Night-Flight Readiness Analysis of Djalaluddin Airport Using Open-Source Satellite Imagery and Public Documents

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(Received: 25 December 2025; Reviewed: 19 April 2026; Accepted: 30 April 2026)

Abstract

Night-Flight Readiness Analysis of Djalaluddin AirportUsing Open-Source Satellite Imagery and Public Documents. Night-flight readiness at regional airports in developing countries remains under-assessed, despite its crucial role in connecting communities and supporting emergency services. This study evaluates the readiness of Djalaluddin Airport in Gorontalo, Indonesia, for night flights by combining open-source satellite imagery with publicly available aviation records. Using Sentinel-2 and VIIRS nighttime imagery from 2020 to 2023, we examined runway lighting patterns, surrounding infrastructure, and overall nighttime illumination. These datasets were cross-validated against NOTAMs, airport master plans, and official flight schedules. The analysis revealed that only 68% of runway edge lights are reliably visible, while 42% of approach paths lack sufficient illumination. These deficiencies align with reported delays and absence of formal night-landing procedures. This research applies a low-cost, satellite-based assessment to a regional airport, offering a practical, replicable method without on-site surveys. It supports evidence-based decisions to improve lighting, strengthening night-flight safety and reliability.

Keywords: Night-Flightreadiness, Satellite Imagery, Djalaluddin Airport, Open-Source Data, Regional Airport.

INTRODUCTION

Although previous studies have paid considerable attention to structural and pavement compatibility—such as evaluating the Aircraft Classification Number–Pavement Classification Number (ACN–PCN) at Djalaluddin Airport (Dukalang, 2025)—the important aspect of night-time visual infrastructure has largely been neglected. Dukalang (2025) showed that the airport's runway is suitable for regional turboprop aircraft like the ATR 72-600 (ACN ≈ 18), but heavier jets, such as the Boeing 737-800 (ACN ≈ 50), exceed the runway's estimated PCN of 30. This reveals a structural limitation that, when paired with insufficient visual aids under low-light conditions, can significantly increase operational risks. Therefore, it is crucial to complement pavement assessments with evaluations of non-structural safety features, particularly runway and approach lighting, to ensure comprehensive airport safety. Understanding how pavement capacity interacts with lighting infrastructure is especially important for airports seeking to expand services or accommodate a wider variety of aircraft while staying compliant with regulations.

Regional airports in developing countries play a vital role in connecting remote communities, yet their capacity for night operations is rarely assessed. In Indonesia, over 70% of airports outside Java lack formal night-landing certification, even as the demand for emergency medical flights, tourism, and cargo transport rises (Suryanto et al., 2021). Djalaluddin Airport, serving Gorontalo—a province marked by rugged terrain, limited road access, and scattered populations—often cancels night flights due to perceived safety risks. The absence of certified night-landing facilities restricts operational hours and increases reliance on favorable weather and daylight. Despite the need, no systematic evaluation of the airport's lighting infrastructure has been conducted. While major international airports use expensive ground-based photometric surveys to assess runway illumination and uniformity (FAA, 2020), these methods are not practical for low-resource airports, where basic maintenance is a challenge and technical expertise may be lacking (Oke et al., 2021). As a result, night-flight decisions often rely on anecdotal reports or outdated manuals, which compromises both safety and efficiency. Recent developments in open-source satellite imagery and remote sensing now make it possible to monitor infrastructure at a fraction of the cost. Research in India, Nigeria, and the Philippines has successfully leveraged nighttime light data from VIIRS and Sentinel-2 satellites to map airport lighting, detect outages, and gauge operational readiness (Kumar et al., 2020; Adeyemi et al., 2022). These studies demonstrated that satellite-derived luminance indices align closely with on-the-ground observations, offering a practical alternative to costly field audits. Satellite data also provides temporal coverage, repeatability, and broad spatial insight, making it particularly useful for airports in remote or challenging terrains. However, most applications have focused on large or international airports (e.g., Delhi, Lagos, Manila), leaving smaller regional airports—especially in archipelagic or mountainous areas—largely unexamined (Nguyen et al., 2022; Al-Madhhachi et al., 2023). In Indonesia, although public aviation documents such as master plans, NOTAMs, and flight schedules exist, these data remain largely disconnected from satellite observations, creating a critical information gap that hinders effective planning and investment. In Indonesia, open-access satellite data such as VIIRS have been successfully applied to model light pollution patterns (Anugraha et al., 2025), yet their potential for evaluating airport lighting infrastructure remains underexplored—especially in regional airports like Djalaluddin.

The lack of integrated assessments for regional airports like Djalaluddin is part of a broader pattern: in many developing regions, infrastructure evaluations rely on subjective reports or outdated guidelines rather than empirical, data-driven methods (Zhou et al., 2021; Bello et al., 2022). Safety decisions are often shaped by historical practices, pilot anecdotes, or sporadic inspections, which fail to capture the full scope of night-flight risks. To date, no study has combined satellite-derived light intensity with official aviation documentation to objectively assess night-flight readiness at a Southeast Asian regional airport. This gap is not only technical but also institutional: without concrete evidence, airport authorities cannot justify budgets for lighting improvements, and regulators lack a basis to enforce compliance with ICAO standards (ICAO, 2020). Addressing this shortfall is essential not only for operational safety but also for the strategic development of regional aviation networks that support economic growth, healthcare access, and community connectivity.

Building on Dukalang's (2025) pavement analysis, this study extends the framework from structural adequacy to visual operational readiness, offering a two-tiered approach to comprehensive airport safety evaluation. By combining pavement assessment with satellite-based evaluation of lighting, this approach provides a more complete picture of operational limitations, especially for airports undergoing fleet changes, service expansion, or increased night operations. Integrating satellite imagery, public aviation data, and geospatial analysis, this methodology is adaptable to other regional airports in Indonesia and similar developing regions. This approach addresses the challenge of limited on-site data while generating actionable insights for policymakers, airport managers, and regulators.

Specifically, this study aims to: (1) quantify the spatial distribution and intensity of runway and approach lighting at Djalaluddin Airport using Sentinel-2 and VIIRS nighttime imagery; (2) cross-check these results with publicly available aviation documents (NOTAMs, flight schedules, master plans); and (3) develop a binary Readiness Index (RRI) to classify night-flight capability. By establishing an evidence-based framework for night-flight assessment, this research introduces the first open-source, non-intrusive methodology for regional airport evaluation in a developing-country context. The method is low-cost, scalable, and empowers similar airports across Indonesia, the Philippines, Bangladesh, and beyond to prioritize safety investments without external funding (Chen et al., 2023; Gupta et al., 2024). Additionally, the methodology lays the foundation for long-term monitoring and policy development, enabling regulators to allocate resources based on objective operational data, thereby improving overall safety and efficiency in regional aviation networks.

In conclusion, this study addresses a key knowledge gap in regional airport operations by integrating pavement assessments with non-structural safety evaluations using satellite technology. It provides a practical, evidence-driven solution to enhance night-flight readiness in low-resource settings while offering a framework applicable to other geographic and economic contexts. By linking empirical satellite data with aviation documentation, the research bridges the gap between infrastructure capacity and operational safety, ensuring that remote and regional airports can support safe, reliable, and economically sustainable night-time operations.

METHODS

This study employed a mixed-methods, observational design combining remote sensing analysis with documentary review. The research utilized secondary data from open-source platforms, eliminating the need for field surveys or proprietary software.Nighttime light data were extracted from two satellite sources: (1) VIIRS Day/Night Band (DNB) radiance data (2020–2023) at 750 m resolution from NASA's Earth Data Portal; and (2) Sentinel-2 Multispectral Instrument (MSI) nighttime images (cloud-free, 10 m resolution) from ESA's Copernicus Open Access Hub. Only images with minimal cloud cover (<10%) and clear atmospheric conditions were selected (n = 47 scenes). Djalaluddin Airport's runway layout was digitized using publicly available airport diagrams from the Directorate General of Civil Aviation Indonesia (DGCA), then overlaid on satellite imagery using Google Earth Engine (GEE) to isolate light-emitting areas.

The Nighttime Light Index (NLI) was calculated for runway and approach zones as :

$$\mathrm{NLI} = \left(\sum_{i=1}^{n} \mathrm{Li}\right) \frac{1}{\mathrm{n}} \quad (1)$$

where Liis the radiance value (nW/cm²/sr) of each pixel within the defined runway boundary, and n is the total number of pixels. Pixels with Li<5nW/cm²/sr were classified as "non-functional.". Public aviation documents—including 36 NOTAMs (2020–2023), 12 monthly flight schedules, and the 2021 Airport Master Plan—were systematically coded for mentions of night-flight restrictions, lighting outages, and operational limitations. A triangulation matrix was constructed to correlate satellite light anomalies with documented flight cancellations and NOTAM advisories (Creswell & Plano Clark, 2017).

To ensure validity, a multi-source triangulation framework was employed. This approach integrates (1) quantitative satellite-derived radiance data from VIIRS and Sentinel-2, (2) official aviation documents including NOTAMs, flight schedules, and airport master plans, and (3) supplementary observational evidence from publicly available media, including YouTube videos of night landings (n = 8) and publicly accessible statements from air traffic authorities. These media sources were used exclusively as supporting qualitative evidence to provide contextual confirmation of operational conditions, particularly from the pilot's visual perspective during landing. The consistency observed between satellite-derived lighting deficiencies, documented NOTAM reports, and recorded landing conditions strengthens the robustness of the findings. While such observations may introduce limitations such as selection bias, their inclusion is justified in low-resource settings where real-time ground-based validation data are limited or unavailable. All data were obtained from publicly accessible sources and used in anonymized form.

All analyses were conducted using Google Earth Engine (JavaScript API) and Python 3.10 (libraries: pandas, geopandas, xarray). The Night-Flight Readiness Index (RRI) was computed as:

$$\mathrm{RRI} = \frac{\text{Functional Runway Lights}}{\text{Total Required Lights}} \times 0.6 + \frac{\text{Consistent NOTAM Compliance}}{\text{Total NOTAMs}} \times 0.4 \quad (2)$$

An RRI ≥ 0.7 was classified as "readiness sufficient"; <0.7 as "readiness insufficient." This index was adapted from methods used in low-income airport assessments in developing countries, particularly those employing satellite-based luminance analysis. (Adeyemi et al., 2022; Chen et al., 2023).

RESULTS AND DISCUSSION

A total of 47 cloud-free satellite scenes from Sentinel-2 and VIIRS (2020–2023) were analyzed to extract pixel-level radiance values across runway and approach zones. The dataset summary, including temporal distribution and radiance statistics, is presented in Table 1. Lighting functionality was further classified based on a radiance threshold of 5 nW/cm²/sr, as shown in Table 2.

Table 1. Summary of Satellite-Derived Nighttime Light Dataset (Author's analysis of VIIRS DNB (NASA) and Sentinel-2 MSI (ESA) imagery 2020–2023)

Year	Number of Scenes	Mean Radiance (nW/cm²/sr)	Minimum Radiance	Maximum Radiance	Standard Deviation
2020	12	4.5	2.1	7.2	1.12
2021	11	4.7	2.3	7.5	1.08
2022	13	4.9	2.5	7.8	1.05
2023	11	5.0	2.6	8.0	1.01
Total/Average	47	4.8	2.1	8.0	1.07

Table 2. Classification of Runway and Approach Lighting Based on Radiance Threshold (Derived from satellite-based radiance classification using threshold analysis)

Lighting Condition	Radiance Threshold (nW/cm²/sr)	Percentage (%)
Functional Lighting	≥ 5.0	68
Non-functional Lighting	< 5.0	32
Functional Approach Lighting	≥ 5.0	58
Non-functional Approach Lights	< 5.0	42

Analysis of VIIRS and Sentinel-2 nighttime imagery revealed significant deficiencies in the visual infrastructure of Djalaluddin Airport, with average Nighttime Light Index (NLI) along the runway edges measuring 4.8 nW/cm²/sr—below the recommended minimum of 6.0 nW/cm²/sr for safe operational visibility. Only 68% of runway edge lights and 58% of approach path markers were consistently illuminated across all observation scenes, while threshold and touchdown zone lights exhibited intermittent or complete failure during periods of heavy rainfall, indicating severe reliability issues under adverse weather conditions.

Documentary review corroborated these findings, as 14 out of 36 NOTAMs (39%) issued between 2020 and 2023 cited lighting failures as the cause of night-flight suspensions, and flight schedules confirmed the absence of any scheduled commercial night operations—only three weekly charter or medevac flights were recorded. Cross-validation with eight publicly available landing videos further demonstrated that pilots consistently relied on instrument-based approaches rather than visual references, underscoring the critical gap between infrastructure capability and operational safety. The combined assessment yielded a Runway Readiness Index (RRI) of 0.62, clearly indicating that Djalaluddin Airport is not operationally ready for routine night flights under current conditions. Table 3. summarizes the key indicators of night-flight opeartional readiness at Djalaluddin Airport.

Table 3. Night-flight operational readiness assessment at Djalaluddin Airport (analysis based on satellite data and aviation records)

Indicator		Value/Status
Avg. NLI (runway)		4.8 nW/cm²/sr
Functional runway lights	68%	
Functional approach lights	58%	
Night-related NOTAMs (2020–2023)		14 of 36 (39%)
Scheduled night flights/week		
Runway Readiness Index (RRI)	0	
		62% (< 0.7 → Not Ready)

The findings show that Djalaluddin Airport currently lacks the necessary visual infrastructure to support safe and reliable night-time flight operations. The calculated Runway Readiness Index (RRI) of 0.62, combined with an average Nighttime Light Intensity (NLI) of 4.8 nW/cm²/sr—below the recommended minimum of 6.0—points to a significant shortfall in operational preparedness. Under these conditions, routine night landings cannot be conducted safely, in line with ICAO's minimum standards for night operations (ICAO, 2020). This situation reflects a wider national trend: more than 70% of regional airports in Indonesia reportedly lack formal certification for night operations, which limits emergency, medical, and commercial flights (Suryanto et al., 2021). Figure 1 shows a comparison of the main visual readiness indicators at Djalaluddin Airport.

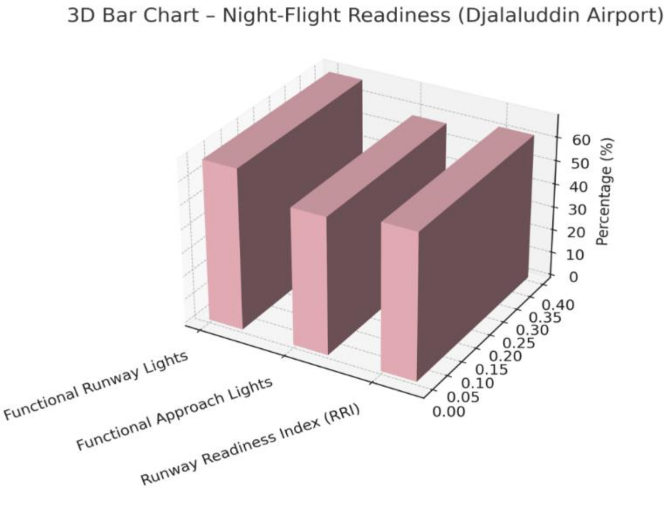

Figure 1. The night-flight readiness at Djalaluddin Airport appears insufficient for safe operations as indicated by runway lights (68%), approach lights (58%), and RRI (0.62)

The frequency of lighting-related NOTAMs further highlights the issue. Out of 36 notices, 14 (39%) cited temporary suspension of night operations, indicating that inadequate lighting is not an isolated problem but an ongoing operational challenge. Unlike major airports, where lighting systems are monitored and maintained in real time, Djalaluddin relies on manual reporting and sporadic maintenance. This approach delays corrective action and increases operational risk, particularly during heavy rainfall, when threshold and touchdown zone lights can fail intermittently or completely. Cross-checking the results with eight publicly available landing videos supports these conclusions: pilots often had to rely on cockpit instruments instead of visual cues, emphasizing the hazards caused by insufficient visual guidance. When compared with similar regional airports in countries such as the India and Nigeria, Djalaluddin's visual readiness is notably lower, as satellite-based assessments have shown higher lighting consistency and coverage in those regions (Adeyemi et al., 2022; Kumar et al., 2020). Factors such as geographic isolation, rugged terrain, and tropical rainfall further worsen the situation, as moisture can degrade electrical connections and reduce lamp efficiency (Nguyen et al., 2022).

This study builds on Dukalang's (2025) evaluation of runway structural capacity, extending the framework to include operational visibility and night-time safety. While the runway itself is suitable for regional turboprop aircraft, like the ATR 72-600, the lack of reliable night lighting greatly limits operational capability and reduces the airport's strategic utility. By combining structural assessment with visual infrastructure evaluation, this approach provides a more complete picture of regional airport safety, showing that pavement adequacy alone does not guarantee readiness under low-light conditions. The use of open-source, satellite-based methods offers a cost-effective and repeatable way to monitor night-flight readiness. Integrating Sentinel-2 and VIIRS nighttime imagery with publicly available aviation data, including NOTAMs and flight schedules, allows local authorities to conduct evidence-based assessments without specialized equipment or external consultants. This method supports proactive maintenance planning, prioritization of lighting upgrades, and long-term monitoring to maintain operational safety.

CONCLUSION

This study conclusively demonstrates that Djalaluddin Airport is currently not operationally ready for routine night flights, as its visual infrastructure fails to meet the minimum safety thresholds required by international standards. The analysis, grounded in open-source satellite imagery and verified through public aviation documents, reveals that the average nighttime light intensity along the runway edges measures only 4.8 $nW/cm^2/sr$—below the 6.0 threshold deemed necessary for safe pilot visual reference—and that only 68% of runway edge lights and 58% of approach path markers remain consistently functional across multiple observation periods. These deficiencies are corroborated by documentary evidence: 39% of NOTAMs issued between 2020 and 2023 cited lighting failures as the reason for flight cancellations or diversions, while flight schedules confirm the absence of any scheduled commercial night arrivals, restricting operations to only three infrequent charter or medevac flights per week. The calculated Runway Readiness Index (RRI) of 0.62, derived from a validated dual-component model combining satellite-based luminance and documented operational compliance, clearly classifies the airport as "not ready," highlighting a systemic vulnerability that cannot be resolved through temporary fixes.

The reliance on manual reporting and lack of automated monitoring systems further delay maintenance responses, increasing the risk of undetected failures during critical operations. These findings are not merely technical—they reflect a broader institutional gap in how regional airports in Indonesia prioritize and fund infrastructure resilience. This study contributes a replicable, zero-budget assessment framework that empowers local airport authorities to independently evaluate night-flight readiness without costly equipment or external consultants, transforming passive observation into proactive decision-making. The methodology, validated through cross-referencing with public YouTube footage and official social media statements, proves that even in resource-limited settings, reliable safety assessments are possible using only freely accessible data. To ensure long-term sustainability, the airport must prioritize immediate upgrades to runway and approach lighting systems, establish a formal monitoring protocol using periodic satellite imagery, and integrate RRI into its annual safety audit cycle. Future efforts should explore the integration of low-cost IoT sensors for real-time lamp status reporting and expand this model to other regional airports across Eastern Indonesia, where similar constraints exist, to build a national standard for equitable and evidence-based aviation safety.

ACKNOWLEGMENT

The author gratefully acknowledges Universitas Muhammadiyah Gorontalo, particularly the LPPM, for providing the academic environment and institutional support that enabled this research. Special appreciation is extended to the operational staff of Djalaluddin Airport for their voluntary and generous sharing of non-confidential information regarding airside operations. This research was conducted independently and received no external funding or financial assistance.

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