Analysis of Determining Holding Area for Flights: Case Study of Halim Perdanakusuma Airport

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Abstract: This study analyzes the determination of holding areas for flights at Halim Perdanakusuma Airport, which serve as temporary zones for aircraft during delays in departure or arrival. With increasing flight activities, optimizing holding areas is essential to ensure smooth airport operations. The study integrates weather radar and rainfall data with evaluations of airport operational capacity and flight safety considerations. This approach identifies optimal holding area locations by accounting for rainfall intensity, visibility, and weather disruptions. Key findings highlight that using weather radar for predictive analysis can significantly reduce delays and enhance safety in challenging weather conditions. The contribution of this research lies in proposing a data-driven methodology for holding area management that can be applied to airports facing similar challenges. This approach not only supports better decision-making but also offers practical strategies for adapting to dynamic weather conditions. Future research could explore incorporating advanced technologies, such as artificial intelligence, to further refine predictive capabilities and expand the scope of analysis to multiple airports.

Keywords: Holding area, flight, bad weather, Halim Perdanakusuma Airport, remote sensing

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Introduction

The determination of holding areas is a critical aspect of air traffic management, serving as temporary zones for aircraft to wait for clearance to land or take off. Previous studies, such as thoseby Jin et al. (2021), focused on the importance of holding areas in minimizing delays and ensuring smooth air traffic flow during peak hours. However, these studies often overlook the impact of dynamic weather conditions, such as rainfall intensity and visibility, which significantly influence the safety and efficiency of flight operations. For instance, Zhang et al. (2018) highlighted the importance of weather radar for predicting delays but did not explore its integration with holding area optimization. At Halim Perdanakusuma Airport, challenges in managing holding areas are compounded by its dual function as a civil and military airport, resulting in unique operational constraints. Operational security is of utmost importance due to the high risk of accidents(Harahap, 2022). Despite existing research on air traffic management strategies (Ng & Lee, 2017), limited studies address holding area management tailored to airports with similar characteristics and extreme weather conditions.

This study is distinct in its application of high-resolution weather radar imagery and its focus on mitigating risks associated with extreme weather. It provides a foundation for future research, which could explore advanced technologies like artificial intelligence to further enhance predictive accuracy and operational resilience in air traffic management. Bad weather often forces flight diversions or longer delays in the air, which risks fuel shortages and disrupts flight schedules. A plane is considered late if it lands later than scheduled. Even if there is a delay, airlines usually set a time tolerance, for example, 10 minutes, which is still considered on-time (Case et al., 2024). Therefore, an effective solution is needed to overcome this situation, such as the use of weather radar technology that can predict weather conditions more accurately and provide early warning to airport authorities and flight crews. Weather radar allows air traffic control to monitor and anticipate weather changes around the holding area so that diversion to an alternative holding area or another airport can be done more safely and efficiently. Identification of improvements in service quality can reduce losses due to flight schedule delays(Sarasi et al., 2022).

Air traffic flow can be overcome by rerouting when there are obstacles in take-off or landing so that it can reduce flight delays (Condé & Murça, 2018). The main focus of this research is the utilization of weather radar data as a tool in operational decision-making and the evaluation of aircraft diversion procedures to alternative areas or airports. Through a case study approach, this research is expected to contribute to the development of air traffic management strategies that are more resilient to extreme weather conditions, so that it can improve the safety and efficiency of flight operations at the airport, especially for Air Traffic

Control which must accommodate many flights every day, so that disruptions to take-off and landing paths are difficult to avoid (Vito et al., 2022). Wind conditions and low visibility have the most substantial impact, with additional delays observed during high temperatures and specific cloud formations (Rodríguez-Sanz et al., 2021). Flight control can be done by analyzing errors and feedback (Y. S. Lee & Juang, 2019).

Halim Perdanakusuma International Airport (HPA) is located in the DKI Jakarta Province and is managed by PT. Angkasa Pura II (Persero). This airport is a civil enclave airport, so it serves VVIP, military (TNI AU), and commercial flights (Supriyadi, 2023). Air transportation plays a crucial role in promoting regional development due to its strong positive correlation with regional economic growth. Airports, serving as key hubs for air travel, attract more visitors to cities, thereby boosting the local economy and fostering the direct development of regional potential (Putro et al., 2023). Since January 10, 2014, HPA has temporarily functioned as a commercial airport to assist flights at the already congested Soekarno-Hatta Airport. Since it was opened as a commercial airport, the number of aircraft and passengers flying to and from this airport has continued to increase.

Figure 1 Halim Perdanakusuma (Source: Angkasa Pura II)

Halim Perdanakusuma Airport serves domestic flights and some limited international flights. As a dual-purpose airport (civil and military), its flight routes focus on domestic flights and short-haul routes. Domestic flight routes served by Halim Perdanakusuma Airport include Juanda Airport in Surabaya, Adisutjipto Airport in Yogyakarta, Abdul Rachman Saleh Airport in Malang, Ahmad Yani Airport in Semarang, Ngurah Rai Airport in Bali, and Kualanamu Airport in Medan. As a military base, Halim Perdanakusuma Airport also serves military flights and special flights for state officials. International flight services at Halim are usually charter or special flights such as official or VIP flights. These flights are often non-commercial and follow different routes from civil flight routes. International routes that have been operated include Kuala Lumpur, Malaysia and Singapore.

Figure 2 Halim Perdanakusuma Airport Flight Route Map (Source: Angkasa Pura II)

Literature Review

Holding Area

A holding area is a designated airspace or ground area where aircraft wait during specific phases of flight operations, such as before landing or takeoff, due to air traffic congestion, weather disruptions, or operational delays (Y. Lee et al., 2021). An airport is a sophisticated infrastructure made up of numerous functional subsystems, designed to meet anticipated traffic demands over time through a well-structured airport master planning process (Di Mascio et al., 2020). However, improper placement or insufficient capacity of holding areas can lead to increased risks, such as mid-air collisions or ground incidents, especially under adverse weather conditions. The most significant risks associated with ramp activities are evident, including exposure to noise, the danger of being hit by operational vehicles, and the risk of being trapped by Ground Support Equipment (Sari et al., 2016).

Meteorological Observation Data

Meteorological observation data refers to information collected from direct observation of atmospheric conditions and meteorological elements at a specific location and time. Accurate meteorological observation data is essential for decision-making regarding flight operations during bad weather. BMKG plays an important role in providing data such as real-time rainfall. This information is then analyzed by airports and airlines to determine whether weather conditions allow aircraft to take off or land safely. To understand the environment of the research area, BMKG station observation data is based on standards set by the World Meteorological Organization (WMO)(Park et al., 2017). Until now, surface observation systems for institutional needs have been important special assets owned and operated by governments or research institutions.(Denis et al., 2017). The data used in this study is rainfall data obtained from Automatic Weather Services located at Halim Perdanakusuma Airport during the last five years.

Weather Radar Imagery Data

High-resolution observations from the surface and remote sensing are now commonly used to calculate every rotation on every scale and in every layer of the atmosphere.(Tziotziou et al., 2018). Radar radial velocity data is available every 6 minutes with a radial resolution of 250 meters, thus very helpful for the analysis of convective cloud growth. Radio Detection and Ranging (Radar) imagery data is an important component in observing the growth of convective clouds (Kholiviana et al., 2022). This data can provide information about atmospheric conditions that can support cloud growth and monitor its movement and intensity. The working principle of this weather radar uses radio waves to detect humidity and movement in the atmosphere. Radar signals are reflected by water particles or solid material in clouds, which then provide an overview of cloud structure and air movement (H. Zhang et al., 2021). The information that can be obtained from this radar image is air humidity, wind direction and speed, and rain intensity. These data are important for detecting the potential for cloud formation. Weather radar is able to provide information in real time. In this study, the author used a Weather Radar located in Tangerang with the SRI (Surface Rainfall Intensity) product with a radius of 100 km.

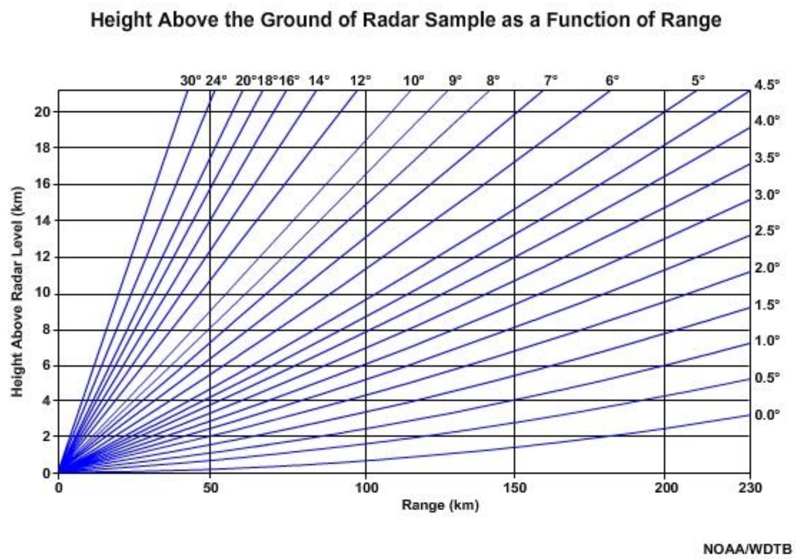

Figure 6 Height vs Range (NOAA/WDBT)

Research Method

This research adopts a descriptive-analytical design to evaluate and optimize holding areas at Halim Perdanakusuma Airport by integrating meteorological and operational data. The methodology begins with the collection of weather radar data from the BMKG station, specifically the Surface Rainfall Intensity (SRI) product, which provides high-resolution rainfall intensity data every six minutes. Operational data, including airport traffic and disruption reports, is also gathered to understand the context of flight activities.

The collected data undergoes a detailed processing phase. Weather radar imagery is analyzed to visualize rainfall patterns, map high-risk zones, and identify potential hazards. These visualizations are then geospatially mapped onto the airport layout to determine the suitability of different areas as holding zones. Descriptive statistical techniques are employed to calculate average rainfall and identify trends over the past five years.

In the last ten years, there have been at least five incidents, ranging from the total closure of the airport in October 2017 to periodic delays. Bad weather has proven to be the main factor disrupting flight operations at Halim Perdanakusuma Airport. Extreme weather conditions such as heavy rain, strong winds, or thick fog can endanger the take-off and landing process of aircraft. One of the extreme weather conditions when the aircraft is about to take off and land is icing which endangers flight safety.(Wang et al., 2021). As a result, airport authorities often take decisions to delay or cancel flights for the safety of passengers and aircraft crew.

Table 1 Flight disruption data (Source: Media)

No.	Date	Incident	Impact
1	October 1, 2017	Bad weather	Halim Perdanakusuma Airport is closed
2	March 3, 2018	Bad weather	Flight delay
3	22-Nov-19	Bad weather	Landing diversion
4	January 1, 2020	Bad weather	Flight activities at Halim Perdanakusuma Airport are paralyzed
5	January 21, 2024	Bad weather	Flight delay

From the data listed, it can be concluded that bad weather is a significant challenge for the aviation industry, especially in areas with airports such as Halim Perdanakusuma.

Table 1 presents data on flight disruptions caused by bad weather, detailing incidents that occurred at various times and their corresponding impacts. On October 1, 2017, adverse weather conditions forced the complete closure of Halim Perdanakusuma Airport, halting all operations. A similar weather-related issue on March 3, 2018, led to flight delays. On

November 22, 2019, bad weather caused flights to be diverted to alternative airports, highlighting the impact of poor visibility or unsafe flying conditions. On January 1, 2020, bad weather again disrupted flight operations at Halim Perdanakusuma Airport, this time paralyzing all activities. Most recently, on January 21, 2024, bad weather resulted in another instance of flight delays. This data underscores the recurring challenges posed by weather-related disruptions, particularly for airports like Halim Perdanakusuma, where such incidents have significantly affected aviation activities over the years. Resource allocation for fairly dense flights, the focus of the holding area unit configuration in ATC must be optimized(Han, 2021). These flight delays due to bad weather not only harm airlines, but also impact passengers' comfort and travel plans.

To overcome this problem, various related parties need to work together. Starting from the Meteorology, Climatology, and Geophysics Agency (BMKG) which is tasked with providing accurate weather information, to airports and airlines that must have effective bad weather handling procedures. In addition, the development of more sophisticated aviation technology is also expected to help reduce the negative impact of bad weather on flight operations. Based on data collected through the DKI Jakarta Central Statistics Agency (BPS), the number of aircraft departing from Halim Perdanakusuma Airport from 2021 to 2022 reached 25,530 flights and the number of aircraft arriving at reached 25,416 flights.

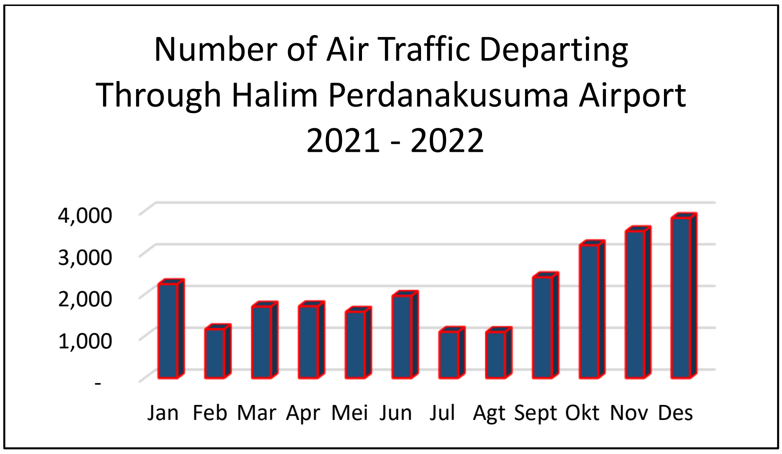

Figure 3 Number of departing aircraft traffic (Source: BPS DKI Jakarta Province)

From Figure 3 above, it can be seen that the number of flights fluctuates throughout the year, with peaks occurring in certain months. This indicates seasonal factors or special events that affect the level of flight activity at Halim Perdanakusuma Airport.

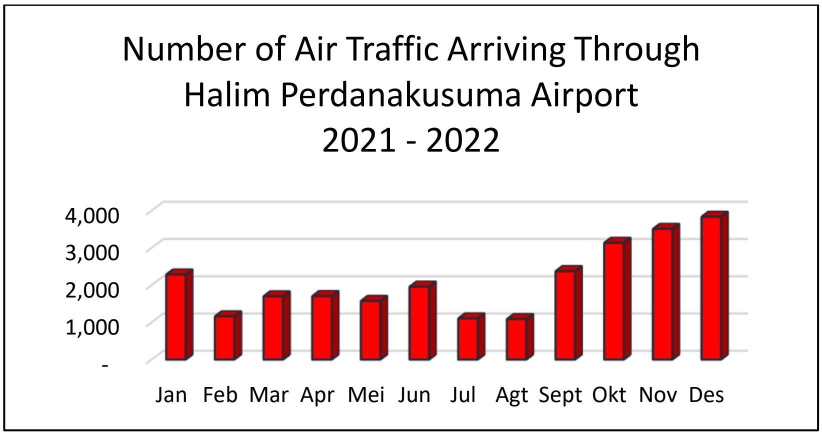

Figure 4 Number of incoming aircraft traffic (Source: BPS DKI Jakarta Province)

The fluctuation pattern in Figure 4 is similar to Figure 3, which shows a correlation between the number of departing and arriving flights. This study focuses on the analysis of weather radar data to study rainfall patterns and identify them with geographical conditions. The first step is to collect weather radar data taken over a period of one year. The radar data that has been collected is then averaged to obtain an overview of rainfall patterns over a period of five years and facilitate further visualization and analysis. The resulting radar imagery is then mapped. This mapping allows for viewing the distribution of rainfall spatially.

The mapped data is then analyzed descriptively. This analysis includes calculating the average rainfall, identifying areas with the highest and lowest rainfall, and identifying general rainfall patterns. Further analysis is carried out by cross-sections to see the vertical profile of rainfall in a particular location. Furthermore, analyzing the mean precipitation per month to calculate the average monthly rainfall in each region. Then, analyzing the holding area related to identifying certain areas that often experience bad weather conditions or have potential flight hazards.

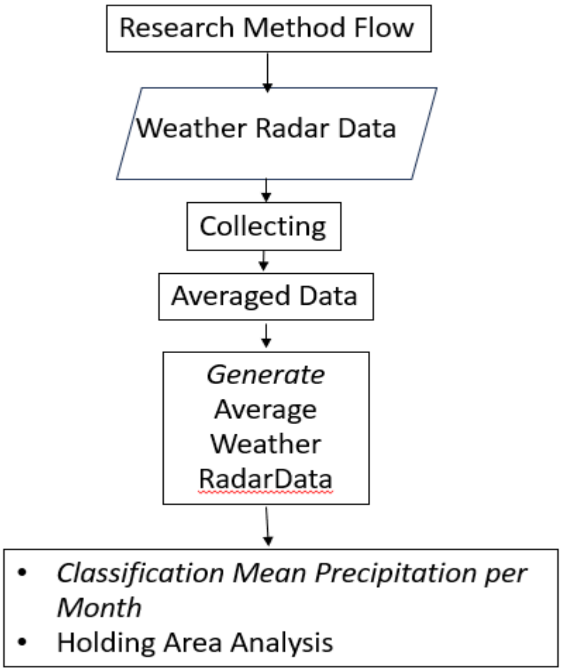

Figure 5 Research Method Flow

Figure 5 describes the research method flow which starts with the use of weather radar data, which provides information on rainfall intensity, distribution patterns, and other atmospheric conditions. This data is sourced from BMKG Tangerang Geophysical Station, providing high-resolution updates (daily data). This data forms the core of understanding how weather impacts holding areas at the airport. In collecting step, data is collected from multiple sources, including weather radar data and airport operational reports. Rainfall data is gathered over the last five years to ensure that the analysis covers long-term and seasonal weather patterns. This step ensures that both weather and operational aspects are factored into the research.

Once the data is collected, the next step is to process it by calculating the monthly and annual average rainfall. This process helps identify general weather patterns that could affect the efficiency and safety of holding areas. The data processed includes the average rainfall values and the maximum intensity levels for each month. The step of generate average weather radar data involves an in-depth analysis of the generated average weather data. The radar data is used to create visualizations showing the rainfall distribution patterns around the airport. Using geopotential tools, the radar data is overlaid onto the airport map to pinpoint areas that may be at higher risk due to rainfall or other weather factors.

The average rainfall data is classified by month to understand seasonal variations. This classification allows for grouping holding areas based on specific weather conditions, such as higher rainfall during the rainy season. This analysis assesses how monthly precipitation levels might affect airport operations and holding area suitability.

The final step involves evaluating the suitability of holding areas based on the rainfall analysis results. Areas with high rainfall or operational risks are excluded from the recommended holding areas. Additionally, recommendations for optimal holding areas are made, taking into account safety, operational efficiency, and seasonal weather conditions.

Result and Discussion

Holding area in aviation is an area where aircraft wait their turn to land or take off. The determination of the location and capacity of the holding area is greatly influenced by various factors, one of which is weather conditions. Heavy rainfall can reduce the pilot's visibility, thus affecting the aircraft's ability to maneuver and land (Škultéty et al., 2022) . Rainwater can also make the runway surface slippery, increasing the risk of accidents when the aircraft takes off or lands. Heavy rain is often accompanied by strong winds and turbulence that can disrupt the stability of the aircraft.

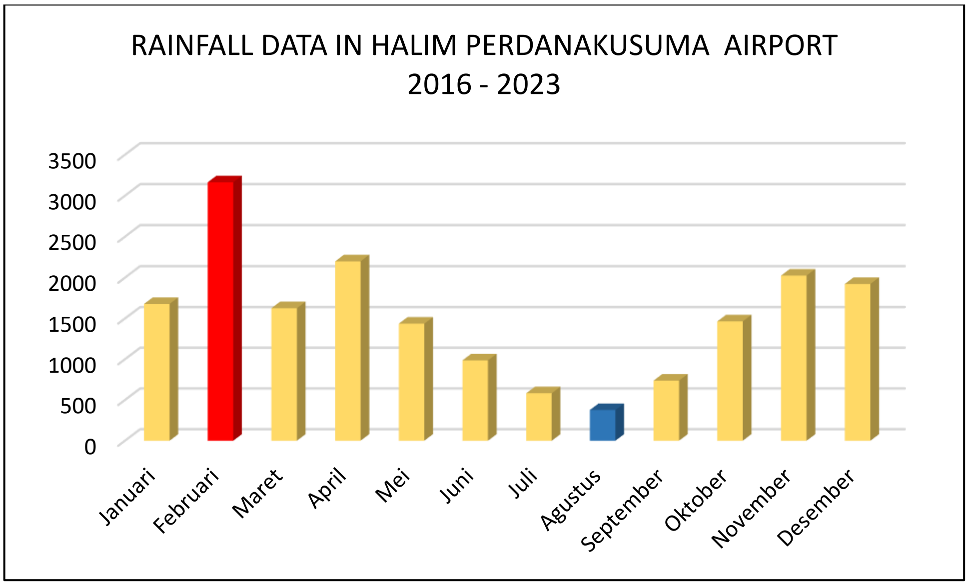

Figure 7 Rainfall Data in Halim Perdanakusuma Airport in 2016 - 2023

Figure 7 shows the distribution of rainfall in the Jakarta area with quite significant rainfall intensity. The Jakarta area is generally dominated by red to yellow, indicating high intensity rainfall. This area includes Central Jakarta, East Jakarta, and most of South Jakarta, thus indicating the potential for weather disturbances that can affect flight operations, especially around Halim Perdanakusuma Airport. The North Jakarta area, although still showing high rainfall intensity, has a slightly lighter color gradation (orange), indicating lower rainfall intensity compared to other parts.

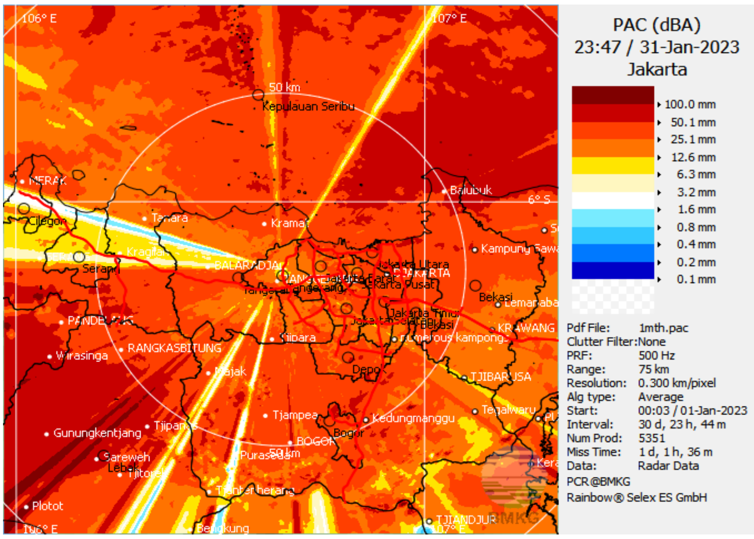

Figure 8 SRI Product Radar Image January 2024

Figure 8. The average SRI product radar imagery for January 2024 shows the distribution of rainfall in the Jakarta area and its surroundings with a resolution of 0.3 km/pixel. Areas with high rainfall intensity (more than 50 mm/hour, marked in dark red to brown) appear to dominate in several parts, especially in the southern area of Jakarta to the border with Bogor. Conversely, areas with low to moderate rainfall intensity (6.5 - 25 mm/hour, marked in orange and yellow) were detected in the northern and central areas of Jakarta. The radar range of up to 75 km covers strategic areas such as Halim Perdanakusuma Airport and its surroundings, which are of concern in flight operational analysis. This high rainfall intensity can be a risk factor in setting up holding areas, so it is important to consider this radar data to improve airport operational safety and efficiency, especially in bad weather conditions.

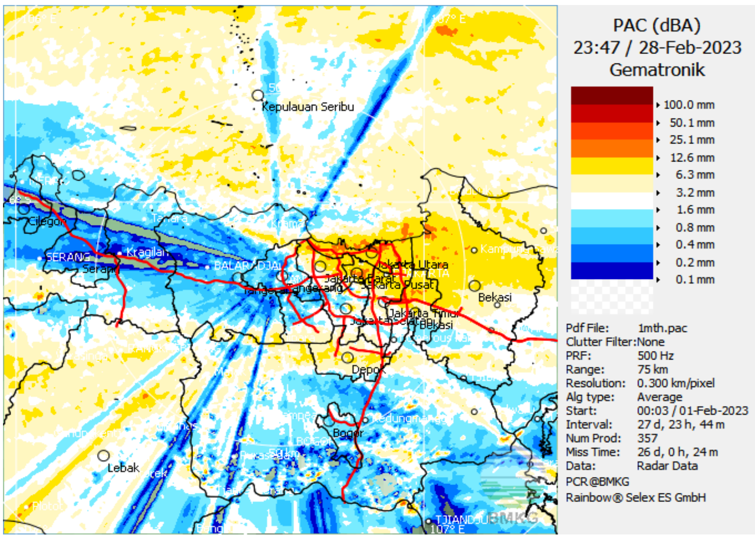

Figure 9 SRI Product Radar Image February 2024

Figure 9 above shows the distribution of low to moderate rainfall intensity (0.1 - 6.5 mm/hour, marked with light blue to yellow) in the Jakarta area and its surroundings. Higher rainfall intensity (12.6 mm/hour and above, red and orange) is only seen in limited areas. This condition indicates relatively light rainfall compared to the previous distribution, so its impact on flight operations, including determination of holding area, more minimal.

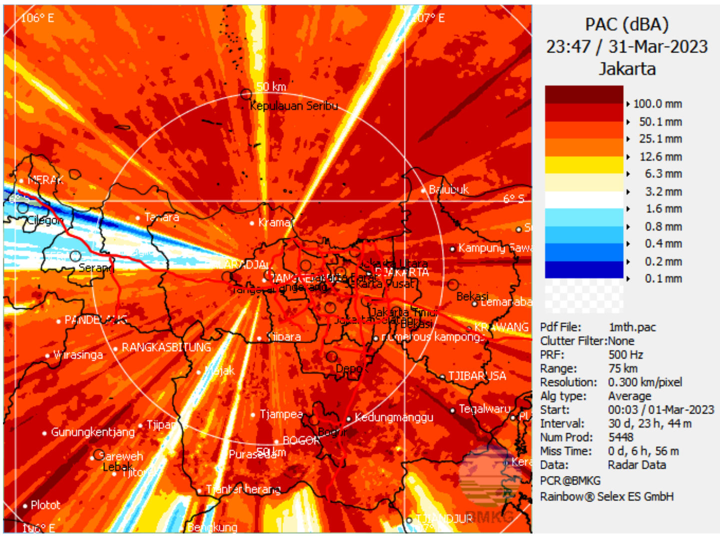

Figure 10 SRI Product Radar Image March 2024

Figure 10 above shows high intensity rainfall (50-100 mm/hour, marked with dark red to brown) spread evenly across the Jakarta area and its surroundings, including the South Jakarta to Bogor area. This high intensity rainfall has the potential to affect flight operations, especially related to visibility and runway conditions.

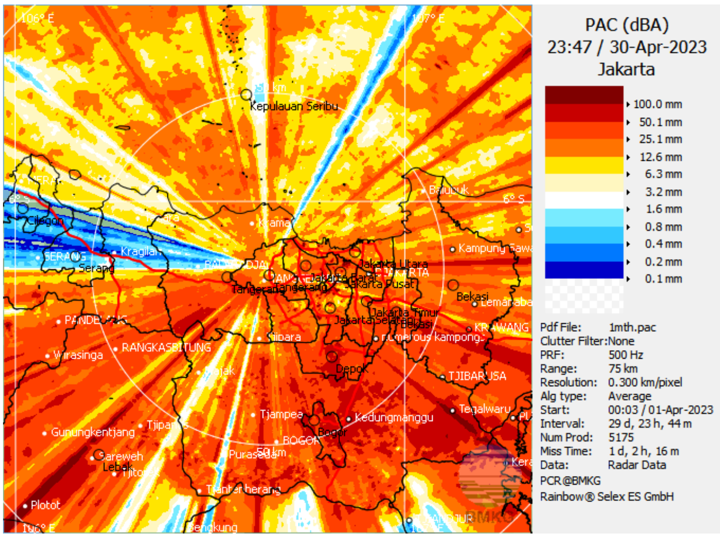

Figure 11 SRI Product Radar Image April 2024

Figure 11 shows the intensity of rainfall in the Jakarta area and its surroundings in April. For the Central Jakarta and South Jakarta areas, it is dominated by red and yellow, indicating high rainfall so it is not recommended for a holding area when the plane takes off or lands. For the East Jakarta, West Jakarta, and North Jakarta areas, the rainfall intensity is dominated by yellow to blue, meaning low to moderate rainfall intensity, making it more likely to be considered as a temporary holding area.

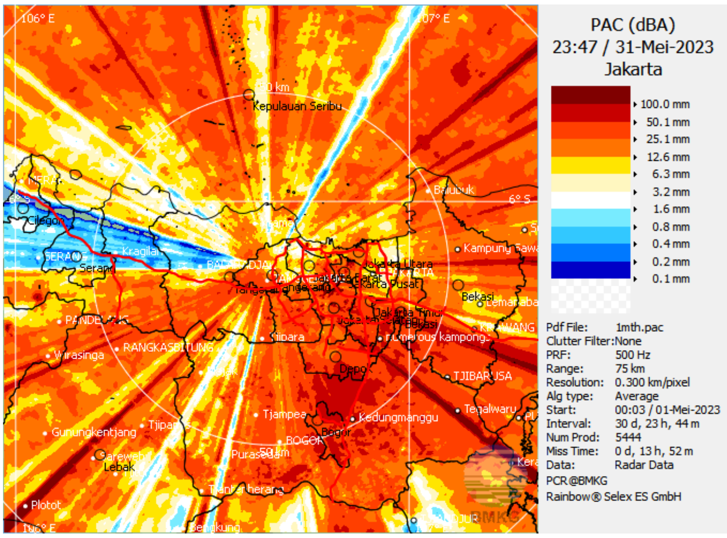

Figure 12 SRI Product Radar Image May 2024

Figure 12 shows that in May, East Jakarta, Central Jakarta, West Jakarta, and South Jakarta were monitored as showing a dominant red color, meaning that the rainfall intensity in the area was high, making it not ideal for a holding area. The North Jakarta area appears to have a lower rainfall intensity (dominated by yellow to orange), making it an alternative temporary holding area.

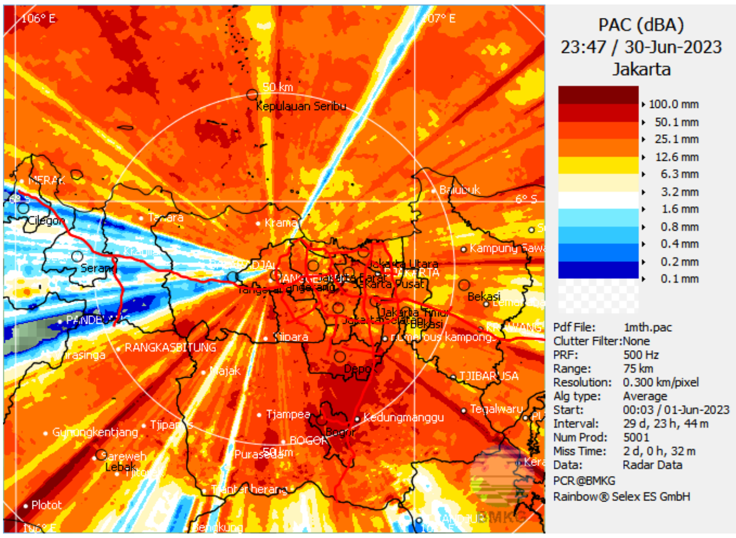

Figure 13 SRI Product Radar Image June 2024

Figure 13 shows the distribution of rainfall in the Jakarta area with quite significant rainfall intensity. The Jakarta area is generally dominated by red to yellow, indicating high intensity rainfall. This area includes Central Jakarta, East Jakarta, and most of South Jakarta, thus indicating the potential for weather disturbances that can affect flight operations, especially around Halim Perdanakusuma Airport. The North Jakarta area, although still showing high rainfall intensity, has a slightly lighter color gradation (orange), indicating lower rainfall intensity compared to other parts.

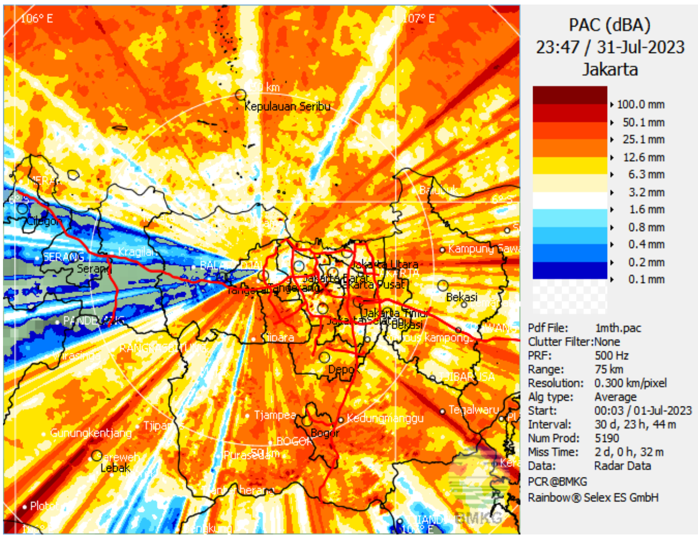

Figure 14 SRI Product Radar Image July 2024

Figure 14 shows the distribution of rainfall intensity in the Jakarta area dominated by yellow to orange colors for Central Jakarta, East Jakarta, and South Jakarta, indicating moderate to high intensity rainfall. Meanwhile, the West Jakarta and North Jakarta areas appear to have relatively lighter rainfall intensity (dominated by blue and green), so they can be used as an alternative for airport operations when taking off or landing.

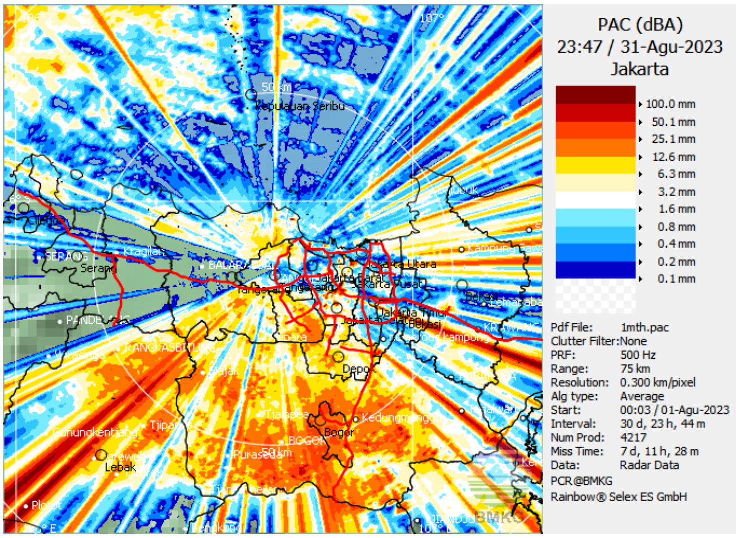

Figure 15 SRI Product Radar Image August 2024

Figure 15 shows that in August the distribution of rainfall in the Jakarta area is dominated by blue to green colors, especially for North Jakarta and Central Jakarta, indicating that the rainfall intensity is light. However, for South Jakarta, orange to red colors are visible, indicating moderate to high rainfall. For the East Jakarta area, the rainfall intensity appears lower (blue to green), so this condition tends to be safe for flight activities considering that Halim Perdanakusuma Airport is located in the East Jakarta area.

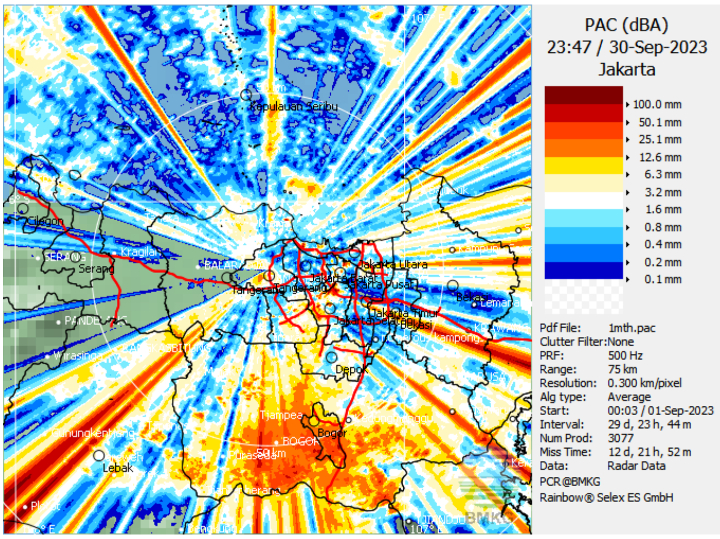

Figure 16 SRI Product Radar Image September 2024

In Figure 16, the Jakarta area is mostly dominated by blue to green, indicating light rainfall intensity. However, for the South Jakarta area, it is dominated by yellow to orange indicating moderate rainfall intensity and in certain areas it is dominated by red indicating high rainfall intensity. For the Halim Perdanakusuma Airport area, the area is dominated by blue to green, indicating light rainfall intensity. This condition is relatively safe for flight activities, but still requires monitoring, especially the movement of rain from the South to the North causing significant changes in weather conditions.

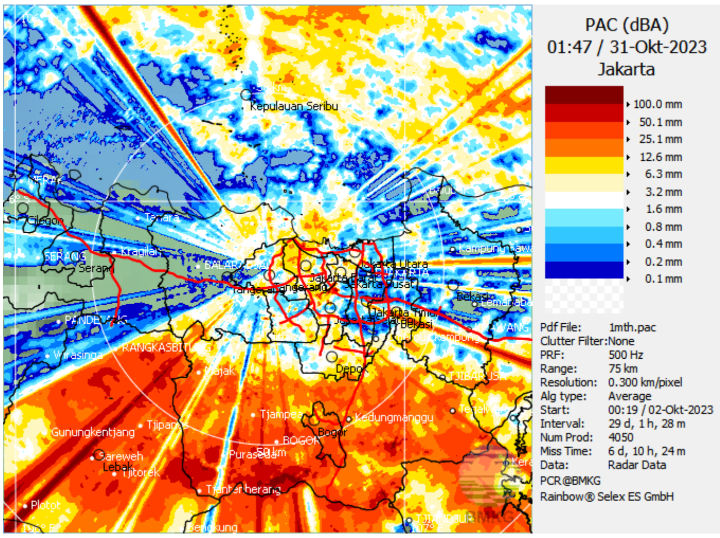

Figure 17 SRI Product Radar Image October 2024

Based on Figure 17 above, it can be seen that the Jakarta area experiences rainfall with varying intensity. Areas with high rainfall intensity are concentrated in North Jakarta and parts of Central Jakarta. This is indicated by the red and orange colors on the color scale indicating rainfall of more than 50 mm/day. Meanwhile, the West Jakarta and parts of South Jakarta are dominated by yellow to green colors indicating moderate rainfall intensity. Meanwhile, the East Jakarta area tends to have lower rainfall intensity compared to other areas so that activities around Halim Perdanakusuma Airport are not too affected by weather factors.

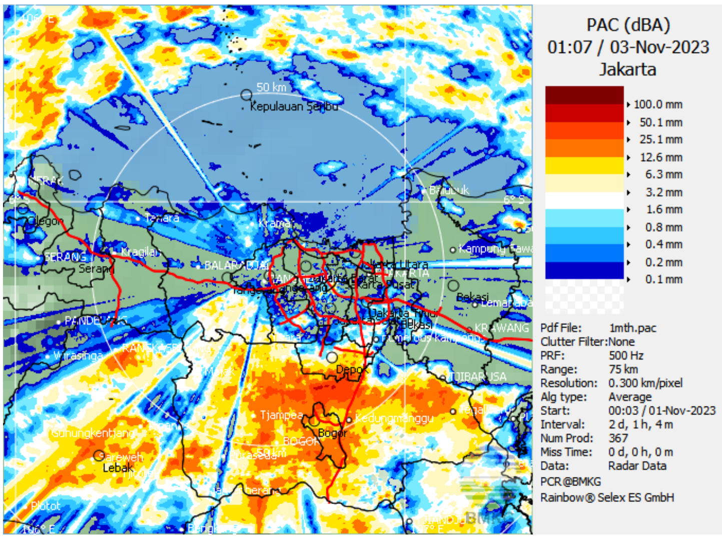

Figure 18 SRI Product Radar Image November 2024

Figure 18 shows light to moderate rainfall marked with blue to yellow colors spread across the Jakarta area. High rainfall intensity (orange to red) is seen at several points in South Jakarta. Judging from the radar image, it shows a varied distribution of rain, with minimal potential impact on flight operations, but still needs to be considered for mitigating the risk of local weather factors.

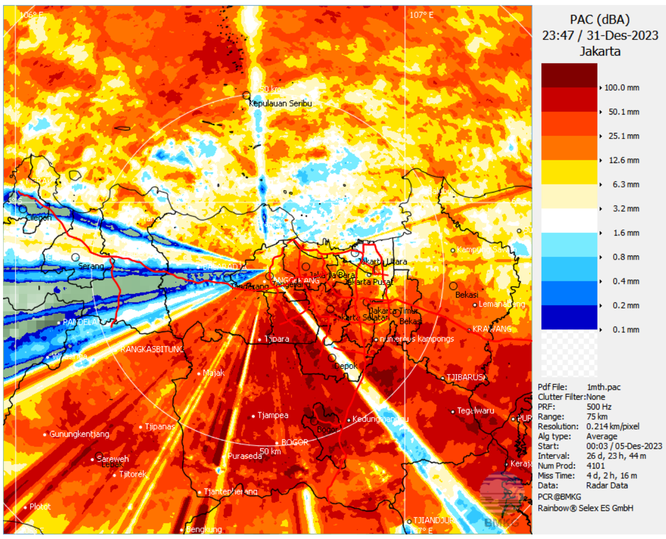

Figure 19 SRI Product Radar Image December 2024

Figure 19 shows that high intensity rainfall marked with dark red to brown dominates most of Jakarta, especially South Jakarta and East Jakarta. Meanwhile, areas with light to moderate rainfall intensity marked with blue to yellow are seen in several areas of North Jakarta and

West Jakarta. This condition indicates a high potential risk to flight operations, including delays due to low visibility and slippery runways.

Conclusions

The study at Halim Perdanakusuma Airport focused on optimizing holding areas by integrating weather radar and rainfall data to enhance operational safety and efficiency during adverse weather conditions. Key findings highlighted the benefits of weather radar in predicting high-risk zones, reducing delays, and improving flight safety. However, the research faced several limitations. It was limited to a single airport, raising concerns about the generalizability of its findings to other locations with different layouts or traffic patterns. Additionally, the study relied heavily on rainfall and weather radar data, necessitating consistent access to high-resolution meteorological information, which may not be universally available. Furthermore, the analysis primarily addressed rainfall while other critical weather factors, such as wind shear, temperature fluctuations, and icing conditions, were underexplored.

To address these limitations, future research should broaden its scope to include multiple airports to validate the methodology under diverse conditions. Incorporating advanced technologies like artificial intelligence could enhance real-time meteorological data processing and predictive accuracy. Expanding the analysis to include other environmental factors, such as wind shear and turbulence, would provide a more comprehensive approach to managing holding areas. Lastly, conducting longitudinal studies would allow for an assessment of the long-term impact of optimized holding area strategies on airport operations.

References

Condé, M., & Murça, R. (2018). *Journal of Air Transport Management Collaborative air tra ffi c fl ow management: Incorporating airline preferences in rerouting decisions*. *71*(February), 2017–2019.

Denis, G., Claverie, A., Pasco, X., Darnis, J. P., de Maupeou, B., Lafaye, M., & Morel, E. (2017). Towards disruptions in Earth observation? New Earth Observation systems and markets evolution: Possible scenarios and impacts. *Acta Astronautica*, *137*(December 2016), 415–433. https://doi.org/10.1016/j.actaastro.2017.04.034

Di Mascio, P., Moretti, L., & Piacitelli, M. (2020). Airport landside sustainable capacity and level of service of terminal functional subsystems. *Sustainability (Switzerland)*, *12*(21), 1–21. https://doi.org/10.3390/su12218784

Han, Y. X. (2021). Modeling and optimization of the terminal control area with holding unit. *PLoS ONE*, *16*(3 March), 1–11. https://doi.org/10.1371/journal.pone.0241204

Harahap, R. W. A. (2022). Criminal Liability of Air Flight Accidents. *Locus Journal of Academic Literature Review*, *1*(5), 349–356. https://doi.org/10.56128/ljoalr.v1i6.86

Jin, H., Hu, Z., Li, K., Chu, M., Zou, G., Yu, G., & Zhang, J. (2021). Study on How Expert and Novice Pilots Can Distribute Their Visual Attention to Improve Flight Performance. *IEEE Access*, *9*, 44757–44769. https://doi.org/10.1109/ACCESS.2021.3066880

Kasus, S., Halim Perdanakusuma, B., Suryani, F., & Edwin Kin, M. (2024). *Tingkat Tundaan Penerbangan Maskapai On Time Performance (OTP)*. *12*(2), 23–35.

Kholiviana, P. A., Ruhiat, Y., & Saefullah, A. (2022). Analisis Vertical Wind Shear Pada Pertumbuhan Awan Cumulonimbus Di Wilayah Kabupaten Tangerang. *Newton-Maxwell Journal of Physics*, *3*(1), 17–23. https://doi.org/10.33369/nmj.v3i1.21080

Case, S., Halim Perdanakusuma, B., Suryani, F., & Edwin Kin, M. (2024). Flight Delay Level of On Time Performance (OTP) Airlines. 12(2), 23–35.

Lee, Y., Lee, J., & Lee, J. W. (2021). Holding area conceptual design and validation for various urban air mobility (Uam) operations: A case study in seoul–gyungin area. *Applied Sciences (Switzerland)*, *11*(22). https://doi.org/10.3390/app112210707

Lee, Y. S., & Juang, J. G. (2019). Color identification for quadcopter flight control and object inspection. *Advances in Mechanical Engineering*, *11*(2), 1–16. https://doi.org/10.1177/1687814018822559

Ng, K. K. H., & Lee, C. K. M. (2017). Aircraft scheduling considering discrete airborne delay and holding pattern in the near terminal area. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10361 LNCS*, 567–576. https://doi.org/10.1007/978-3-319-63309-1_50

Park, M. S., Park, S. H., Chae, J. H., Choi, M. H., Song, Y., Kang, M., & Roh, J. W. (2017). High-resolution urban observation network for user-specific meteorological information service in the Seoul Metropolitan Area, South Korea. *Atmospheric Measurement Techniques*, *10*(4). https://doi.org/10.5194/amt-10-1575-2017

Putro, H. P. H., Trinanda, R. F., & Iscahyono, A. F. (2023). Understanding Airport Leakage at Multi Airport in West Java through Accessibility Characteristics to the Airport. *Jurnal Teknik Sipil Dan Perencanaan*, *25*(2), 161–169. https://doi.org/10.15294/jtsp.v25i2.44661

Rodríguez-Sanz, Á., Cano, J., & Fernández, B. R. (2021). Impact of weather conditions on airport arrival delay and throughput. *IOP Conference Series: Materials Science and Engineering*, *1024*(1). https://doi.org/10.1088/1757-899X/1024/1/012107

Sarasi, V., Primiana, I., & Kusnadiuthor, D. A. (2022). Application of value stream mapping to improve service in The Departure Terminal at Halim Perdanakusuma Airport (Implementasi value stream mapping untuk meningkatkan kualitas pelayanan pada Terminal Keberangkatan Bandara Halim Perdanakusuma). *Operations Excellence: Journal of Applied Industrial Engineering*, *2022*(1), 25–35.

Sari, M., Arubusman, D. A., & Abbas, S. (2016). Airport Ramp Risk Analysis At Halim Perdanakusuma. *Jurnal Manajemen Transportasi & Logistik (JMTRANSLOG)*, *2*(3), 275. https://doi.org/10.54324/j.mtl.v2i3.111

Škultéty, F., Jarošová, M., & Rostáš, J. (2022). Dangerous weather phenomena and their effect on en-route flight delays in Europe. *Transportation Research Procedia*, *59*, 174–182. https://doi.org/10.1016/j.trpro.2021.11.109

Supriyadi, A. A. (2023). Obstruction Zone Modeling at Halim Perdanakusuma Airport using Remote Sensing Data. *International Journal of Remote Sensing and Earth Sciences (IJReSES)*, *20*(1), 66. https://doi.org/10.30536/j.ijreses.2023.v20.a3883

Tziotziou, K., Tsiropoula, G., Kontogiannis, I., Scullion, E., & Doyle, J. G. (2018). A persistent quiet-Sun small-scale tornado: I. Characteristics and dynamics. *Astronomy and Astrophysics*, *618*, 1–13. https://doi.org/10.1051/0004-6361/201833101

Vito, V. Di, Bucchignani, E., Montaquila, R. V., Cerasuolo, G., Montesarchio, M., Zollo, A. L., & Cinquegrana, D. (2022). Analysis of vulnerability of ATM to weather phenomena. *IOP Conference Series: Materials Science and Engineering*, *1226*(1), 012020. https://doi.org/10.1088/1757-899x/1226/1/012020

Wang, K., Xue, Y., Tian, H., Wang, M., & Wang, X. (2021). The Impact of Icing on the Airfoil on the Lift-Drag Characteristics and Maneuverability Characteristics. *Mathematical Problems in Engineering*, *2021*. https://doi.org/10.1155/2021/5568740

Zhang, H., Liu, X., Wang, Q., Zhang, J., He, Z., Zhang, X., Li, R., Zhang, K., Tang, J., & Wu, S. (2021). Low-level wind shear identification along the glide path at bcia by the pulsed coherent doppler lidar. *Atmosphere*, *12*(1). https://doi.org/10.3390/atmos12010050

Zhang, M., Liu, K., Kong, X., & Zhang, M. (2018). Base of Aircraft Data–based operating cost prediction of arrival flight delay under short-term weather. *Advances in Mechanical Engineering*, *10*(4), 1–14. https://doi.org/10.1177/1687814018769231