Analysis of Airspace Sectorization Effectiveness in the East Sector of Jakarta FIR Area Control Centre

Rizky Dwi Utami [1,] **Rahmawati Sukra** [2,] **Martha Saulina** [3]
[1,2,3] Air Traffic Control Study Programme/ Applied Undergraduate Programme Indonesian Aviation Polytechnic of Curug

*Corresponding Author
Email: rizky.dwi@airnavindonesia.co.id

Abstract

This study analyzes the effectiveness of airspace sector division at the Area Control Centre (ACC) Sector East, Jakarta Flight Information Region (FIR), in supporting the operational efficiency of Air Traffic Controllers (ATCs). The research aims to evaluate the current airspace sectorization in terms of operational, technical, and human resource aspects to determine whether the existing configuration meets the growing traffic demand. Using a quantitative descriptive and evaluative approach, the study focuses on two main variables: ATC workload and inter-sector coordination. Data were collected from 58 ATC personnel at the Jakarta Air Traffic Service Centre (JATSC) through a Likert-scale questionnaire. The data were analyzed using statistical methods including Pearson correlation and multiple linear regression. The results reveal that both workload and inter-sector coordination significantly affect the effectiveness of sector division, with workload having a stronger influence. The findings indicate that unbalanced workload distribution and limited coordination efficiency reduce overall sector performance. The study concludes that an adaptive and dynamic sectorization model is needed to ensure balanced workload, enhanced communication, and improved operational safety at ACC-East Jakarta.

Keywords: Airspace Sectorization, Effectiveness, Area Control Centre (ACC), Air Traffic Controller (ATC), Jakarta FIR

INTRODUCTION

Air traffic control service is a system designed to prevent collisions between aircraft or between aircraft and obstacles within the movement area while maintaining an orderly and efficient flow of air traffic (ICAO, 2021). The Jakarta Area Control Centre (ACC) is responsible for providing area control services for aircraft operating within the Jakarta Upper Control Area (UTA). These services include both Surveillance Service which utilizes radar monitoring systems and Procedural Service, which ensures safety when aircraft operate beyond radar coverage (SOP ACC, 2025).

Airspace sectorization constitutes a fundamental component of the air traffic control system, aimed at dividing the workload among Air Traffic Controllers (ATCs) proportionally to enhance communication efficiency, coordination, and flight safety. In Indonesia, particularly within the operational scope of the Area Control Centre (ACC) East Sector – Jakarta Flight Information Region (FIR), the continuous increase in air traffic movements each year demands an adaptive and efficient sectorization system (AirNav Indonesia, 2022).

The ACC-East Jakarta is responsible for managing the eastern portion of Indonesia's airspace, encompassing both domestic and international flight routes with dense and complex traffic flows. This sector handles hundreds of aircraft movements daily, including overflying, arrival-departure, and crossing traffic, which require a high level of coordination among controllers. In recent years, however, challenges have arisen, such as uneven workload distribution, overlapping responsibilities, inefficient coordination flows, and sectoral saturation during peak operational hours. Previous studies have demonstrated that imbalanced workloads and poor inter-sector coordination can reduce situational awareness and increase the likelihood of human error (Müller et al., 2019; Zhang & Wang, 2023).

The effectiveness of airspace sectors is influenced by three principal factors: sector design, human resource capacity, and communication and coordination systems (Eurocontrol, 2020). Within ACC-East Jakarta, certain sectors experience excessive workload (overload), while others are underutilized (underload). This imbalance increases the risk of unresolved conflict points and decreases the situational awareness of ATCs.

Given the complexity of the East Jakarta FIR, it is essential to conduct a comprehensive and systematic assessment of its current airspace sectorization. Therefore, this study aims to analyze and evaluate the effectiveness of airspace sector division at the Area Control Centre (ACC) Sector East Jakarta Flight Information Region (FIR) as a foundation for improving operational performance, communication, and flight safety in the future.

Problem Formulation

Based on the above background, the following research problems are identified:

1. How effective is the current airspace sector division at the Area Control Centre (ACC) East Jakarta Flight Information Region (FIR)?
2. How does the workload of Air Traffic Controllers (ATC) influence the effectiveness of airspace sector division at ACC-East Jakarta?
3. How does inter-sector coordination affect the effectiveness of airspace sector division at ACC-East Jakarta?

Research Objectives

The objectives of this study are as follows:

1. To analyze the effectiveness of airspace sector division in the Area Control Centre (ACC) East Jakarta.
2. To determine the influence of Air Traffic Controller (ATC) workload on the effectiveness of airspace sector division.
3. To examine the influence of inter-sector coordination on the effectiveness of airspace sector division.

RESEARCH METHODS

Research Design and Approach

This study employs a quantitative descriptive approach with an evaluative design to analyze the effectiveness of airspace sector division in the Area Control Centre (ACC) Sector East Jakarta Flight Information Region (FIR). The research focuses on two primary independent variables Air Traffic Controller (ATC) workload and inter-sector coordination and one dependent variable, sector division effectiveness. The purpose of this design is to provide a measurable evaluation of operational performance through statistical analysis of numerical data obtained from respondents (Sugiyono, 2019). The research was conducted at AirNav Indonesia, Jakarta Air Traffic Service Centre (JATSC), within the ACC East Unit, which is responsible for managing one of Indonesia's most complex airspace regions.

Population and Sample

The population of this study comprises all Air Traffic Controllers (ATCs) serving at the ACC-East Jakarta, totaling 113 personnel. The sample was determined using the Slovin formula with a 10% margin of error, resulting in a minimum sample size of 53, which was expanded to 58 respondents to anticipate potential non-responses. The purposive sampling technique was applied with inclusion criteria:

1. Active ATC personnel with at least five years of service,
2. ATCs who have operated in more than one sector, and
3. Willingness to participate in the research.

This sampling method was selected to ensure data accuracy and representativeness of experienced controllers in high-density operational environments (Sugiyono, 2019).

Variables and Operational Definitions

This study includes two independent variables ATC workload (X_1) and inter-sector coordination (X_2) and one dependent variable, sector division effectiveness (Y).

1. Workload (X_1): The perceived physical and cognitive burden of ATCs, measured by traffic volume, radio communication frequency, and task complexity (McGee et al., 1997; Endsley & Jones, 2025).
2. Coordination (X_2): The effectiveness and clarity of information exchange between sectors during handover and control transfer (Eurocontrol, 2023).
3. Sector Division Effectiveness (Y): The degree to which airspace sector design aligns with traffic distribution, controller workload, and communication efficiency (Eurocontrol, 2020).

These variables were operationalized using indicators measured on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

Data Collection Techniques

Primary data were collected through a structured questionnaire, distributed directly and via digital platforms (Google Forms) to participating ATCs. The questionnaire consisted of three sections:

1. Demographic Information,
2. Perceptions of Sector Effectiveness,
3. Perceptions of Workload and Coordination.

Secondary data were obtained from AirNav Indonesia operational reports, sector charts, and traffic movement statistics within the ACC-East Jakarta FIR.

Data Analysis Methods

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) software. Two stages of analysis were applied:

1. Descriptive Statistics to summarize respondents' characteristics and general tendencies, including frequency distributions, mean scores, and standard deviations.
2. Inferential Statistics to test the research hypotheses using the following methods:
    1. Validity and Reliability Tests: Pearson Product Moment correlation and Cronbach's Alpha coefficient ($\alpha \geq 0.70$).
    2. Pearson Correlation Analysis: To measure the strength and direction of relationships between variables.
    3. Multiple Linear Regression Analysis: To determine the influence of ATC workload (X_1) and inter-sector coordination (X_2) on sector effectiveness (Y).
    4. t-test and F-test: To assess the significance of partial and simultaneous effects at a 5% significance level.
    5. Coefficient of Determination (R^2): To determine how much of the variation in sector effectiveness is explained by the independent variables.

This statistical model allows for both explanatory and predictive insights regarding operational efficiency within ACC-East Jakarta (Field, 2018; Ghozali, 2018).

Research Location and Duration

The study was conducted at AirNav Indonesia Jakarta Air Traffic Service Centre (JATSC), focusing on the ACC East Sector. The research was carried out over eight months, from June 2025 to January 2026, encompassing four main stages: preparation, data collection, data analysis, and report writing.

Research Instruments

The main research instrument is a Likert-scale questionnaire, consisting of 15 items measuring the three variables. The instrument was designed to assess ATC perceptions of

workload, coordination, and sector effectiveness based on operational experience and traffic management challenges. Instrument reliability and validity were established through pre-testing with representative ATC respondents before formal deployment (Sugiyono, 2019).

RESULT AND DISCUSSION

The analysis of data collected from 58 Air Traffic Controllers (ATCs) at the Area Control Centre (ACC) Sector East, Jakarta Flight Information Region (FIR), provides a comprehensive understanding of how workload distribution and inter-sector coordination influence the overall effectiveness of airspace sectorization.

Descriptive findings reveal that the majority of respondents are male (65.5%) and fall within the 31-40 age range (48.3%), representing the productive operational age group. Most respondents (60.3%) have served between 10 and 20 years, implying that their evaluations are grounded in extensive operational experience and a solid understanding of sector structure and procedural changes within ACC-East Jakarta. These characteristics enhance the reliability and validity of perceptions used as the foundation of this analysis.

Sector Effectiveness and Workload Dynamics

Table 1 presents the demographic characteristics of respondents.

Category	Sub-category	Frequency	Percentage (%)
Gender	Male	38	65.5
	Female	20	34.5
Age	20–30 years	12	20.7
	31–40 years	28	48.3
	>40 years	18	31.0
Length of Service	<10 years	10	17.2
	10–20 years	35	60.3
	>20 years	13	22.5

The analysis of the Effectiveness of Sector Division variable indicates that respondents generally perceive the current sector configuration as moderately effective. However, a wide variation exists in the responses, suggesting unequal operational conditions among sectors within East Jakarta FIR. Certain sectors with well-balanced lateral and vertical boundaries are perceived as efficient, while others particularly those handling crossing and overflying traffic are viewed as more congested, especially during peak hours.

High workload levels (X_1) are reported by a majority of respondents, particularly regarding traffic volume, radiotelephony intensity, and coordination frequency. These conditions imply that several sectors experience operational overload, leading to uneven workload distribution. Sectors handling complex crossing routes and multiple altitude changes accumulate significantly more cognitive load, which directly affects ATCs' situational awareness. This finding supports prior research by Müller et al. (2019) and Zhang & Wang (2023), who identified workload imbalance as a major contributor to reduced operational efficiency and increased potential for human error.

Correlation analysis confirms a strong positive relationship between workload balance and perceived sector effectiveness. ATCs who reported a more evenly distributed workload also rated the current sectorization as more effective. Conversely, persistent overload in certain sectors corresponds with lower effectiveness ratings, affirming that sector workload management is the most decisive factor in sector design success (Eurocontrol, 2020).

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Coordination and Communication Efficiency

For the inter-sector coordination variable (X_2), most respondents rated communication and coordination efficiency as moderate to high. Nevertheless, lower scores were observed on handover clarity and communication consistency during high-traffic periods. This suggests that coordination strain increases exponentially with traffic density, potentially delaying transfer-of-control processes and increasing cognitive load.

According to Eurocontrol (2023) and FAA (2020), effective coordination minimizes transfer delays and ensures seamless traffic handovers between sectors. In ACC-East Jakarta, inefficiencies in coordination processes particularly during high-traffic peaks may reduce the intended benefits of sectorization. When handovers require multiple confirmations or repeated clarifications, coordination becomes an additional workload rather than a support mechanism.

Regression analysis further substantiates this interrelation. Both workload (X_1) and coordination (X_2) significantly influence sector effectiveness (Y), with workload exhibiting the more dominant impact. This pattern aligns with human factors theory (Endsley & Jones, 2025), where excessive cognitive demand undermines controller alertness, decision speed, and predictive accuracy. Hence, no matter how optimized the communication structure is, a sectorization model will fail if the human system remains overloaded.

Operational Implications and Model Recommendations

Figure 1 illustrates the relationship between workload and coordination in determining overall sectorization effectiveness.

Figure 1. Relationship between ATC Workload, Coordination, and Sector Effectiveness

A conceptual diagram showing workload balance and coordination efficiency as dual determinants of operational performance.
Source: Processed Research Data (2025).

Figure 1. Relationship between ATC Workload, Coordination, and Sector Effectiveness

The results suggest that workload equilibrium and coordination clarity are interdependent components. Balanced workload promotes smoother inter-sector communication, while efficient coordination reduces unnecessary workload escalation. Conversely, when one element deteriorates such as an overload condition the other becomes strained, decreasing overall system resilience.

These findings indicate that static sectorization models are increasingly inadequate for dynamic traffic conditions in Jakarta FIR. Implementation of dynamic sectorization, where airspace sectors can be merged or split in real time according to actual traffic volume, is recommended (Eurocontrol, 2020). This adaptive model can maintain ATC workload within optimal limits, enhance communication efficiency, and strengthen operational safety.

Additionally, the integration of predictive traffic modeling and simulation-based workload forecasting similar to that recommended by Rahman et al. (2021) would enable AirNav Indonesia to anticipate peak congestion and adjust sector boundaries proactively. Such data-driven adjustments could mitigate chronic overload patterns while ensuring operational continuity and safety.

Overall, the findings affirm that the effectiveness of airspace sector division at ACC-East Jakarta is primarily determined by two interacting factors: the balance of ATC workload and the efficiency of inter-sector coordination. The study underscores that imbalanced workload distribution and suboptimal coordination undermine the benefits of existing spatial design. Consequently, sectorization improvements must adopt a human-centered approach, prioritizing workload management, adaptive sector design, and enhanced communication systems to maintain safety and efficiency within Jakarta FIR.

CONCLUSION

The results of this study conclude that the effectiveness of airspace sector division at the Area Control Centre (ACC) East Jakarta Flight Information Region (FIR) is primarily determined by the balance of Air Traffic Controller (ATC) workload and the efficiency of inter-sector coordination. The analysis shows that excessive workload and inconsistent coordination significantly reduce operational performance, situational awareness, and communication efficiency among controllers. Conversely, when workload is distributed evenly and coordination procedures function effectively, sector performance improves markedly, leading to enhanced safety and smoother traffic management. These findings emphasize the need for a dynamic and adaptive sectorization model, supported by predictive workload analysis and human-centered design principles, to ensure sustainable operational effectiveness within Jakarta FIR. Consequently, sector management must focus on maintaining workload equilibrium, strengthening communication systems, and implementing real-time sector configuration adjustments to achieve optimal safety and efficiency standards in Indonesia's airspace operations.

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