procedures, the use of wildlife monitoring systems or radar detection, and emergency pilot procedures such as *go-around* or *emergency stop*. Moreover, the effectiveness of risk control largely depends on the implementation of **escalation factor barriers (8)** designed to neutralize escalation conditions. Examples include the provision of a dedicated maintenance team with emergency material stock, weather forecast-based vegetation management schedules, rotation shift systems with cross-functional training, and routine maintenance and testing of detection systems. Through the combined implementation of preventive, recovery, and escalation control measures, the risk of wild boar intrusion into the airport's airside can be minimized, thereby maintaining overall aviation safety.

Meanwhile, bowtie analysis is a diagram that visualizes the risks we face in a single, easy-to-understand image. This diagram is shaped like a bowtie, creating a clear distinction between proactive and reactive risk management. The advantage of a bowtie diagram is that it provides an overview of several plausible scenarios in a single image. In short, this diagram provides a simple visual explanation of risks that would be much more difficult to explain otherwise. The advantage of this research lies in the bowtie analysis. While many studies have discussed wildlife hazards, none have used the bowtie analysis method to analyze their data.

Research conducted by (Putra, 2024) entitled Efforts to Prevent Wildlife Hazards Against Operational Activities at Pondok Cabe Airport. The gap analysis method is used to determine the difference between actual conditions in the field and the ideal conditions that should be. This research only uses the gap analysis method. Research conducted by (Aswiratin et al., 2024) entitled Wildlife Hazard Management for Flight Safety at Aji Pangeran Tumenggung Pranoto Samarinda International Airport. This research applies a qualitative descriptive approach. Data were collected through documentary studies and direct observation at the research location. Research conducted by (Alfarisi & Sonhaji, 2024) entitled Wildlife Hazards to Air Traffic Services at Hang Nadim International Airport, Batam. The approach used is descriptive qualitative. Data collection was conducted through documentation studies and direct field observations. Research conducted by (Lusi Amelia Simanjuntak & Sri Sutarwati, 2023) entitled Analysis of the Implementation of Wild Animal Hazard Management in Supporting Aviation Safety Using the Hazard Identification and Risk Assessment (HIRA) Method at Hang Nadim International Airport, Batam. This study uses the HIRA method to identify risks. Research conducted by (Dian Dwi Indriyani et al., 2024) entitled Implementation of Feral Animal Management: Preventing Feral Animal Hazards in Supporting Aviation Safety and Solving Feral Animal Control Problems. The purpose of this article is to formulate hypotheses regarding the relationships between variables that will be used in further research.

This study demonstrates that the integration of *gap analysis* and *bowtie analysis* provides a comprehensive and systematic overview of wildlife risk management in a visual framework. Nevertheless, the research remains limited to a single location and a specific species, thus further studies with broader scope and quantitative approaches are required to validate the effectiveness of the proposed mitigation measures. These findings are expected to contribute to the development of risk-based safety management systems within the airport environment.

4. CONCLUSION

Based on research conducted at Fatmawati Soekarno Airport in Bengkulu, it can be concluded that controlling wild boar pests as a wildlife hazard still faces several significant obstacles. A gap analysis revealed discrepancies between actual conditions and safety standards, such as damaged fences, tall vegetation, open trash bins, and the lack of an early detection system. Management remains manual, reactive, and lacks standard operating procedures (SOPs). Therefore, a more proactive and risk-based control system is needed. Bowtie analysis identified the presence of wild boars on the airside as a major hazard that could trigger a runway incursion as the top event. Efforts to mitigate the impact of wildlife hazards at Fatmawati Soekarno Airport include preventive barriers such as installing wildlife fences, fence inspections, daily vegetation trimming, and buffer zone development. Recovery barriers include wildlife evacuation procedures, a standby wildlife hazard team, go-around and emergency stop procedures, and the use of wildlife detection radar. Escalation factors such as limited personnel and materials, as well as detection system errors, also need to be taken into account. The integration of gap analysis and bowtie analysis effectively illustrates systematic risk control. However, because the research is limited to a single location and animal species, further, broader, quantitative studies are needed for validation. These findings are expected to form the basis for developing a risk-based safety management system at airports.

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