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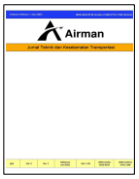

Air Traffic Management Optimization Through the Development of a Visual Flight Rules Holding Pattern for Runway 35 at Sultan Iskandar Muda International Airport

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ABSTRACT

The continuous growth of air traffic has increased the operational complexity managing mixed Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) operatio particularly at regional airports operating within controlled Class C airspace. At Sul Iskandar Muda International Airport, Indonesia, the absence of a standardized Visual Fli Rules (VFR) holding pattern for Runway 35 requires air traffic controllers to apply tacti vectoring and ad hoc holding instructions whenever VFR arrivals conflict with higher-prio IFR traffic. This operational condition increases controller workload, reduces traf predictability, and may affect operational safety and air traffic flow efficiency. This stu aims to optimize Air Traffic Management (ATM) by developing a standardized VFR hold pattern for Runway 35 based on operational requirements, international aviation regulatio and local airspace characteristics. A qualitative operational research approach was employ through direct field observations, interviews with licensed air traffic controllers, analysis local Standard Operating Procedures (SOPs), aeronautical charts, and spatial mapping us Google Earth Pro. The proposed holding pattern was assessed against the provisions of IC Annex 2 (Rules of the Air), ICAO Annex 11 (Air Traffic Services), ICAO Doc 4 (Procedures for Air Navigation Services – Air Traffic Management), Civil Aviation Saf Regulations (CASR), and Indonesian airspace classification standards. The operatio analysis identified the absence of a designated VFR holding point as a significant limitat in sequencing mixed IFR–VFR traffic during Runway 35 operations. Based on terr characteristics, operational visibility, aircraft maneuvering requirements, and contro workload considerations, a VFR holding point was proposed near Seumileum, loca approximately 13.4 NM from Banda Aceh VOR (BAC VOR) on the 130° radial, wit recommended holding altitude of 7,000 ft. The proposed holding pattern provides adequ terrain clearance, maintains safe separation from IFR procedures, supports standardiz aircraft sequencing, and minimizes tactical controller interventions during high traf demand. Furthermore, the proposed design contributes to achieving the five objectives of Traffic Services established by ICAO by improving flight safety, maintaining orderly traf flow, reducing operational complexity, and enhancing situational awareness for b controllers and flight crews. The findings demonstrate that implementing a standardized V holding pattern constitutes an effective Air Traffic Management optimization strategy Runway 35 operations at Sultan Iskandar Muda International Airport. The proposed proced is expected to improve operational safety, increase air traffic flow efficiency, strengt procedural standardization, and support future revisions of local Standard Operat Procedures (SOPs). Moreover, this research provides a practical reference for developing V holding procedures at regional airports with comparable operational environments and mix IFR–VFR traffic characteristics.

INTRODUCTION

The continuous growth of air transportation has increased the complexity of aircraft operations and highlighted the need for more effective Air Traffic Management (ATM) to ensure safe, orderly, and efficient air traffic flow. According to the International Civil Aviation Organization (ICAO), Air Traffic Services (ATS) are responsible for preventing aircraft collisions, maintaining an orderly flow of air traffic, providing essential flight information, and supporting search and rescue services when required. Achieving these objectives becomes increasingly challenging in terminal airspace where Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) aircraft operate simultaneously.

Sultan Iskandar Muda International Airport operates within Class C controlled airspace, where both IFR and VFR flights are managed by Air Traffic Control (ATC). During Runway 35 operations, IFR arrivals are generally prioritized to maintain separation standards, requiring VFR aircraft to delay their approach until landing clearance can be safely issued. However, operational observations indicate that no standardized VFR holding pattern is currently available to support traffic sequencing. Consequently, controllers rely on tactical vectoring and visual reference points that may vary according to operational conditions, potentially increasing controller workload, reducing traffic predictability, and affecting operational efficiency.

From an Air Traffic Management perspective, a standardized holding pattern is an important traffic management tool because it enables controllers to regulate aircraft sequencing while maintaining safe separation and orderly traffic flow. Although holding procedures have been widely implemented for IFR operations, the development of standardized VFR holding procedures has received relatively limited attention, particularly at regional airports with mixed IFR–VFR operations. Most previous studies have focused on IFR arrival management, terminal airspace optimization, and delay management, leaving a research gap regarding the integration of VFR holding procedures into operational Air Traffic Management.

To address this gap, this study proposes the development of a standardized Visual Flight Rules (VFR) holding pattern for Runway 35 at Sultan Iskandar Muda International Airport. The proposed procedure is developed based on operational observations, ICAO regulations, local airspace characteristics, and controller operational requirements. Unlike previous studies, this research integrates Air Traffic Management principles with operational safety considerations, terrain characteristics, traffic sequencing, and controller workload analysis to produce a practical and standardized VFR holding procedure.

The objective of this study is to develop and evaluate a standardized VFR holding pattern as an Air Traffic Management optimization strategy for Runway 35 operations at Sultan Iskandar Muda International Airport. The proposed design is expected to improve operational safety, enhance traffic flow efficiency, reduce controller workload, and provide a technical reference for future revisions of local Standard Operating Procedures (SOPs) and the implementation of VFR traffic management at regional airports with similar operational characteristics.

LITERATURE REVIEW

Air Traffic Management (ATM) is a comprehensive framework that integrates Air Traffic Services (ATS), Airspace Management (ASM), and Air Traffic Flow Management (ATFM) to ensure the safe, orderly, and efficient movement of aircraft throughout all phases of flight. According to the International Civil Aviation Organization (ICAO), ATS is designed to achieve five primary objectives: preventing aircraft collisions, maintaining an orderly flow of air traffic, providing information for safe flight operations, and supporting search and rescue services when required. Consequently, optimizing operational procedures is an essential component of improving ATM performance, particularly within terminal airspace where traffic complexity is relatively high.

Visual Flight Rules (VFR) operations continue to play an important role in regional airport operations because they accommodate general aviation, military flights, charter operations, and commercial turboprop

aircraft. Unlike Instrument Flight Rules (IFR), VFR operations rely primarily on visual navigation and are therefore highly dependent on local operational procedures and controller instructions. In controlled Class C airspace, IFR and VFR aircraft operate simultaneously under Air Traffic Control supervision, requiring controllers to manage aircraft sequencing while maintaining operational safety and efficiency in accordance with ICAO Annex 2, Annex 11, and ICAO Doc 4444.

A holding pattern is a standardized flight procedure used to delay aircraft safely within protected airspace until further Air Traffic Control clearance is issued. While holding procedures are well established for IFR operations through navigation aids such as VOR, NDB, and RNAV waypoints, standardized VFR holding procedures are less commonly implemented at regional airports. From an Air Traffic Management perspective, a standardized holding pattern improves traffic predictability (Zanin & Olivieri, 2021), reduces controller workload, enhances situational awareness, and supports orderly traffic sequencing during periods of increased traffic demand.

Previous studies have primarily focused on IFR holding optimization, arrival sequencing, terminal airspace capacity, and delay management. Limited attention has been given to the development of standardized VFR holding patterns in mixed IFR–VFR operational environments, particularly at regional airports operating within Class C controlled airspace. Consequently, a research gap remains regarding the integration of VFR holding procedures into Air Traffic Management optimization strategies (ICAO, 2020).

This study addresses that gap by developing a standardized VFR holding pattern for Runway 35 at Sultan Iskandar Muda International Airport based on operational observations, ICAO regulatory requirements, airspace characteristics, controller workload considerations, and traffic sequencing principles. The proposed procedure is expected to improve operational safety, enhance traffic flow efficiency, strengthen procedural standardization, and support future revisions of local Standard Operating Procedures (SOPs), while contributing to the implementation of Air Traffic Management principles at regional airports with similar operational characteristics.

RESEARCH METHOD

Research Design

This study employed a qualitative operational research approach using a descriptive-analytical design to develop and evaluate a standardized Visual Flight Rules (VFR) holding pattern for Runway 35 at Sultan Iskandar Muda International Airport. A qualitative approach was selected because the research focused on analysing operational procedures, controller practices, airspace characteristics, and regulatory compliance rather than testing statistical hypotheses.

The study adopted the Air Traffic Management (ATM) operational framework by integrating operational observations, controller experience, aeronautical regulations, and spatial analysis to develop a holding pattern that supports safe and efficient mixed IFR–VFR operations. The proposed procedure was evaluated based on operational feasibility, traffic sequencing, controller workload, terrain clearance, and compliance with ICAO standards.

Data Collection

Data were collected using a combination of operational observation, semi-structured interviews, document review, and spatial analysis to obtain comprehensive information on the existing air traffic management procedures for Runway 35 at Sultan Iskandar Muda International Airport. Operational observations were conducted to examine traffic characteristics, aircraft sequencing, controller workload, and operational constraints during mixed Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) operations. Semi-structured interviews with licensed Air Traffic Controllers (ATCOs) were carried out to obtain professional insights into current VFR procedures, traffic management challenges, and the operational need for a standardized VFR holding pattern. In addition, relevant operational documents, including the Standard Operating Procedures (SOP), Aeronautical Information Publication (AIP), ICAO Annex 2, ICAO Annex 11, ICAO Doc 4444 (PANS-ATM), Civil Aviation Safety Regulations (CASR), aeronautical charts, and airport operational manuals, were reviewed to ensure compliance with applicable aviation standards. Furthermore, spatial analysis using Google Earth Pro and aeronautical charts was performed to evaluate terrain characteristics, obstacle clearance, visual reference points, navigation aid locations, communication coverage, and the compatibility of the proposed holding pattern with the existing airspace structure.

Data Analysis

The collected data were analysed using descriptive qualitative analysis consisting of four sequential stages.

First, operational problems associated with mixed IFR–VFR operations were identified through field observations and controller interviews. Second, operational requirements and regulatory provisions were analysed to determine an appropriate holding point location, entry procedure, circuit direction, holding altitude, and outbound track.

Third, the proposed holding pattern was evaluated from the perspectives of operational safety, traffic flow efficiency, aircraft separation, controller workload, terrain clearance, and compatibility with existing arrival and departure procedures. Finally, the proposed design was validated by comparing the operational configuration with ICAO standards and local ATS operational procedures to determine its feasibility for future implementation within the airport's Standard Operating Procedures (SOPs).

Research Framework

The research framework begins with identifying operational constraints in mixed IFR–VFR operations through observations, interviews, document analysis, and spatial mapping. The collected information is subsequently analysed using applicable ICAO regulations, Air Traffic Management principles, and local operational procedures to develop a standardized VFR holding pattern. The proposed design is then evaluated based on safety, operational efficiency, controller workload, traffic sequencing, and regulatory compliance before producing recommendations for SOP improvement and future operational implementation.

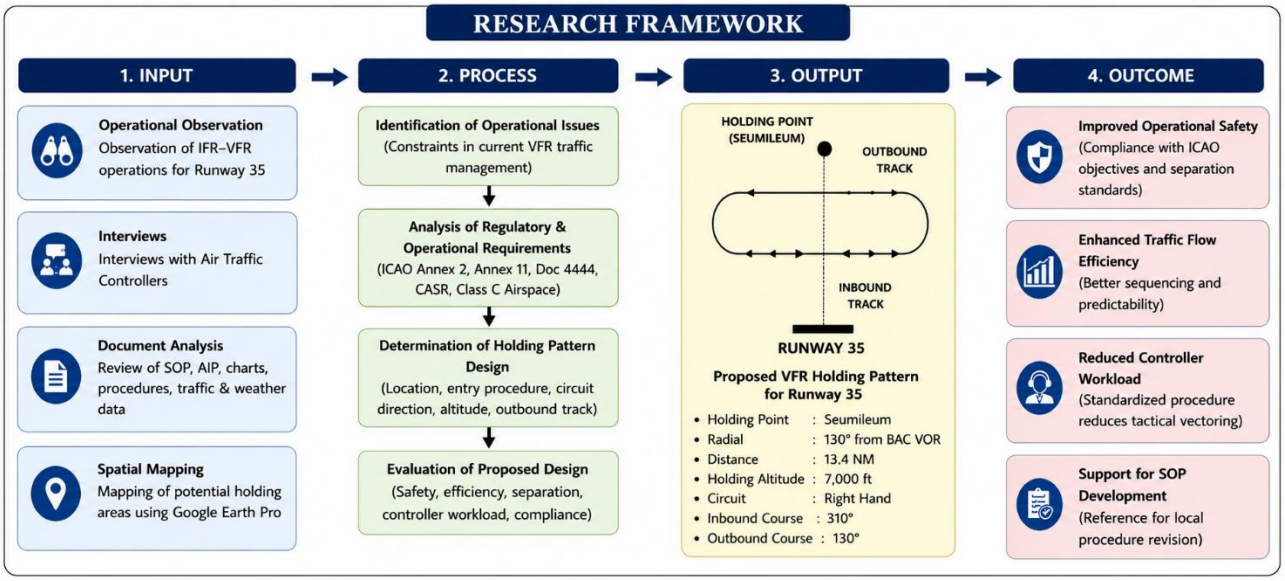


Figure 1. Research Framework for Developing a Standardized Visual Flight Rules (VFR) Holding Pattern for Runway 35

RESULTS AND DISCUSSION

Existing Operational Condition

Sultan Iskandar Muda International Airport operates within Class C controlled airspace, where Air Traffic Control (ATC) is responsible for providing separation between Instrument Flight Rules (IFR) aircraft while simultaneously managing Visual Flight Rules (VFR) operations. Air traffic services include departure, arrival, missed approach, emergency, local flight, and VFR traffic management under the responsibility of the Aerodrome Control Tower and Approach Control units.

Operational observations indicated that VFR aircraft approaching Runway 35 are required to maintain separation from IFR arrivals that receive operational priority. However, no published VFR holding pattern currently exists to support traffic sequencing during periods of increased traffic demand. Consequently, controllers frequently apply tactical vectoring or instruct pilots to hold over temporary visual reference areas depending on traffic conditions. Although this practice maintains operational continuity, it reduces traffic predictability and increases controller workload, particularly when several aircraft operate simultaneously within the terminal control area.

Field observations also identified that VFR aircraft operating near the western coastal area occasionally experience communication limitations due to surrounding terrain. This operational condition may reduce

controller situational awareness and increase the complexity of managing mixed IFR–VFR traffic, especially during adverse weather or high-density traffic periods.

Identification of Operational Constraints

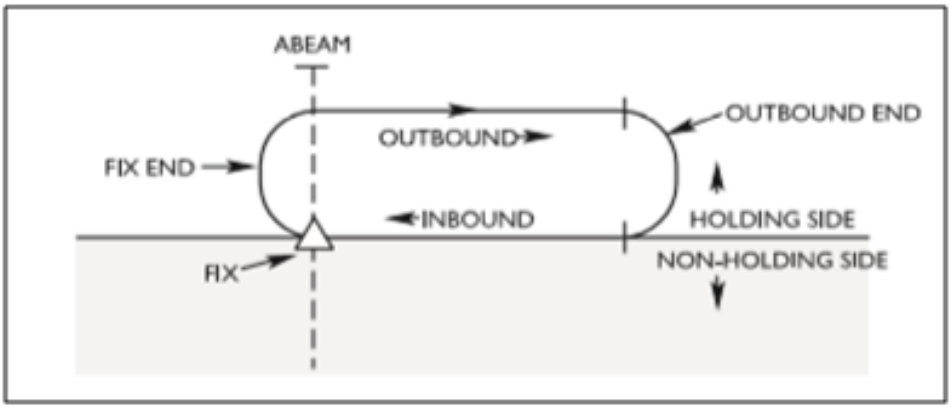
The absence of a standardized VFR holding point creates several operational challenges affecting both safety and efficiency. First, aircraft sequencing becomes highly dependent on controller judgment because no designated holding location is available for delaying VFR arrivals. Second, repeated tactical vectoring increases radio communication frequency and controller workload. Third, inconsistent holding locations may reduce pilot situational awareness and create operational uncertainty during mixed traffic operations.

From an Air Traffic Management perspective, these constraints may affect two of ICAO's Five Objectives of Air Traffic Services, namely preventing collisions between aircraft and maintaining an orderly flow of air traffic. Therefore, a standardized holding procedure is required to improve operational consistency while supporting safer aircraft sequencing.

Development of the Proposed VFR Holding Pattern

Based on operational observations, document analysis, and spatial evaluation, a standardized VFR holding point was proposed near Seumileum, located approximately 13.4 NM from BAC VOR on the 130° radial. The proposed holding altitude is 7,000 ft, which provides adequate terrain clearance while maintaining compatibility with existing arrival procedures for Runway 35.

The proposed holding pattern adopts a standard right-hand circuit to facilitate controller monitoring and pilot navigation. The selected location provides clear visual references, adequate communication coverage, and sufficient separation from instrument arrival routes. In addition, the proposed configuration minimizes the possibility of conflict with IFR traffic while maintaining operational flexibility for VFR aircraft awaiting landing clearance.



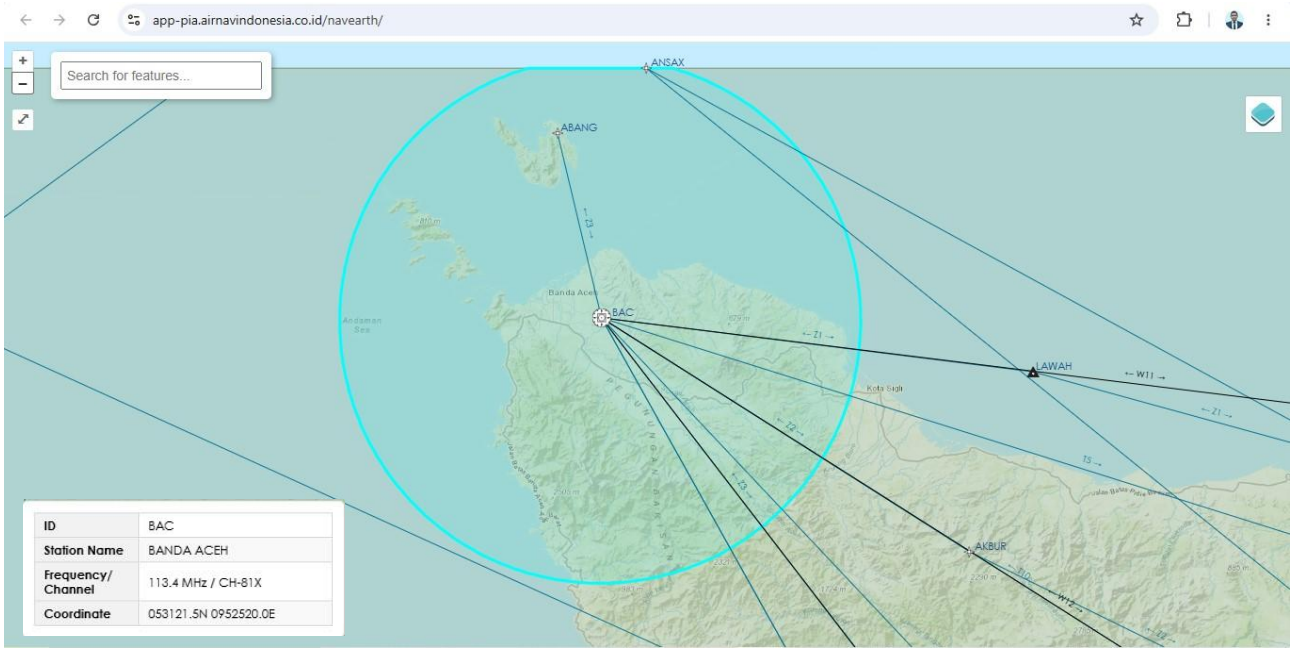


Figure 2. Proposed Standardized VFR Holding Pattern near Seumileum for Runway 35 Operations

Operational Safety and Air Traffic Managem ent Assessment

The proposed VFR holding pattern contributes to Air Traffic Management optimization by providing a standardized traffic sequencing procedure for mixed IFR–VFR operations. Standardization enables controllers to anticipate aircraft trajectories more accurately, reduces the need for tactical vectoring, and improves communication efficiency between pilots and controllers.

From an operational safety perspective, the selected holding point satisfies the fundamental considerations of terrain clearance, visual navigation, operational accessibility, and compatibility with the surrounding airspace structure. Furthermore, the proposed procedure supports ICAO operational principles by enhancing traffic predictability, reducing controller workload, and maintaining orderly aircraft flow within the terminal control area.

Overall, the implementation of the proposed VFR holding pattern is expected to strengthen operational safety, improve air traffic flow efficiency, and provide a technical basis for updating local Standard Operating Procedures (SOPs). The proposed design may also serve as a practical reference for other regional airports operating mixed IFR–VFR traffic under similar airspace conditions.

Operational Issue	Safety Impact	ATM Impact
No VFR Holding Point	High	High
Tactical Vectoring	Medium	High
Radio Congestion	Medium	Medium

Terrain Constraint	High	Medium

Tabel 1. Existing Operational Constraints

Parameter	Existing	Proposed
Holding Point	None	Seumileum
Standard Procedure	No	Yes
Traffic Predictability	Low	High
Controller Workload	High	Reduced
Operational Safety	Moderate	Improved

Tabel 2. Evaluation of Proposed Holding Pattern

CONCLUSION

This study developed a standardized Visual Flight Rules (VFR) holding pattern for Runway 35 at Sultan Iskandar Muda International Airport as an Air Traffic Management (ATM) optimization strategy to improve the safety and efficiency of mixed IFR–VFR operations. The analysis demonstrated that the absence of a designated VFR holding point requires controllers to rely on tactical vectoring and temporary visual reference areas, resulting in increased controller workload, reduced traffic predictability, and less standardized aircraft sequencing.

Based on operational observations, regulatory analysis, and spatial evaluation, a standardized VFR holding point was proposed at Seumileum, approximately 13.4 NM from BAC VOR on the 130° radial with a holding altitude of 7,000 ft. The proposed design provides an operationally feasible holding area by considering terrain clearance, visual navigation, communication coverage, and compatibility with existing Runway 35 arrival procedures.

The proposed VFR holding pattern supports the implementation of Air Traffic Management principles by enhancing traffic predictability, improving aircraft sequencing, reducing controller workload, and strengthening compliance with ICAO operational standards. Furthermore, the proposed procedure contributes to achieving the fundamental objectives of Air Traffic Services by improving operational safety, maintaining an orderly flow of air traffic, and increasing the consistency of controller decision-making during mixed IFR–VFR operations.

Overall, this research demonstrates that the development of a standardized VFR holding pattern represents a practical and effective operational solution for improving air traffic management at Sultan Iskandar Muda International Airport. The findings also provide a technical reference for other regional airports with similar operational characteristics that require standardized VFR traffic management within controlled airspace.

RECOMMENDATION

The proposed VFR holding pattern should be further evaluated through operational simulations and safety assessments involving Air Traffic Controllers, procedure designers, and aviation authorities before operational implementation. Such evaluations will ensure compatibility with existing Standard Instrument Departure (SID), Standard Arrival Route (STAR), and missed approach procedures while maintaining compliance with ICAO and Indonesian Civil Aviation Safety Regulations.

Future studies are recommended to incorporate quantitative operational indicators, including controller workload assessment, aircraft delay analysis, communication frequency, traffic density, and flight efficiency metrics, to measure the operational benefits of the proposed holding pattern more comprehensively. In addition, validation using real-time flight data or fast-time simulation would strengthen the practical applicability of the proposed design and support evidence-based improvements in Air Traffic Management at regional airports.

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