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Impact of Air Traffic Volume on Air Traffic Controllers' Decision-Making in the Jakarta Control Zone at Perum LPPNPI JATSC

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Abstract

Air transportation is an essential element in strengthening regional connectivity and driving national economic growth. The rise in aircraft movements at Soekarno-Hatta International Airport following the COVID-19 pandemic has increased the complexity of air traffic management, particularly within the Jakarta Control Zone overseen by the Perum LPPNPI JATSC Branch. In this demanding environment, air traffic controllers (ATCs) must make rapid and accurate decisions to ensure flight safety and operational efficiency. This study examines the impact of traffic volume on ATC decision-making quality in the Jakarta Control Zone. Using a quantitative survey approach, data were collected from 71 randomly selected respondents out of 188 ATC personnel through observation, documentation, and questionnaires. The data were analyzed using SPSS version 25, employing Pearson correlation and simple linear regression tests. The results indicate a strong positive correlation between traffic volume and decision-making quality, showing that higher traffic density increases workload and reduces decision accuracy. The study concludes that effective airspace sector management requires revising sector divisions and updating AIRAC AIP AMDT documentation to align with current operational demands and maintain air traffic safety and efficiency.

Keywords: Decision-Making, Air Traffic Controller, Air Traffic Volume, Jakarta Control Zone

INTRODUCTION

Air transportation is one of the most critical components of both national and global transport systems, playing a vital role in supporting regional connectivity, economic growth, and the smooth flow of logistics. The increase in aircraft movements at Soekarno–Hatta International Airport following the COVID-19 pandemic has led to higher operational complexity in air traffic management, directly contributing to a rise in the workload of Air Traffic Controllers (ATCs) (Kamat & Li, 2024). According to data from the Directorate General of Civil Aviation (2024), the number of domestic flight movements increased from 164,301 in 2020 to 266,000 in 2024, while international flights reached 96,591 movements in the same year. This surge requires ATCs to make rapid and accurate decisions under high workload conditions to ensure both safety and operational efficiency.

The Jakarta Control Area, administered by the Jakarta Air Traffic Service Center (JATSC) under the management of Perum LPPNPI, represents one of the most congested and operationally demanding airspaces within Indonesia's aviation network. Despite the existence of established regulatory guidelines, certain inconsistencies are observed between the operational conditions stipulated in the *AIRAC AIP AMDT 151* (Aeronautical Information Regulation and Control Aeronautical Information Publication Amendment) and the manner in which these procedures are implemented in daily operations. The amendment document formally outlines a structural division of the control area into two distinct operational sectors: the Jakarta Control Zone North (CN) and the Jakarta Control Zone East (CE).

In practical application, however, these two sectors are frequently consolidated into a single operational unit. This consolidation, while intended to enhance coordination efficiency during peak traffic periods, often leads to a significant increase in air traffic controllers' workload. The resulting operational strain has the potential to affect situational awareness and the consistency of decision-making within air traffic control (ATC) operations. Such discrepancies between

prescribed procedures and field realities underscore the importance of continuous monitoring and adaptive management in maintaining optimal levels of aviation safety and service quality (Muchaddats et al., 2023).

Previous research has underscored the close connection between air traffic volume and the performance of air traffic controllers (ATC) in making operational decisions. According to D'Arcy and Della Rocco (2001), an increase in air traffic density tends to elevate controllers' psychological pressure and cognitive workload, which consequently affects both the precision and timeliness of their decisions. When mental demands exceed manageable levels, the ability of controllers to assimilate complex information and to react swiftly in critical or emergency conditions can become compromised. These findings collectively suggest that cognitive overload represents a key factor influencing ATC performance under high-traffic conditions. Nevertheless, empirical evidence specifically examining how variations in traffic volume impact the decision-making quality of air traffic controllers within the Jakarta Control Zone remains scarce. This limited body of research indicates a meaningful gap in current literature, highlighting the need for further in-depth studies focusing on this context.

This study offers a novel contribution in the Indonesian context by analyzing the impact of air traffic density on ATC decision-making quality specifically within the Jakarta Control Zone, while also assessing the alignment between operational data and AIRAC AIP AMDT regulations. The findings are expected to serve as a foundation for revising sector division policies and improving air traffic management efficiency in high-density regions such as the Jakarta Control Zone.

RESEARCH METHODS

This study adopts a quantitative approach using the survey method to examine the extent to which air traffic volume influences the decision-making quality of Air Traffic Control (ATC) personnel operating within the Jakarta Control Zone, under the management of Perum LPPNPI Jakarta Air Traffic Service Center (JATSC). The research process consisted of three main stages: data collection, data processing, and statistical analysis.

1. Population and Sample

The population of this study comprised all ATC personnel assigned to the Tower and Approach (APP/TMA) units of Perum LPPNPI JATSC, totaling 188 individuals. The sampling was carried out using the simple random sampling technique, with the sample size determined through the Slovin formula and a 10% margin of error. Based on this calculation, 65 respondents were selected, and an additional 10% was included to anticipate potential dropouts, resulting in a final total of 71 respondents.

2. Operational Definition of Variables

The independent variable (X) is air traffic volume, measured by the average number of aircraft handled by an ATC within one hour of operational control in the Jakarta Control Zone.

The dependent variable (Y) is the quality of ATC decision making, measured using a structured questionnaire. The measurement indicators were developed based on the decision-making theory of D'Arcy and Della Rocco (2001), which includes three dimensions:

a. Individual-related factors (decision-maker characteristics such as attention, stress tolerance, and cognitive focus),
b. Task-related factors (complexity, workload, and time constraints), and
c. Contextual factors (environmental and organizational conditions influencing decision quality).

3. Data Collection Techniques

Data were collected using three complementary methods:

a. Observation, to obtain empirical insights into ATC operational activities within the Jakarta Control Zone.
b. Document study, involving the analysis of official JATSC traffic movement reports and AIRAC AIP AMDT data to ensure data validity and regulatory alignment.
c. Questionnaire, employing a four-point Likert scale (1- 4) to measure ATC perceptions regarding their decision-making quality under varying traffic conditions.

4. Data Analysis Techniques

The collected data were processed and analyzed using the Statistical Package for the Social Sciences (SPSS) version 25, applying the following statistical methods:

a. Normality Test Conducted using the Kolmogorov–Smirnov test to ensure that data distribution met parametric test assumptions.
b. Pearson Correlation Test Used to evaluate the degree and direction of the relationship between traffic volume and decision-making quality.
c. Simple Linear Regression Analysis Applied to determine the magnitude of influence exerted by the independent variable on the dependent variable.
d. Partial t-Test Used to test the hypothesis and verify whether the correlation between the two variables was statistically significant.

The hypothesis structure for this study was formulated as follows:

a. H_0: Air traffic volume does not have a significant effect on ATC decision-making quality.
b. H_1: Air traffic volume has a significant effect on ATC decision-making quality.

This research was conducted at Perum LPPNPI - Jakarta Air Traffic Service Center (JATSC), Soekarno-Hatta International Airport, over the period of August to November 2025, in accordance with the research schedule established by the author.

RESULT AND DISCUSSION

Results

This research was conducted based on data collected through observation, document analysis, and the distribution of questionnaires to 71 Air Traffic Controllers (ATCs) assigned to the Jakarta Control Zone, under the management of Perum LPPNPI - Jakarta Air Traffic Service Center (JATSC). Data analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 25, aimed at testing the correlation and influence between traffic volume (variable X) and decision-making quality (variable Y).

1. Description of the Traffic Volume Variable (X)

The traffic volume variable (X) represents the workload level of air traffic controllers, measured by the average number of aircraft handled per hour during operational duties. Based on the results of the statistical analysis, the mean value of traffic volume was 24.42 aircraft per hour, with a maximum value of 35, a minimum value of 13, and a standard deviation of 6.67. The data range was 22, indicating a substantial variation in workload intensity among ATC personnel operating within the Jakarta Control Zone.

Table 1. Descriptive Statistical Analysis of Variable X (Traffic Volume)

No	Statistic	Value	Description
1	N	71	Total number of respondents
2	Maximum Value	35	Highest number of aircraft handled per hour
3	Minimum Value	13	Lowest number of aircraft handled per hour
4	Mean	24.42	Average number of aircraft handled per hour
5	Median	24	Midpoint of data distribution
6	Mode	18	Most frequently occurring traffic count

7	Standard Deviation	6.67	Degree of data dispersion
8	Range	22	Difference between maximum and minimum values

The similarity between the mean and median values indicates that the data distribution is relatively normal and symmetrical, while the difference between the extreme values reflects variations in operational conditions experienced by different ATC personnel.

2. Description of the Decision-Making Variable (Y)

Data on the decision-making variable (Y) were obtained through a Likert-scale questionnaire (1- 4), designed based on the three dimensions proposed by D'Arcy and Della Rocco (2001): decision-maker-related factors, task-related factors, and contextual factors. These dimensions collectively assess the cognitive, procedural, and environmental aspects influencing ATC decision quality.

The results of the descriptive statistical analysis indicate an average score of 28.34, with a maximum value of 39, a minimum value of 18, a standard deviation of 5.58, and a median of 28. These findings suggest that the overall decision-making quality among ATC personnel in the Jakarta Control Zone falls within the "Good" category.

Table 2. Descriptive Statistical Analysis of Variable Y (Decision-Making Quality)

No	Statistic	Value	Description
1	N	71	Total number of respondents
2	Maximum Value	39	Highest decision-making score
3	Minimum Value	18	Lowest decision-making score
4	Mean	28.34	Average score of decision-making quality
5	Median	28	Midpoint of data distribution
6	Mode	26	Most frequently occurring score
7	Standard Deviation	5.58	Degree of data variation
8	Range	21	Difference between maximum and minimum values

The distribution of scores indicates that the majority of Air Traffic Controllers (ATCs) demonstrate good decision-making abilities, although a small number of respondents scored lower, which should draw the attention of JATSC's human resource management to ensure targeted development and performance improvement efforts.

3. Normality Test Results

The Kolmogorov-Smirnov test produced a significance value of 0.198, which is greater than 0.05, indicating that the data are normally distributed. This result confirms that the dataset meets the statistical assumptions required for subsequent parametric testing.

4. Pearson Correlation Test Results

The Pearson correlation analysis yielded a correlation coefficient (r) of 0.671 with a significance level (p) of $0.000 < 0.05$, indicating a strong and statistically significant positive relationship between traffic volume and decision-making quality. This finding suggests that as traffic volume increases, ATC workload also rises, which can in turn negatively affect decision-making performance due to higher cognitive demands and time pressure. The relationship implies that while higher traffic requires greater vigilance and responsiveness, excessive workload may lead to reduced decision accuracy and slower situational response.

5. Simple Linear Regression Analysis Results

The simple linear regression analysis produced the following regression equation:

$$Y=15.217+0.537X$$

This equation indicates that for every one-unit increase in traffic volume, the decision-making score increases by 0.537 points. This demonstrates a positive influence, meaning that higher operational demand may stimulate more active decision engagement; however, the effect is not entirely linear, as performance may decline once workload exceeds the optimal threshold.

The coefficient of determination (R^2) was 0.451, meaning that 45.1% of the variance in ATC decision-making quality can be explained by traffic volume, while the remaining 54.9% is influenced by other factors such as weather conditions, inter-sector coordination, and psychological stress.

6. Hypothesis Test (t-Test) Results

The t-test results show a t-calculated value ($t_{han}d$) = 7.734, which is greater than the t-table value (1.995), and a significance level (p) = 0.000 < 0.05. Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted.

This means that traffic volume has a statistically significant effect on the decision-making quality of ATC personnel in the Jakarta Control Zone. The result confirms that increasing traffic intensity directly impacts the cognitive load and performance efficiency of controllers, thereby underscoring the importance of workload management and sector optimization in maintaining safe and effective air traffic operations.

Discussion

The findings of this study confirm a significant relationship between traffic volume and the quality of decision making among Air Traffic Controllers (ATCs) operating within the Jakarta Control Zone. Empirically, the results demonstrate that the higher the volume of air traffic handled, the greater the cognitive and operational pressure experienced by ATC personnel, which can consequently reduce decision accuracy and effectiveness.

This outcome aligns with the Mental Workload Theory proposed by Wickens (2008), which asserts that increased task complexity and workload intensity reduce an individual's cognitive capacity to process information efficiently. In the context of air traffic management, such conditions directly affect an ATC's ability to maintain situational awareness and make safe and timely operational decisions.

The present findings also reinforce those of D'Arcy and Della Rocco (2001), who identified traffic volume, sector complexity, and time pressure as significant variables influencing ATC decision-making performance. Similarly, Cain (2007) argued that high workload pressure can diminish a controller's analytical ability and heighten the risk of operational errors.

From an operational perspective, the regression analysis revealed that 45.1% of the variance in decision-making quality is explained by traffic volume, indicating that while traffic density is a dominant factor, other elements also play critical roles. These include shift management, work experience, inter-unit coordination, and technological support systems. This is consistent with the findings of Moon et al. (2011), which showed that increasing air traffic without adequate automation and decision-support tools can elevate the probability of human error by up to 40%.

Furthermore, the study highlights a gap between the ideal and actual operational conditions outlined in AIRAC AIP AMDT 151 (2024). The document specifies that the Jakarta Control Zone should be divided into two operational sectors Control Zone North (CN) and Control Zone East (CE). However, in practice, both sectors are combined into a single sector, resulting in workload concentration within one control area and increasing the potential for degraded decision-making performance.

Accordingly, the practical implication of this research lies in the recommendation to revise the AIRAC AIP AMDT documentation and to restructure the control sector configuration to better reflect actual operational conditions. Additionally, the study recommends the implementation of targeted decision-making training programs for ATC personnel particularly stress-based decision-making training and the adoption of a dynamic workload management system that adjusts to real-time traffic fluctuations.

Overall, this research contributes to the strengthening of national aviation safety policies by emphasizing that human cognitive performance particularly that of air traffic controllers must

be considered equally important as technical and navigational systems in managing increasingly complex and high-density air traffic environments.

CONCLUSION

The results of this study indicate that the increase in air traffic volume has a significant influence on the decision-making quality of Air Traffic Controllers (ATCs) in the Jakarta Control Zone, managed by Perum LPPNPI - JATSC. Based on the Pearson correlation analysis, the study obtained a correlation coefficient (r) of 0.671 with a significance level (p) of 0.000, signifying a strong positive correlation between traffic volume and ATC decision-making performance. This implies that the greater the number of aircraft movements controlled simultaneously, the higher the workload and mental pressure experienced by ATCs, which in turn affects the accuracy and speed of their operational decisions.

The simple linear regression analysis further revealed that traffic volume accounts for 45.1% of the variance in decision-making quality, while the remaining 54.9% is influenced by other factors such as work experience, time pressure, weather conditions, and inter-sector coordination. These findings are consistent with the Mental Workload Theory (Wickens, 2008), which posits that increasing task intensity and complexity can reduce an individual's cognitive capacity to make optimal decisions particularly in dynamic operational environments such as air traffic control.

Empirically, the study also identified a discrepancy between the operational standards stated in the AIRAC AIP AMDT 151 (2024) and the actual field implementation. While the document stipulates that the Jakarta Control Zone should be divided into two sectors CN (Control North) and CE (Control East) in practice, both sectors remain combined, concentrating workload within a single control area. This condition heightens the risk of mental fatigue, reduced situational awareness, and an increased likelihood of operational errors in the decision-making process.

Accordingly, this research underscores the necessity for sectoral restructuring and updates to operational documentation to align with current field conditions. Furthermore, the study recommends enhancing ATC competence through stress-based decision-making training and implementing a dynamic workload management system that adapts to real-time traffic density.

Overall, the findings reaffirm that the effectiveness of air traffic management depends not only on the sophistication of navigation technology but also on the cognitive capability, mental resilience, and decision-making proficiency of human operators. Human factors remain the cornerstone of aviation safety, emphasizing that technological advancement must be balanced with continuous human performance optimization to sustain safety and efficiency in increasingly complex airspace environments.

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