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RUNWAY END SAFETY AREA: OVERRUN AND UNDERSHOT SAFETY RISK ANALYSIS

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Abstract

An airport is a complex facility for passenger and cargo processing, aircraft arrival, departure, and maintenance. Ensuring safe and comfortable flights for its passengers requires implementing aviation security and safety improvements in tandem with the growing number of aircraft in operation. Aviation operators and regulators are always focused on issues and potential incidents that jeopardize aviation safety and security, particularly during the landing and takeoff phases of flight, which include overrun and undershoot occurrences. Therefore, a study is required to determine the event's probability. By adopting research methods that have been developed by the European Aviation Safety Agency (EASA), this research aimed to analyze the risk of overrun and undershoot at Sultan Syarif Kasim II Airport (SSK II) and Raja Haji Fisabilillah Airport (RHF). The research method is quantitative by comparing data collected with the Target Level of Safety (TLS), which is quantified and recommended by the aviation authority International Civil Aviation Organization (ICAO) and the British Civil Aviation Authority (CAA UK), where the acceptable TLS according to ICAO is 6.6 x 10-7 while according to the UK CAA it is 4 x 10-7. The result showed that the probability value of overrun and undershoot at SSK II Airport averages 0.66 x 10-7 and 2.98 x 10-7 at RHF Airport. This indicates that at RHF Airport, there is a higher possibility of overrun and undershooting risk frequency than at SSK II Airport. The fact that RHF Airport has just one RESA is the primary element affecting the high-risk likelihood at RHF Airport. The chance of overrun and undershoot occurrence frequency dropped to an average of 2.06 x 10-7 after simulating RESA compliance per ICAO regulations.

Keywords: *Safety Risk Analysis, Runway End, Safety*

Introduction

Airports are facilities or places for aircraft to take off and land. (Riyadi et al. 2021) Ensuring safe and comfortable air travel for its passengers requires the implementation of aviation security and safety enhancements in tandem with the growing number of aircraft in operation. Aviation operators and authorities constantly monitor issues and potential events related to aviation safety and security, particularly during the most crucial flight phases, which are the landing and departure stages (Štumper et al. 2015).

Aircraft accidents (Szczepaniak et al., 2020) can occur in various places, such as in the air or on the ground. Ground aircraft accidents c occur inside, around, or outside the airport (Usui et al. 2022). The location of aircraft accidents inside aerodromes often occurs in the runway area. Many of these events involve runway overruns and runway veer-offs, where the aircraft skids to the right or left of the runway (Saputra, 2017). When an airplane crosses the end of the runway while landing or taking off, it is said to have overrun. When an aircraft makes touch with the ground before reaching the runway during the landing approach, it is said to be undershot.

Undershoot events occur due to misestimation of distance, speed, and altitude on the final approach. The standard protection for an aircraft and its passengers against an occurrence or incident is to provide a Runway End Safety Area (RESA). According to the International Civil Aviation Organization (ICAO), RESAs are symmetrical to the extended runway centerline and adjacent to the runway ends. RESAs are intended to reduce the risk of damage to landing aircraft during overrun and undershoot conditions on the runway. (Desryanto, 2018a) due to the increasing requirements of aviation safety standards demanded by the international aviation world and in line with the process of disseminating civil aviation safety regulations and Civil Aviation Safety Regulations (CASR) 139 on Aerodrome. Given the technical categorization of each airport and the typically small surrounding region, all airports in Indonesia must have completed aviation safety facilities, or RESA.

Currently, Raja Fisabilillah Airport has runway non-conformities, which are situations or conditions of deviation or non-conformity to existing rules and regulations. Sultan Syarif Kasim II Airport is one of the airports that has fulfilled the requirements for the availability of two RESA with dimensions of 90 m x 90 m at both ends of the runway strip as a form of fulfillment of flight technical and operational standards obligations. An analysis of the probability of overrun and undershoot events is needed to assess the risk so that the airport operator can develop recommendations for appropriate mitigation measures to control the risk. Whatever the dimensions of the RESA, it is essential to ascertain the likelihood of occurrence and the potential impacts arising from overrun and undershoot (EASA, 2014). The European Aviation Safety Agency (EASA) analysis model assists airport operators in assessing the probability of overrun and undershoot events in meeting civil aviation safety standards (Drees et al., 2017).

Therefore, Sultan Syarif Kasim II Airport in Pekanbaru City and Raja Haji Fisabilillah Airport in Tanjung Pinang City were assessed using a frequency analysis model based on the probability of occurrence that was developed and researched by the EASA authorities in 2014. The safety risk probability values of the two airports will be compared to compare the chance of occurrence at the airport with one RESA activity and the airport with two RESA activities. The airport's compliance with the Target Level of Safety (TLS), which has been advised by aviation authorities including the International Civil Aviation Organization (ICAO) and the United Kingdom Civil Aviation Authority (UK CAA), will be assessed using the likelihood value as a guide.

Method

Research methodology is a scientific way to obtain data, where the data obtained through research is empirical data with specific valid criteria and purposes and uses that are discovery, proof, and development. In this study, the type of research used is quantitative research, namely processing data and analyzing problems using quantitative methods developed by the European Aviation Safety

Agency in 2014. In quantitative methods, the numerical data is then processed using statistical work formulas and derived from variables operationalized with specific measuring scales such as nominal, ordinal, interval, and ratio scales (Franklin, 2022). While the research belonged to (Arnaldo Valdés et al. 2011), it used a probabilistic approach, whereas (Jones, 2016) used the traditional approach to mitigate the risks associated with accidents or incidents to enlarge the runway safety area. The International Civil Aviation Organization's and the Federal Aviation Administration's standard standards for RSA are still not supported by the land area of many airports.

In 2014, EASA classified the variables to be considered in the logistic regression calculation based on their occurrence: overrun during takeoff, overrun during landing, and undershoot during landing. Each case is further divided by aircraft category: small aircraft with Maximum Takeoff Weight (MTOW) ≤5.670 kg and large aircraft with MTOW >5.670 kg. The variables considered based on the event are identified by identifying the variables that will be used in modeling the probability of overrun at takeoff during normal operations subdivided into large and small aircraft movements.

The variables to be used in modeling the probability of overrun at landing during normal operations are subdivided into large and small aircraft movements; compared to overrun at takeoff, there are new variables to be considered in the calculation, the type of approach Instrument Meteorological Conditions (IMC) conditions, visibility, and so on. The variables to be used in modeling the probability of undershooting at landing during normal operations are subdivided into large and small aircraft movements (Ayiei et al. 2020).

The probability approach type differs for large and small aircraft, and the same is true for IMC and Glidepath conditions where the visual system is installed. In the analysis stage of unweighted probability modeling to obtain risk values, researchers perform calculation analysis based on the probability of occurrence category and aircraft type (Moore et al. 2016). Unweighted probabilities are the initial stage in calculating the probability model of overrun and undershoot events. In contrast, the aircraft weighting variables have not been considered when calculating non-weighted probabilities (Iqbal et al. 2023). The weighted probability model is the total probability weighted using the aircraft movement traffic for each event. For example, they land with a small aircraft, take off with a large aircraft, etc. Probability weighting aims to spread the risk according to the distribution of aircraft traffic. This avoids one scenario dominating the overall probability, which does not reflect actual runway usage (EASA, 2014). The distribution of aircraft traffic can be calculated using the percentage of runway usage.

In 2017, Najamudin explained the stages of safety risk modeling, including data collection around runway dimensions and related airports' Runway End Safety Area (RESA). Collection of primary data required in TOOR calculations, LDOR, and LDUS for each type of aircraft landing and takeoff event to be analyzed, calculate the safety risk/non-weighted probability (P1) of TOOR, LDOR, and LDUS. Suppose there is more than one TOOR, LDOR, and LDUS value. In that cas it is necessary to calculate the average value of the traffic distribution to obtain the weighted probability, calculate the probability of occurrence using the location probability model while calculating the aircraft traffic distribution, calculate the mixed probability of the aircraft, compare the analysis results with the TLS value (Di Mascio et al., 2020).

Results And Discussions

The results of modeling the risk probability value of the possibility of overrun and undershoot locations during dry runway and wet runway conditions at each airport which describes the longitudinal distance and lateral distance in each RESA of Sultan Syarif Kasim II Airport and Banda Udar Raja Haji Fisabilillah Airport. The probability of both airports then obtained the probability of overrun and undershoot safety risks.

Table 1. Results of Overrun and Undershoot Safty Risk Probability Analysis

No.	Airport	Dry	Wet
1.	Sultan Syarif Kasim II	0.45×10^{-7}	0.87×10^{-7}
2.	Raja Haji Fisabilillah	1.82×10^{-7}	4.15×10^{-7}

The comparison of the results of the probability value of safety frequency results shows that the probability of overrun and undershoot events is most likely when the runway conditions are wet. Then, in addition to climatic and geographical factors, airport characteristics such as dimensions and RESA fulfillment also affect the frequency probability. The significant difference between Sultan Syarif Kasim II Airport and Raja Haji Fisabilillah Airport is that Sultan Syarif Kasim II Airport has two RESA on its runway. In comparison, Raja Haji Fisabilillah Airport only has one RESA on its runway 22. To implement the research methodology developed by EASA. Furthermore, the analyzed risk probability values will be converted into a combined qualitative risk assessment frequency table presented by ICAO and a quantitative risk assessment table. After obtaining the probability value of the overrun and undershoot events along with the location modeling, the average probability value of the risk of the event can be taken, which is equal to 0.66×10^{-7}. Then the probability value can be converted into the frequency category table of each airport.

Table 2. Probability Categories of Overrun and Undershoot Event Frequency Sultan Syarif Kasim II Airport

No.	Category	Criteria	Score
1.	Frequent	$P(x) \geq 10^{-3}$	5
2.	Probable	$10^{-3} > P(x) \geq 10^{-5}$	4
3.	Remote	$10^{-5} > P(x) \geq 10^{-7}$	3
4.	Extremely Remote	$10^{-7} > P(x) \geq 10^{-9}$	2
5.	Extremely Improbable	$P(x) < 10^{-9}$	1

Based on the table above, the probability of overrun and undershoot events at Sultan Syarif Kasim II Airport is in the Extremely Remote or Very Rare category with a value of two (2). In this case, through EASA modeling, the frequency of possible Overrun and Undershoot events is more than once (> 1) per 10-100 years or every 25 million departures at Sultan Syarif Kasim II Airport.

Table 3. Probability Categories of Frequency of Overrun and Undershoot Events at Raja Haji Fisabilillah Airport

No.	Category	Criteria	Score
1.	Frequent (often)	$P(x) \geq 10^{-3}$	5
2.	Probable (Possibly)	$10^{-3} > P(x) \geq 10^{-5}$	4
3.	Remote (rarely)	$10^{-5} > P(x) \geq 10^{-7}$	3
4.	Extremely remote (very rarely)	$10^{-7} > P(x) \geq 10^{-9}$	2
5.	Extremely improbable (highly Impossible)	$P(x) < 10^{-9}$	1

Based on the table above, the safety risk probability of overrun and undershoot events at Raja Haji Fisabilillah Airport is in the Remote or rare category with a value of three (3). In this case, through EASA modeling, the frequency of possible Overrun and Undershoot events is more than once (> 1) per year or every 2.5 million departures at Raja Haji Fisabilillah Airport.

Table 4. Comparison of Safety Risk Probability Results with Target Level of Safety

No.	Airport	Condition	Comparison to Level of Safety Target Value	
			ICAO (6.6×10^{-7})	CAA (4×10^{-7})
1.	Sultan Syarif Kasim II	Wet	Less	Larger
		Dry	Less	Less
2.	Raja Haji Fisabilillah	Wet	Less	Larger
		Dry	Less	Larger

It is evident from the preceding table that a higher excellent likelihood value denotes a higher possibility of safety hazards. Sultan Syarif Kasim II Airport and Raja Haji Fisabilillah Airport have complied with current safety regulations while utilizing the TLS standard of 6.6x10-7. Raja Haji Fisabilillah Airport does not fulfill the TLS during wet runway circumstances while utilizing TLS 4x10-7 because of its greater value. The notable outcome is that when the runway is wet, there is a greater safety risk of overrun and undershooting. This implies that there may be a greater risk to runway safety if standing water is on the runway.

RESA is an area that must be available at each end of the airport runway strip. In this case, Raja Haji Fisabilillah Airport in 2022 only has one RESA, and the probability value of the risk of occurrence is more excellent or does not meet the TLS of the UK CAA authority. Thus, to further research, a simulation will be carried out to provide RESA that meets the standards, namely the minimum RESA dimensions of 90 m x 90 m for airports with runway code four at the end of runway strip 04 of Raja Haji Fisabilillah Airport.

The RESA fulfillment simulation aims to determine the difference between using one RESA and two RESAs. SSK II Airport does not apply RESA fulfillment simulation because SSK II Airport in 2022 already has two RESAs at each end of runway strip 18 and runway strip 36. The following is the simulation results.

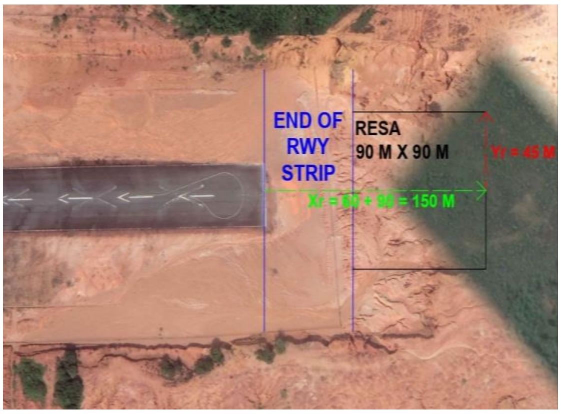

Figure 1. The simulation of Resa 04 Fulfilment at Raja Haji Fisabilillah Airport

In this simulation, the presence of obstacles and land is not considered, so it only focuses on calculating the frequency probability if the addition of RESA is by applicable standards.

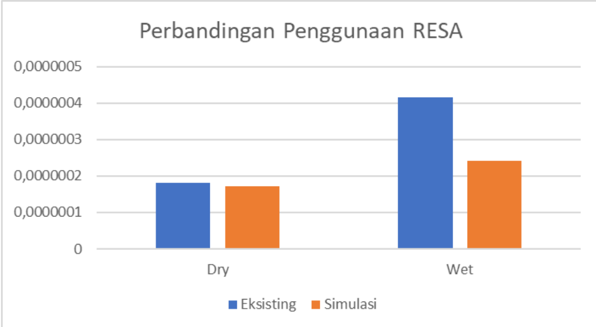

Figure 2. The Comparison of Existing RESA and Simulation

The results of the risk probability calculation after the fulfillment of RESA 04 will be compared with the TLS recommended by ICAO and UK CAA. Table 5 presents the comparison between the simulation results of RESA 04 compliance and the TLS values as follows:

Table 5. Comparison of Safety Risk Probability Results with TLS After Fulfilment of RESA 04

No.	Airport	Condition	Comparison to Level of Safety Target Value	
			ICAO (6.6 x 10^{-7})	CAA (4 x 10^{-7})
1.	Raja Haji Fisabilillah	Wet	Less	Less
		Dry	Less	Less

Based on the comparison graph in Figure 2, it can be seen that the fulfillment of RESA by the standard at the end of runway strip 04 can reduce the potential risk of overrun and undershoot events at Raja Haji Fisabilillah Airport down to an average of 2.06×10^{-7}. This also makes the safety risk value smaller or has fulfilled the TLS from ICAO and UK CAA both in dry and wet runway conditions (Desryanto, 2018b; Nadhirah et al. 2021). In the existing condition, the risk of overrun events and undershooting in wet runway conditions still has a more significant number or has not fulfilled the TLS recommended by the UK CAA (Hong et al. 2016). So, it is necessary to fulfill RESA at both ends of the runway to reduce the probability of safety risks.

Conclusion

Based on the analysis results, SSK II Airport has an average risk value of overrun and undershoot events of 1.19×10^{-7} and 5.5×10^{-7} at RHF Airport. The main factor affecting the high probability of risk at RHF Airport is that RHF Airport only has one RESA when using the TSL standard recommended by ICAO, namely then Sultan Syarif Kasim II Airport and Raja Haji Fisabilillah Airport have met the Target Level of Safety.nAnd if using the Target Level of Safety standard recommended by CAA UK, which is 4×10^{-7}. then Sultan Syarif Kasim II Airport has met the T At the same time, Raja Haji Fisabilillah Airport does not meet or has a number greater than the Target Level of Safety in wet runway conditions. By using the analysis model, it is found that the frequency category of the risk of occurrence at Sultan Syarif Kasim II Airport is in the Extremely remote category (scarce) with a value of two (2) while Raja Haji Fisabilillah Airport is in the remote category (rare) with a value of three Airports that have one RESA have a higher risk of overrun and undershoot events than airports that have two RESAs at the end of the runway strip. Furthermore, appropriate mitigation measures can be developed to control the safety risk of overrun and undershoot events at related airports.

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