

The Impact of the STCA System on ATCs' Conflict Projection Ability in Jakarta APP/TMA

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Abstract

This study aims to analyze the influence of the Short Term Conflict Alert (STCA) system on the conflict projection ability of Air Traffic Controllers (ATC) at the APP/TMA Jakarta Unit. The increasing air traffic volume by 19.6% between 2022 and 2025 has heightened operational complexity, emphasizing the need for effective decision-support systems. A quantitative research method was employed using a survey approach involving 105 active ATCs with at least two years of experience. The variables examined include Perception of STCA (X), Situational Awareness (SA), Workload Management (WM), Training and Experience (TE), and Conflict Projection Ability (Y). Data analysis consisted of validity, reliability, normality, Pearson correlation, and multiple linear regression tests. The results indicate that STCA has a positive and significant influence on conflict projection ability, with an Adjusted R² value of 0.80 and a multiple correlation coefficient (R) of 0.90. Among the predictors, SA and TE make the strongest contributions, while WM functions as a supporting factor. In conclusion, the integration of STCA technology and human performance factors plays a crucial role in enhancing safety and efficiency in air traffic control operations at APP/TMA Jakarta.

Keywords: STCA, Air Traffic Controller, Situational Awareness, Workload Management, Conflict Projection

INTRODUCTION

Air Traffic Control (ATC) is a critical component of aviation safety, ensuring the orderly and efficient flow of air traffic to prevent collisions and maintain separation standards. With the continuous increase in air traffic volume and operational complexity within terminal airspace, particularly in the Jakarta area, there is a growing need for advanced decision-support systems to assist controllers in maintaining safety and efficiency. One of the key automation tools implemented in the Approach Control (APP) and Terminal Maneuvering Area (TMA) Jakarta Units is the *Short Term Conflict Alert* (STCA) system.

The STCA system is an automation feature designed to predict and provide early warnings of potential loss of separation between aircraft within a short prediction window typically 120 seconds ahead. By analyzing real-time radar data, flight plans, and aircraft altitude information, STCA alerts controllers to potential conflicts before minimum separation standards are breached (Dominikus, 2018; ICAO, 2022).

Operational data from the APP/TMA Jakarta Unit show a significant increase in traffic movements between 2022 and 2025. Total traffic movements rose from 303,158 in 2022 (an average of 830 per day) to 362,677 in 2024 (an average of 991 per day), marking a 19.6% growth overall. This surge in traffic has increased controller workload and task complexity. Despite the deployment of the STCA system, *Breakdown of Separation* (BOS) incidents persist, averaging 11.7 cases per year, with fluctuations from 13 incidents in 2022 to 8 in 2023 and back to 14 in 2024. These inconsistencies indicate that the STCA system's operational effectiveness may not yet be fully optimized by controllers (Masalha & Shmueli, 2020; Harris & Harris, 2019).

The effectiveness of STCA depends not only on the system's technical performance but also on *human factors* including situational awareness, workload management, and trust in automation (Endsley, 1995; Lee & See, 2015). Inadequate training, misinterpretation of alerts, or overreliance on automation can reduce system benefits and even contribute to new types of

operational errors (Sarter & Alexander, 2014; Parasuraman et al., 2017). Therefore, a comprehensive study is required to examine how STCA influences controllers' conflict projection ability and to identify the human and system-related factors affecting its effectiveness in APP/TMA Jakarta.

Based on the background above, the main research problems are formulated as follows:

1. How do Air Traffic Controllers perceive and understand the STCA system at the APP/TMA Jakarta Unit?
2. How does the STCA system influence controllers' ability to project and anticipate potential conflicts?
3. What human factor variables affect the effectiveness of STCA in enhancing conflict projection ability?
4. What recommendations can be proposed to optimize STCA implementation in reducing *Breakdown of Separation* incidents?

This study aims to:

1. Identify the perception and understanding of Air Traffic Controllers toward the STCA system in the APP/TMA Jakarta Unit.
2. Measure the influence of STCA on the conflict projection ability of controllers.
3. Analyze the contributing human factors such as situational awareness, workload management, and training experience that affect STCA effectiveness.
4. Formulate recommendations for optimizing STCA implementation and enhancing ATC training programs to support conflict management performance.

RESEARCH METHODS

This study employed a quantitative research method using a cross-sectional survey design to examine the influence of the *Short Term Conflict Alert* (STCA) system on the conflict projection ability of Air Traffic Controllers (ATC) at the Jakarta Approach (APP) and Terminal Maneuvering Area (TMA) Units. The quantitative approach was chosen to objectively measure relationships among variables and to enable statistical generalization from the sample to the population (Sugiyono, 2019).

The research focused on five main variables:

1. Perception of STCA (X_1)
2. Situational Awareness (SA) (X_2)
3. Workload Management (WM) (X_3)
4. Training and Experience (TE) (X_4)
5. Conflict Projection Ability (Y)

Each variable was measured through validated questionnaire items using a 5-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree).

Population and Sampling Technique

The population comprised all certified Air Traffic Controllers working at the APP/TMA Jakarta Unit under AirNav Indonesia, totaling 150 personnel who met the inclusion criteria:

1. Minimum two years of operational experience,
2. Valid ATC license, and
3. Active duty during the research period (June-December 2025).

The sample size was determined using the Slovin formula with a 5% margin of error, yielding a minimum of 110 respondents. Sampling was conducted through simple random sampling to ensure representativeness across sectors and shifts of duty controllers.

Research Instruments

Data were collected using a structured questionnaire consisting of five sections:

1. Demographic information (age, experience, position, frequency of STCA use),
2. Perception of STCA (12 items),
3. Conflict Projection Ability (11 items),
4. Situational Awareness, Workload Management, and Training & Experience (11 items), and
5. Open-ended responses regarding STCA operational impacts and improvement suggestions.

Instrument validity was tested using the Pearson Product Moment correlation, where $r \geq 0.30$ indicated valid items, while reliability was assessed using Cronbach's Alpha, with $\alpha \geq 0.70$ considered reliable (Ghozali, 2021).

Data Collection Procedures

Data collection was conducted between June and August 2025, using two main techniques:

1. Questionnaire Distribution distributed electronically and manually to ATCs during operational shifts.
2. Document Analysis reviewing secondary data such as BOS (Breakdown of Separation) incident reports (2022-2024), monthly traffic statistics, and AirNav Indonesia's STCA operating procedures and training records.

Ethical considerations were maintained by obtaining respondent consent and ensuring anonymity.

Variables and Operational Definitions

1. Perception of STCA (X_1) measured by indicators of system usability, accuracy, reliability, clarity of alerts, and user satisfaction.
2. Situational Awareness (X_2) measured by awareness of aircraft position, altitude, trajectory, and traffic dynamics (Endsley, 1995).
3. Workload Management (X_3) assessed through the ability to manage mental and operational workload under high traffic conditions.
4. Training & Experience (X_4) included participation in STCA-related training, years of ATC experience, and self-assessed competence.
5. Conflict Projection Ability (Y) measured through items reflecting conflict identification, time-to-conflict estimation, and preventive action capability.

Data Analysis Techniques

Data processing involved the following stages:

1. Editing and Coding: Verification of questionnaire completeness and coding of responses.
2. Descriptive Statistics: Calculation of mean, standard deviation, and frequency distribution to describe variable tendencies.
3. Validity and Reliability Testing: Using Pearson correlation and Cronbach's Alpha in SPSS 25.
4. Normality Testing: Using Shapiro-Wilk method to verify data distribution.
5. Inferential Statistics:
 - a. Pearson Correlation Analysis to identify bivariate relationships.
 - b. Multiple Linear Regression Analysis to determine the direct influence of STCA perception, SA, WM, and TE on conflict projection ability.
 - c. Hypothesis Testing using *t-tests* for partial effects and *F-tests* for simultaneous effects, with a significance level of $p < 0.05$.

The statistical model followed a multiple regression framework:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where Y = Conflict Projection Ability, and X₁-X₄ represent independent variables.

Data analysis was performed using SPSS (Statistical Package for the Social Sciences) version 25, allowing for both descriptive and inferential interpretation of results.

Research Location and Duration

This study was conducted at the Jakarta Air Traffic Service Center (JATSC), specifically within the APP/TMA Jakarta Unit, which manages approach control for Soekarno-Hatta International Airport and Halim Perdanakusuma Airport. The research took place over six months (June-December 2025), covering preparation, data collection, analysis, and report writing.

RESULT AND DISCUSSION

This research was conducted at the Jakarta Approach and Terminal Maneuvering Area (APP/TMA) under AirNav Indonesia Jakarta Air Traffic Service Center (JATSC). The unit manages dense terminal airspace serving Soekarno-Hatta (WIII) and Halim Perdanakusuma (WIHH) airports, where controllers handle approximately 1,000 aircraft movements per day an increase of 19.6% from 2022 to 2025. This operational density demands precise situational awareness and rapid conflict prediction capabilities from Air Traffic Controllers (ATCs).

The Short Term Conflict Alert (STCA) system was introduced as an automation tool to assist ATCs in predicting potential *loss of separation* within 120 seconds. Despite its implementation, the average Breakdown of Separation (BOS) incidents remains 11.7 per year, suggesting that the human system interaction in STCA usage requires deeper assessment.

Perception of STCA

Based on data from 105 ATCs, the total perception score toward STCA reached 5,152 points, or 82% of the ideal score, indicating a *very positive perception*. Controllers agreed that the system is easy to use, reliable, and provides timely and accurate alerts. Respondents emphasized that STCA effectively supports conflict detection, especially during high traffic or adverse weather conditions, while maintaining the importance of human judgment.

Figure 1. Distribution of Perception Scores toward the STCA System
(Source: Processed by the researcher, 2025)

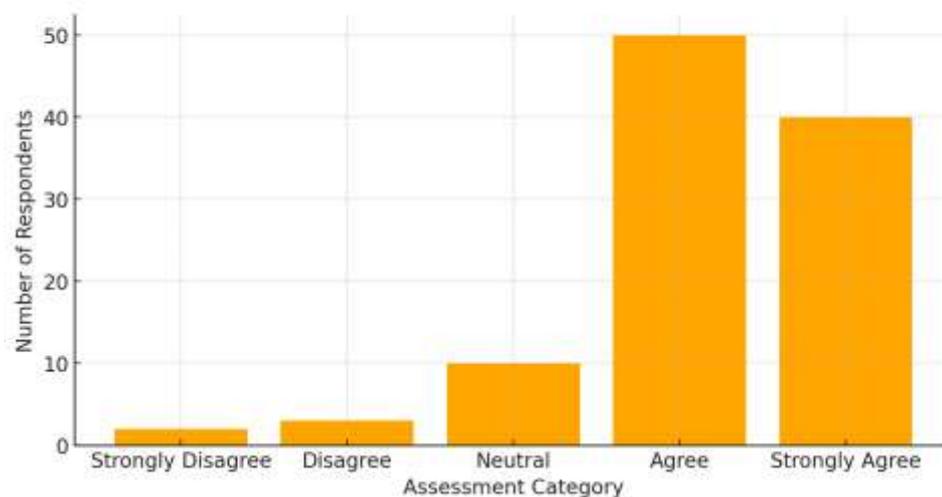


Figure 1. Distribution of STCA Perception Scores
(Majority responses fall in “Agree” and “Strongly Agree” categories.)

These findings align with Ghozali (2021), who states that a system’s perceived reliability directly enhances operational confidence and decision-making effectiveness.

Conflict Projection Ability

The total score for conflict projection ability was 4,522 points (80% of the ideal), categorized as *good performance*. ATCs demonstrated consistent capability in identifying potential conflicts and applying preventive actions promptly. Experienced controllers (>15 years) scored higher, confirming that experience strengthens conflict prediction accuracy, especially when integrated with radar and STCA data.

Figure 2. Distribution of ATC Conflict Projection Ability Scores
(Source: Processed by the researcher, 2025)

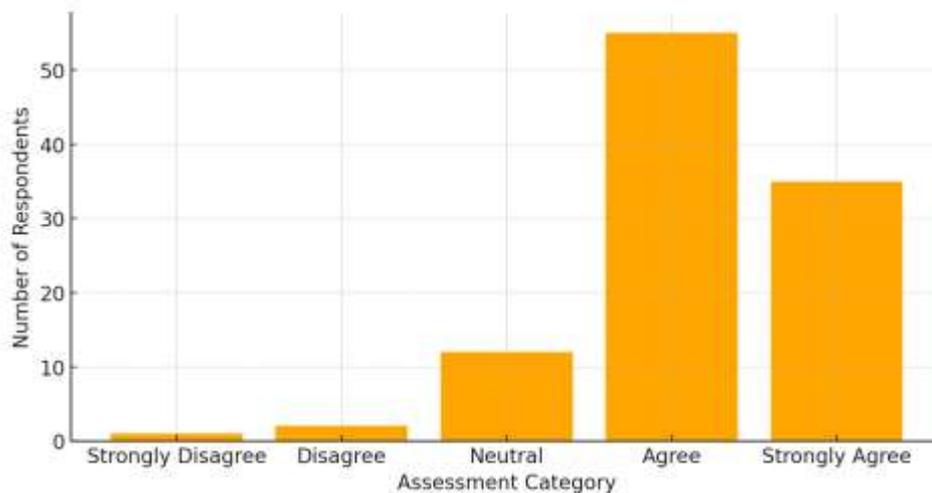


Figure 2. Distribution of Conflict Projection Scores
(The responses cluster around “Agree” and “Strongly Agree.”)

The results support Endsley’s (1995) theory of situational awareness, which emphasizes projection ability as the highest cognitive stage of awareness, linking perception, comprehension, and anticipation for proactive control.

Situational Awareness (SA)

For Situational Awareness, the total score reached 1,710 points (81.4%), classified as *very high*. Respondents agreed that STCA enhances their real-time understanding of traffic dynamics. However, controllers asserted that technology alone cannot replace human vigilance; teamwork, communication, and calm cognition remain essential.

Figure 3. Distribution of Situational Awareness (SA) Scores
(Source: Processed by the researcher, 2025)

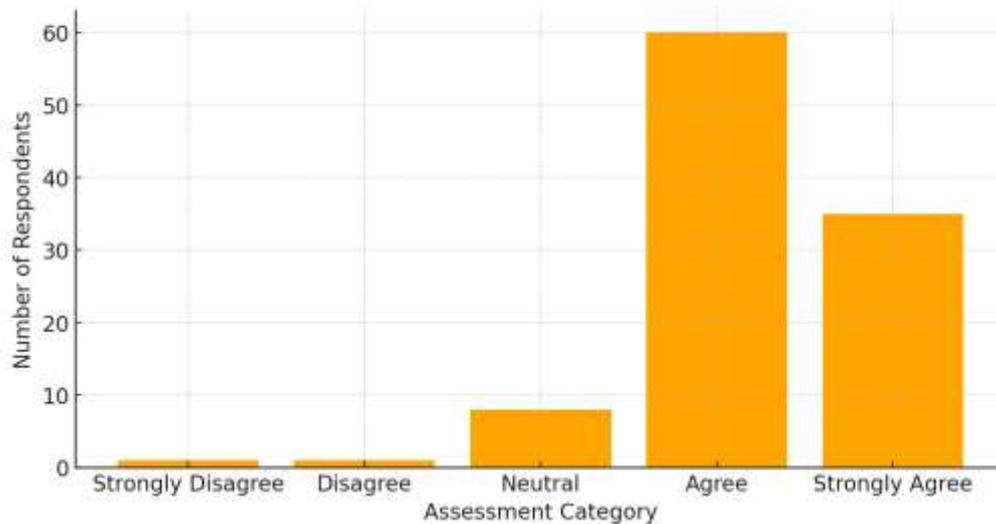


Figure 3. Situational Awareness Level among ATCs
(The graph shows dominant “Agree” responses across all items.)

These findings reaffirm the role of STCA as a *situational support system* that complements rather than substitutes human awareness in maintaining safety-critical performance.

Workload Management (WM)

The Workload Management score reached 1,620 points (77.1%), categorized as *good*. Controllers generally managed workload efficiently, prioritizing tasks and maintaining concentration during simultaneous STCA alerts. However, under extreme traffic or weather conditions, perceived workload remained high, showing that STCA mitigates but does not eliminate mental strain.

Figure 4. Distribution of Workload Management (WM) Scores
(Source: Processed by the researcher, 2025)

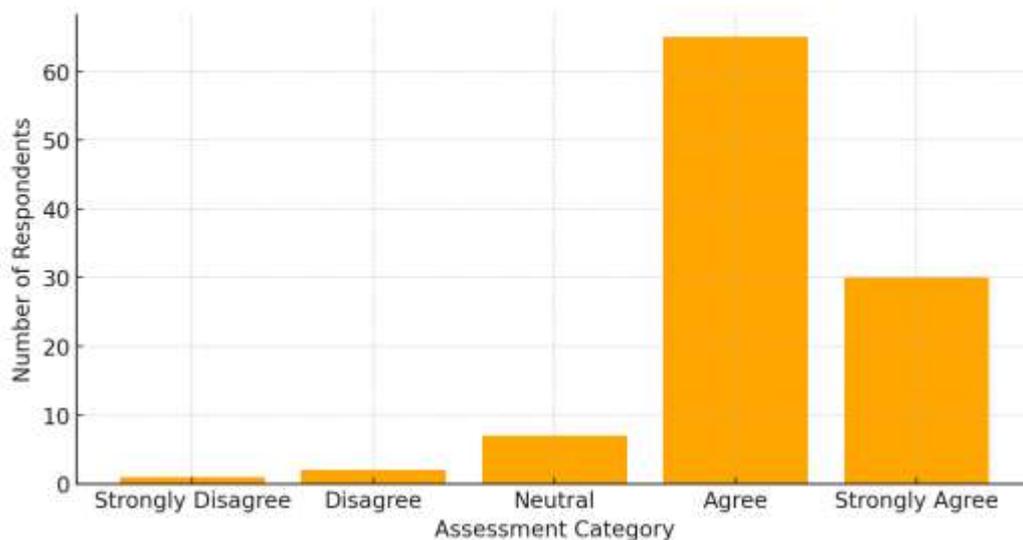


Figure 4. Distribution of Workload Management Scores

This supports prior research (Sefrus et al., 2021) that high-traffic ATC environments require effective workload regulation and stress tolerance for maintaining safe operations.

Training and Experience (TE)

The Training and Experience variable yielded 1,278 points (81.2%), also *very high*. Respondents agreed that structured STCA training improved their operational proficiency and confidence. Simulation-based training enhanced recognition of alert patterns and faster conflict anticipation.

Figure 5. Distribution of Training & Experience (TE) Scores
(Source: Processed by the researcher, 2025)

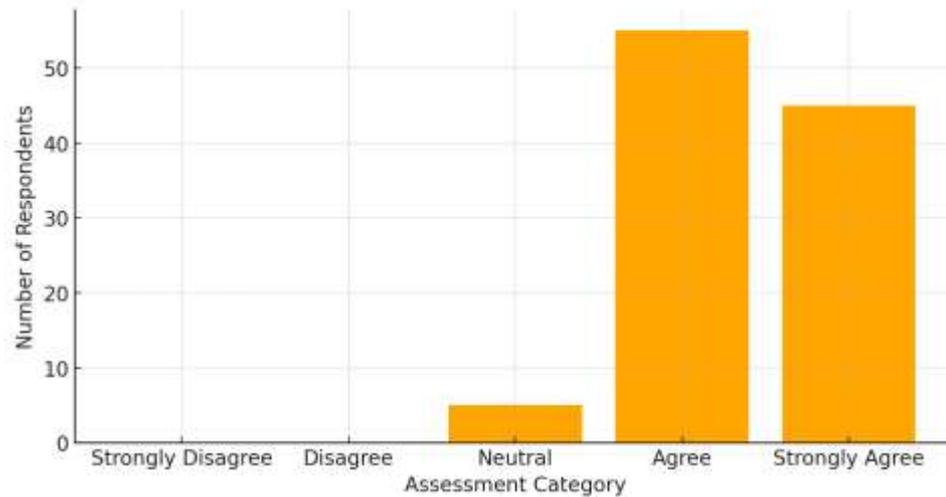


Figure 5. Training and Experience Level

(Data trend indicates that ATCs with >20 years of experience and simulation exposure have higher competence.)

These findings echo Sugiyono (2019), who highlights that technical training and practical experience jointly influence behavioral adaptation to technological systems in aviation environments.

Inferential Analysis

The Pearson correlation test revealed strong relationships among all variables, with R = 0.90 and Adjusted R² = 0.80, implying that 80% of the variance in conflict projection ability can be explained by STCA perception, situational awareness, workload management, and training & experience.

The multiple regression analysis indicated that situational awareness ($\beta = 0.342$) and training & experience ($\beta = 0.310$) had the most substantial contributions, while workload management served as a moderating support variable.

Table 1. Summary of Regression Model

Predictor	β Coefficient	Sig. (p)	Interpretation
STCA Perception (X ₁)	0.245	<0.05	Positive, significant
Situational Awareness (X ₂)	0.342	<0.01	Strong, dominant
Workload Management (X ₃)	0.216	<0.05	Supportive
Training & Experience (X ₄)	0.310	<0.01	Strong, significant

These results demonstrate that technological and human factors interact synergistically. STCA provides predictive alerts, but controllers’ awareness and experience determine how effectively those alerts are translated into safe tactical actions.

The findings collectively affirm that the STCA system significantly enhances conflict projection ability, supporting Air Traffic Controllers in anticipating and resolving potential conflicts proactively.

However, the system's effectiveness depends on the operator's understanding, trust, and workload regulation. In line with Endsley (1995) and Sefrus et al. (2021), automation can augment but not replace human cognition in complex decision-making.

Controllers with extensive operational experience and frequent exposure to simulation training showed superior ability to integrate STCA alerts into real-time decision-making, reducing cognitive overload and minimizing BOS incidents. This reinforces the need for continuous professional development and adaptive training modules tailored to evolving automation tools.

Furthermore, despite automation assistance, ATCs still exhibit manual cross-checking behavior to validate system alerts a reflection of balanced human machine coordination emphasized in modern aviation safety frameworks. Overall, the integration between technology (STCA) and human factors (SA, WM, TE) plays a critical role in achieving sustainable air traffic safety and efficiency in high-density airspace like Jakarta APP/TMA.

CONCLUSION

The findings of this study indicate that the Short Term Conflict Alert (STCA) system significantly contributes to enhancing the conflict projection ability of Air Traffic Controllers (ATCs) at the APP/TMA Jakarta Unit. Overall, the research demonstrates that STCA perception, situational awareness (SA), and training & experience (TE) are the dominant factors influencing ATC performance, while workload management (WM) serves as a supporting variable that helps maintain cognitive stability during high traffic and alert conditions. The multiple regression analysis showed a strong relationship between all independent variables and conflict projection ability, with an Adjusted R^2 value of 0.80 and a multiple correlation coefficient (R) of 0.90, confirming that 80% of the variance in ATC conflict projection performance can be explained by the combination of technological and human factors. These findings emphasize that the integration between automation tools like STCA and human competencies such as awareness, expertise, and training is essential to maintaining air traffic safety and operational efficiency in complex and high-density airspace environments such as Jakarta's APP/TMA.

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