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Priority of AIDC Implementation in AirNav Indonesia's ATS System Using AHP Method

Liber Tommy Hutabarat[1], Inda Tri Pasa[2], Robi Saputra[3], Morist Sony[4], Agung Pramono[5]
[1]Politeknik Penerbangan Medan, Indonesia, limasodara@gmail.com
[2]Politeknik Penerbangan Medan, Indonesia, indatripasa@poltekbangmedan.ac.id
[3]AirNav Indonesia, Indonesia, robzyatc2@gmail.com
[4]AirNav Indonesia, Indonesia, moritssony@gmail.com
[5]AirNav Indonesia, Indonesia, monoagung@rocketmail.com

Corresponding Author: limasodara@gmail.com[1]

Abstract: This study aims to provide decision-making support to AirNav Indonesia regarding the prioritization of AIDC (Air Traffic Services Inter-Facility Data Communication) implementation across its western region branches. The research is grounded in AirNav Indonesia's vision to modernize its ATS system, specifically through AIDC implementation, to enhance flight services and global connectivity with neighboring countries. The Analytical Hierarchy Process (AHP) method was employed, utilizing purposive sampling of ATS System specialists from six AirNav Indonesia branches in the western region. The data was analyzed following the AHP method's hierarchical structure, including criteria, sub-criteria, and alternatives. The key criteria assessed were infrastructure readiness, ATC workload, human resources readiness, traffic volume, and number of connections. The alternatives were the JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang branches. The research findings indicate that JATSC ranked first in priority for AIDC implementation, with a global sub-criterion weight of 0.3648, followed by Medan (0.3109), Palembang (0.3061), Pekanbaru (0.2829), Tanjung Pinang (0.2825), and Pontianak (0.1585). The ATS System specialists, who are directly involved with AIDC equipment, provided objective assessments, as evidenced by all criteria and sub-criteria having consistency ratios below 0.1, indicating acceptable consistency. It is recommended that AIDC implementation at AirNav Indonesia be carried out in phases and continued over time, considering available resources, to improve air traffic services and achieve global flight connectivity with neighboring countries.

Keywords: ATS System, AIDC Implementation, Multi-Criteria AHP, Air Traffic Services

INTRODUCTION

The aviation industry has become increasingly complex and dynamic, making the efficiency and safety of air traffic management a top priority. Ensuring the safety of air travel requires flawless coordination among various air traffic control (ATC) units to avoid errors. The complexity of air traffic, particularly on international and national flight routes, necessitates constant coordination to maintain flight safety from takeoff to landing. As air travel becomes more complex, coordination efforts need to be optimized for efficiency and effectiveness in exchanging critical data and information between aviation units. Data, which is increasingly essential in today's world, has become a valuable asset (Sekera & Novák, 2021). To create an integrated information system, Dou (2020) suggested integrating aviation big data into a cohesive big data platform. However, this goal can only be achieved with adequate connectivity solutions. Communication tools between ATC units are key to achieving this coordination.

According to the ICAO Global Operational Data Link Document (Group, 2013), modern datalink systems rely on the use of Communication Service Provider (CSP) networks and satellite communication or ground-based radio communication stations. One of the key technologies that support this interconnection is Air Traffic Services Interfacility Data Communication (AIDC) (Group, 2013). AIDC plays a vital role as the central nervous system of communication networks, facilitating rapid, accurate, and automatic data exchanges between various air traffic control facilities. AIDC allows for automatic and electronic exchange of flight data (such as Estimates, Coordination, and Transfer of Control) between different ATS systems, such as between Area Control Centers (ACC) or between ACC and Approach Control (APP) or between APP and other relevant units.

AirNav Indonesia (2025), the organization responsible for managing flight navigation services across Indonesia, operates 295 units, including Area Control Centers, Approach Control/Terminals, and Aerodrome Control Towers. It covers an airspace area of 7,789,268 square kilometers. The increasing volume of global air traffic, including in Indonesian airspace, demands a boost in the capacity and complexity of the Air Traffic Management (ATM) system. The full implementation of AIDC at AirNav Indonesia is crucial. According to the International Civil Aviation Organization (ICAO) standards and the Global Air Navigation Plan (GANP), modern ATM systems must offer safe, efficient, and sustainable navigation services. In a crowded airspace, traditional coordination methods that rely heavily on voice communication have been shown to increase ATC workload, potentially leading to communication errors (human error).

The full implementation of digital data communication is a critical prerequisite for AirNav Indonesia to ensure operational efficiency and effectiveness in providing flight navigation services. This aligns with the company's mandate to manage airspace that is both safe and capable of handling high traffic volumes (AirNav Indonesia, 2023). Currently, AirNav Indonesia has implemented AIDC in the eastern region, facilitated by the Makassar Air Traffic Service Centre (MATSC), which exchanges flight data with the Philippines and Australia (Kompas, 2020). Moving forward, AirNav Indonesia continues to develop and expand AIDC implementation in the western region. The full-scale implementation of AIDC across all ATS systems in AirNav Indonesia is a complex project. Its challenges are not limited to technical aspects (interoperability between old and new systems), but also include operational challenges (developing new Standard Operating Procedures), human resources (ATC training), and financial considerations (budget allocation).

The primary function of AIDC is to reduce ATC workload by automating the exchange of flight data between different ATC systems, thus facilitating coordination (Pramono et al., 2024). In crowded airspace, AIDC provides a direct solution to improve safety and reduce the potential for human error resulting from high voice communication workload. ATC workload must be assessed accurately to allow for optimal efficiency. If workload exceeds acceptable levels over extended periods, fatigue may occur (Triyanti et al., 2020).

The implementation of fully integrated AIDC in Indonesia's airspace, particularly in the western region (Jakarta, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang), requires in-depth evaluation. Constraints such as budget limitations, infrastructure, human resources, airspace conditions, and workload necessitate a tested strategy to prioritize critical success factors and select the optimal roll-out strategy.

In this study, the Analytical Hierarchy Process (AHP) method is employed for decision-making by comparing criteria and alternatives hierarchically (Britain & Avenue, 1987). The criteria considered include traffic volume, infrastructure readiness, human resources readiness, number of connections, and workload. The results of this AHP-based study are expected to provide AirNav Indonesia, as the sole provider of ATS in Indonesia, with a roadmap for decision-making in prioritizing programs, planning, and selecting the implementation strategy of AIDC in six branches of AirNav Indonesia located in the western region.

While previous research has examined the importance of AIDC in enhancing air traffic coordination (Pramono et al., 2024), little attention has been given to evaluating the prioritization of AIDC implementation within a diverse geographical and operational environment such as Indonesia's airspace. The gap lies in a comprehensive evaluation model that can provide a clear prioritization framework, based on multiple criteria, to guide decision-makers at AirNav Indonesia. This study seeks to fill that gap by applying the AHP method to prioritize AIDC implementation across various branches, considering factors such as infrastructure, workload, and traffic volume.

As air traffic continues to grow, the urgency of implementing modern communication systems like AIDC becomes more critical for maintaining safe and efficient airspace management. The transition from traditional voice-based coordination to automated data communication systems is essential for minimizing human error and improving overall efficiency. AirNav Indonesia's ability to prioritize AIDC implementation will play a significant role in meeting the future demands of air traffic while ensuring safety standards are upheld.

Several studies have explored the role of AIDC in air traffic management. Sekera and Novák (2021) highlighted the importance of data communication in aviation 4.0, while Lalu et al. (2020) focused on the stress management of air traffic controllers. However, none of these studies specifically addressed the prioritization of AIDC implementation using a systematic approach like AHP across multiple regions. The novelty of this research lies in using AHP to determine the most critical factors for AIDC implementation and how these factors should be prioritized based on AirNav Indonesia's unique operational and infrastructural context.

This study's novelty lies in its application of the AHP method to systematically evaluate and prioritize the implementation of AIDC across AirNav Indonesia's western region. By considering multiple criteria such as infrastructure, workload, and human resources readiness, this study provides a comprehensive decision-making framework that supports strategic planning for the integration of AIDC into AirNav Indonesia's ATS systems.

The objectives of this study are to identify the technical, operational, economic, and organizational criteria that are key determinants for the successful implementation of AIDC in the ATS system. By utilizing the AHP method, the study aims to determine the weight and relative importance of each criterion to better understand which factors are most critical for decision-making. The research will also analyze and rank alternative implementation strategies based on the weighted criteria. Furthermore, strategic recommendations will be provided to AirNav Indonesia regarding the most effective and feasible steps for AIDC implementation, aiming to enhance the overall performance of the ATS system.

This research is expected to provide measurable recommendations to AirNav Indonesia's management in designing the most optimal AIDC implementation strategy. Such recommendations will contribute to more efficient resource allocation, ensuring that AirNav Indonesia maximizes its available assets. Additionally, a well-planned implementation of AIDC is anticipated to directly enhance operational performance by increasing airspace capacity, reducing coordination time, and improving safety standards. Lastly, the findings of this study will serve as a valuable reference and foundation for future research, particularly in analyzing the economic impact of AIDC implementation or evaluating other supporting technologies.

METHOD

Research Phases

The research was systematically designed to ensure a logical flow from the problem identification to the conclusions, reflecting the principles of evidence-based decision-making. The process began with the following steps:

1. Problem Identification: The initial phase focused on mapping the coordination problems in AirNav Indonesia branches that had not yet implemented AIDC (JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang). Through document analysis and interviews with ATC practitioners, Breakdown of Coordination (BOC) was identified as a key issue (ICAO, 2022). The findings led to the formulation of four main research problems: prioritization of criteria, alternative implementation strategies, infrastructure impact, and safety sensitivity.
2. Literature Review: An in-depth literature review was conducted on AIDC theories, ATS system interoperability, multi-criteria assessment methods (particularly AHP), and the application of similar systems in aviation or other transport domains.
3. Data Collection: Data was collected using a quantitative instrument—pairwise comparison questionnaires (scale 1-9) administered to experts (technology managers, systems engineers, and regulators) who provided expert judgment based on their daily fieldwork. Secondary data was gathered from reports and technical documentation related to ATS/AIDC systems.
4. Data Analysis: The data was analyzed using AHP software tools (e.g., Expert Choice or Excel). This included calculating criteria weights, sub-criteria, and alternatives, along with conducting consistency tests (CI, RI, CR). Sensitivity analysis was performed to test the stability of decisions with respect to weight changes. Results were presented in tables showing priority weights and sensitivity matrix graphs illustrating weight change impacts.
5. Conclusion and Recommendations: Based on the results, methodological and practical conclusions were drawn, and implementable recommendations were made for AirNav Indonesia or other stakeholders.

Data Collection, Population, and Sampling

This study collected both primary and secondary data. Primary data was gathered through pairwise comparison questionnaires based on the AHP scale (1-9), distributed to experts or ATC system specialists at each of the study sample locations. These experts provided judgments based on their direct involvement in daily operations. Secondary data was obtained from various reports and documentation available at the research sample locations.

The population for this study consisted of all AirNav Indonesia branches, but the sample was focused on the six branches in the western region that had implemented AIDC infrastructure readiness. These branches were: JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang.

Data Analysis Method

This research employed the Analytical Hierarchy Process (AHP) method for data analysis. The AHP analysis process follows several key steps (Joseph, 1990):

1. Hierarchy Structure Development: A hierarchical structure was built to organize criteria, sub-criteria, and alternatives. Each level of the hierarchy represented a step in the decision-making process, starting with the overall goal and moving down to criteria, sub-criteria, and alternatives.
2. Pairwise Comparison Matrix Construction and Geometric Mean Calculation: For each level (criteria, sub-criteria, alternatives), a pairwise comparison matrix was created where the

elements were compared, and the relative importance was determined. For reciprocal elements (i.e., if element A is compared to element B), the matrix value for A compared to B would be the inverse of the value for B compared to A. The geometric mean was then calculated to determine the priority weights when multiple experts or respondents were involved.

3. Matrix Normalization and Eigenvector Calculation: The pairwise comparison matrix was normalized by dividing each element by the sum of its respective column. The average of each row in the normalized matrix was then computed to obtain the eigenvector priority weights.
4. Consistency Testing (CI, RI, CR): Consistency in the pairwise comparisons was tested using the Consistency Index (CI) and Random Index (RI). The Consistency Ratio (CR) was then calculated as:

$$CR = \frac{CI}{RI}$$

If CR ≤ 0.10, the consistency was considered acceptable; if CR > 0.10, the comparisons needed revision.

The Consistency Index (CI) is calculated as:

$$CI = \frac{(\lambda_{max} - n)}{(n-1)}$$

where λ_{max} is the maximum eigenvalue of the matrix, and n is the size of the matrix (number of criteria).

5. Priority Synthesis and Sensitivity Analysis: Once the consistency was verified, the results were synthesized to provide a global priority score for each alternative. Sensitivity analysis was conducted to evaluate how the decision outcomes would change if the weights of the criteria were altered.

Expert Judgment and AHP Application

Expert judgment plays a crucial role in the application of AHP, especially in the context of complex decision-making problems like AIDC implementation in ATS systems. As noted by Saaty (1987), AHP is particularly effective for solving problems where decision-making involves multiple criteria and subjective evaluations. In this study, experts from various domains provided insights into factors such as infrastructure readiness, ATC workload, and operational efficiency, which were then incorporated into the AHP model.

This methodological approach ensures that the decision-making process is not only systematic but also informed by the expertise of individuals who are directly involved in the operations of the ATS systems at AirNav Indonesia.

RESULTS AND DISCUSSION

Air Traffic Services (ATS)

Air Traffic Services (ATS) is a comprehensive term used in aviation to describe various services such as Flight Information Services (FIS), Alerting Services, Flight Advisory Services, and Air Traffic Control (ATC) services (ICAO, 2001; Primadi Candra Susanto et al., 2020). These services are provided by Air Traffic Controllers (ATCs) across different units, each with its specific jurisdiction and responsibilities. As the aviation world grows increasingly complex, automation is becoming a key factor in easing the workloads of ATCs. According to Timotic and Netjasov (2022), the future of ATC will involve new, more complex tasks, necessitating the use of automation to enhance efficiency and safety in flight operations.

ICAO Document 9426 (ICAO, 1984) emphasizes the importance of communication systems between ATS units to ensure smooth coordination and minimize human error. ATS systems, especially with full automation, can help alleviate ATC workload while improving operational safety, efficiency, and airspace capacity.

Coordination and Communication in ATC

Coordination and communication are crucial in providing air traffic services. All parties involved in a flight must coordinate and communicate effectively to ensure smooth operations and flight safety. In aviation, coordination refers to processes like obtaining clearances, transferring control of aircraft, and exchanging flight information between ATC units (Skybrary, 2025). Ineffective communication or lack of coordination can lead to severe safety risks, including aviation accidents.

Modern communication tools in ATC include both traditional and automated systems, with the latter increasingly becoming vital. According to ICAO (2001), all communication systems, including AIDC (Air Traffic Services Inter-facility Data Communication), must adhere to standardized protocols for message exchange. AIDC, in particular, facilitates the exchange of flight information automatically between ATS units, ensuring a more efficient and error-free coordination process.

Safety and Traffic Management in Air Traffic Control

Air Traffic Controllers (ATCs) play a critical role in maintaining flight safety. However, ATCs are also prone to errors due to fatigue and stress, which significantly affect their performance (Lalu et al., 2020; Costa, 1996). Stress and fatigue are significant risk factors in aviation, which the Safety Management System (SMS) defined by ICAO (2016) aims to mitigate through effective hazard management.

AIDC systems are crucial in this context, as they help reduce ATC workload by automating data exchanges. Such systems can also play a role in identifying and managing risks in flight operations (Pramono et al., 2024). Furthermore, AIDC can aid in hazard analysis, assist in the development of standard operating procedures (SOPs), and support the investigation of accidents by providing accurate, real-time flight data (ICAO, 2001).

Airspace Capacity and Workload Management

Managing airspace capacity is essential for ensuring safe and efficient air traffic operations. According to the AirNav Indonesia Manual on Airspace Capacity (AirNav Indonesia, 2015), sector capacity is determined through observations of ATC workload and the number of aircraft within a specific sector. This workload includes routine tasks, conflict resolution, and the management of altitude changes. The AirNav document categorizes workload into five levels: overload, heavy load, medium load, light load, and very light load.

Overloading ATCs can lead to errors, especially when the workload exceeds a sustainable level, as indicated in the ICAO guidelines (ICAO, 1984). This overload significantly impacts the capacity of an airspace sector, even if the airspace appears to be free of traffic. AIDC can help alleviate such issues by automating routine tasks and ensuring that ATCs are not overwhelmed, thus improving airspace management and safety.

Procedures for Implementing AIDC in Aviation

The implementation of AIDC in ATS is guided by several international standards and procedures. ICAO (1999) emphasizes that automated data exchange between ATC systems, as facilitated by AIDC, improves communication efficiency, especially in flight coordination and control transfer between ATS units. According to ICAO's guidelines, AIDC messages must adhere to specific data conventions, ensuring that all ATS units can exchange data seamlessly and without errors.

AIDC also introduces several phases in communication, such as the Notification, Coordination, and Transfer of Control phases. These phases involve the exchange of various message types, such as Advance Boundary Information (ABI), Coordination Estimates (EST), and Transfer of Control (TOC) messages, all of which help ensure timely and efficient coordination between ATC units (ICAO, 1999).

The Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a decision-making methodology that helps prioritize alternatives based on various criteria through pairwise comparisons (Saaty, 1987). AHP is widely used in complex decision-making scenarios, such as air traffic management, where multiple factors need to be considered. The method involves creating a hierarchy starting with the overall goal, followed by criteria and sub-criteria, and ending with the alternative solutions to be evaluated.

AHP employs a scale of 1 to 9, known as the Saaty Scale, to quantify preferences in pairwise comparisons. This method ensures consistency and provides a mathematical basis for decision-making, as seen in its application to air traffic system management and AIDC implementation (Saaty, 1987; Joseph, 1990). The results of AHP are validated using consistency checks, ensuring that decision-makers' judgments are internally consistent and reliable.

In the context of AIDC implementation at AirNav Indonesia, AHP helps prioritize key factors such as traffic volume, infrastructure readiness, and ATC workload, providing a structured framework for decision-making. The use of AHP ensures that the most critical elements are prioritized in the deployment of AIDC, thereby enhancing air traffic management efficiency and safety

Hierarchy Structure Development

This study utilized the Analytical Hierarchy Process (AHP) method to analyze data related to the implementation of AIDC (Air Traffic Services Inter-facility Data Communication) in the ATS system across several AirNav Indonesia branches. The primary objective was to identify the key technical, operational, economic, and organizational criteria that influence the successful implementation of AIDC. The identified criteria were: Infrastructure Readiness (C1), ATC Workload (C2), Human Resources Readiness (C3), Number of Connections (C4), and Traffic Volume (C5). These criteria were examined for six selected branches: JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang, as shown in Table 1.

Table 1. Research Data Overview

No	Criteria	JATSC	Medan	Pekanbaru	Pontianak	Palembang	Tanjung Pinang
1	Traffic Volume (avg/year)	378,144	50,448	31,848	22,812	29,328	2,161
2	Number of Connections	13	5	4	3	2	1
3	Human Resources (people)	456	72	37	36	65	55
4	ATC Workload (per	81 (Critical)	29 (High)	15 (Medium)	9 (Light)	20 (Medium)	10 (Light)

	hour)						
5	Infrastructure Readiness (%)	50 %	95%	100 %	85%	100 %	100 %

These criteria were further subdivided into sub-criteria to ensure that each factor was broken down into specific, measurable components. This hierarchical structure enables more accurate data processing and eliminates ambiguity in comparisons, thereby enhancing the reliability of the assessment.

Table 2. Criteria and Sub-Criteria

No	Criteria	Sub-Criteria
1	Traffic Volume	< 25,000; >= 25,000–50,000; >50,000–100,000; >100,000
2	Number of Connections	1-3; 4-6; 7-9; >=10
3	Human Resources	< 30; >= 30–50; >50–70; >70
4	ATC Workload	Light; Medium; High; Critical
5	Infrastructure Readiness	< 50%; >= 50%–70%; > 70%–95%; >95%

From the above explanation and overview, the next step is the development of the hierarchy structure, which provides a clear representation of the criteria, sub-criteria, and alternatives within the AHP model. This hierarchy structure helps in the decision-making process and facilitates understanding of the priorities for AIDC implementation. The hierarchy structure used in this study is illustrated in the following figure:

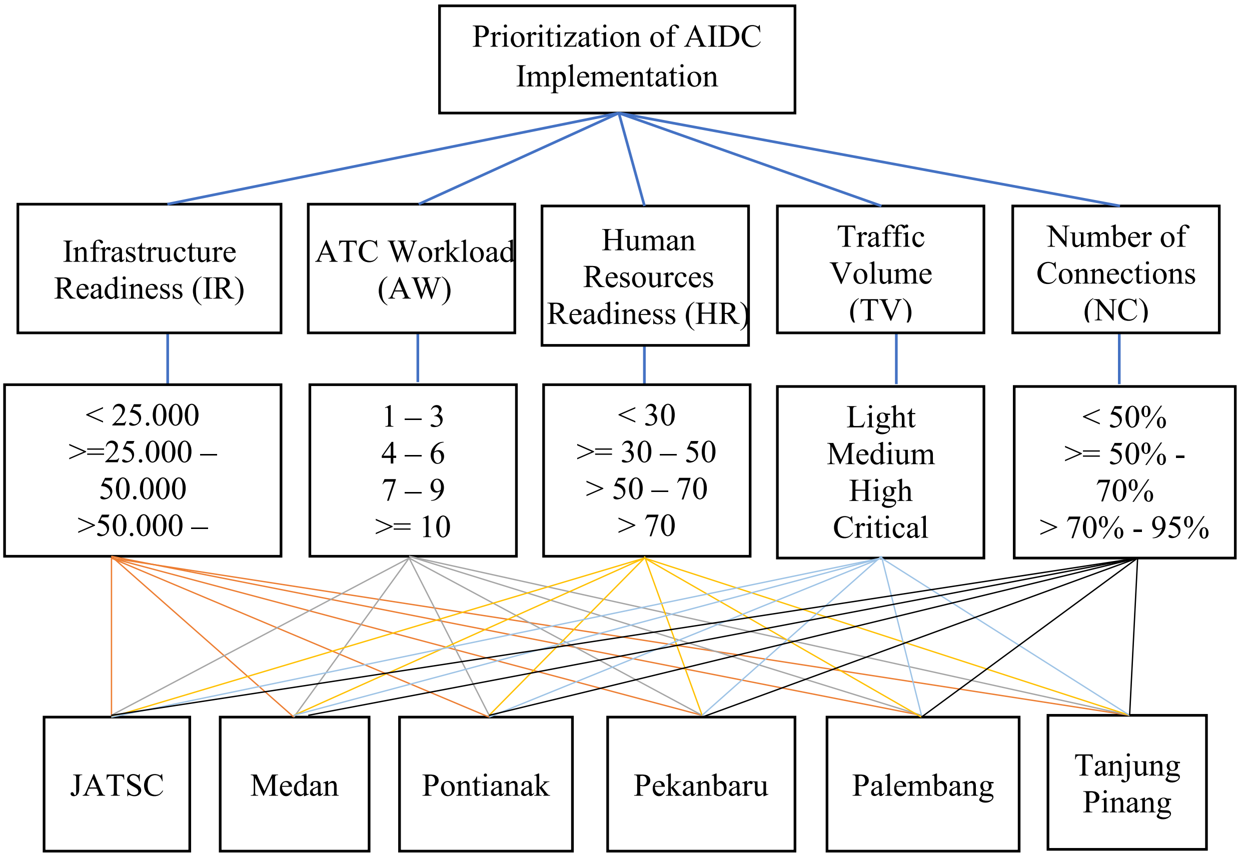

Figure 1. Hierarchy Structure

Data Processing at the Criteria Level

Once the hierarchy structure was established, the next step involved constructing a pairwise comparison matrix for the criteria. This was done by calculating the geometric mean for each pair of criteria based on evaluations from six ATC experts. The data collected through expert assessments for each criterion was processed as follows:

Table 3. Recap of Priority Weight Ratings for Criteria

Pairing Kriteria	Respondent					
	R1	R2	R3	R4	R5	R6
C1 – C2	3	3	2	2	2	2
C1 – C3	2	3	3	3	3	3
C1 – C4	2	5	4	3	3	4
C1 – C5	3	5	5	5	4	5
C2 – C3	2	3	3	2	2	2
C2 – C4	1	4	3	3	4	3
C2 – C5	3	5	4	4	5	4
C3 – C4	2	3	3	3	2	3
C3 – C5	2	4	5	2	3	2
C4 – C5	2	2	3	2	3	2

This table represents the results of pairwise comparisons, where each sub-criterion was rated by six experts. The next step was to calculate the geometric mean for each pair of criteria, using the formula = GEOMEAN (number1, number2, ...) to summarize the relative importance of each pair.

Table 4. Geometric Mean Calculations for Criteria

Pairing Kriteria	Pairing Kriteria	Pairing Kriteria
C1 – C2	=GEOMEAN(3;3;2;2;2;2)	2,289
C1 – C3	=GEOMEAN(2;3;3;3;3;3)	2,804
C1 – C4	=GEOMEAN(2;5;4;3;3;4)	3,360
C1 – C5	=GEOMEAN(3;5;5;5;4;3)	4,424
C2 – C3	=GEOMEAN(2;3;3;2;2;2)	2,289
C2 – C4	=GEOMEAN(1;4;3;3;4;3)	2,749
C2 – C5	=GEOMEAN(3;5;4;4;5;4)	4,107
C3 – C4	=GEOMEAN(2;3;3;3;2;3)	2,621
C3 – C5	=GEOMEAN(2;4;5;2;3;2)	2,798
C4 – C5	=GEOMEAN(2;2;3;2;3;2)	2,289

Next, the results from the geometric mean were used to create the pairwise comparison matrix in fractional form:

Table 5. Pairwise Comparison Matrix in Fractional Form

Kriteria	C1	C2	C3	C4	C5
C1	1	2.289	2.804	3.360	4.424
C2	1/2.289	1	2.289	2.749	4.107
C3	1/2.804	1/2.289	1	2.621	2.798
C4	1/3.360	1/2.749	1/2.621	1	2.289
C5	1/4.424	1/4.107	1/2.789	1/2.289	1

To make the matrix easier to work with, we converted the fractions into decimal form:

Table 6. Pairwise Comparison Matrix in Decimal Form

Kriteria	C1	C2	C3	C4	C5
C1	1	2,289	2,804	3,360	4,424
C2	0,437	1	2,289	2,749	4,107

C3	0,357	0,437	1	2,621	2,798
C4	0,298	0,364	0,382	1	2,289
C5	0,226	0,243	0,357	0,437	1

Next, the matrix was normalized and the priority weights (eigenvector) were calculated for each criterion. The normalization process involved summing each column, dividing each element by the column sum, and calculating the geometric mean (GM) for the normalized matrix. The final eigenvector and priority weights were calculated as follows:

Table 7. Normalized Matrix and Eigenvector Calculation for Criteria

Kriteria	**C1**	**C2**	**C3**	**C4**	**C5**	**Nilai Eigen**	**GM**	**Prioritas w**	**λ_max**
C1	1	2,289	2,804	3,360	4,424	2,003	2,489	0,405	2,096
C2	0,437	1	2,289	2,749	4,107	1,305	1,624	0,264	1,360
C3	0,357	0,437	1	2,621	2,798	0,850	1,027	0,167	0,868
C4	0,298	0,364	0,382	1	2,289	0,523	0,624	0,101	0,525
C5	0,226	0,243	0,357	0,437	1	0,3174	0,386	0,063	0,323
Total	2,317	4,3334	6,8323	10,167	14,619	5	6,150		**5,173**

From the table above, the priority weights for the criteria are as follows (shown in the "Priority Weight (w)" column): Infrastructure Readiness (C1) had the highest priority, with a weight of 40.5%, followed by ATC Workload (C2) at 26.4%, Human Resources Readiness (C3) at 16.7%, Traffic Volume (C4) at 10.1%, and Number of Connections (C5) at 6.3%.

Table 8. Summary of Criteria Priority Weights

Criteria	Priority Weight (%)
Infrastructure Readiness (C1)	40.5%
ATC Workload (C2)	26.4%
Human Resources (C3)	16.7%
Traffic Volume (C4)	10.1%
Number of Connections (C5)	6.3%

This indicates that Infrastructure Readiness (40.5%) is the most dominant factor for successful AIDC implementation, while Number of Connections (6.3%) has the lowest priority weight. This does not imply that the number of connections is not important, but as AIDC is gradually implemented operationally, it is expected to have a lower immediate impact.

This prioritization reveals that infrastructure readiness is the most critical factor in the successful implementation of AIDC, which is consistent with the findings of previous studies on the importance of operational readiness in air traffic management (Pramono et al., 2024; Sekera & Novák, 2021).

The final step is to test the consistency ratio (CR) by dividing the Consistency Index (CI) by the Random Index (RI). A CR value of ≤ 0.10 indicates consistency, meaning the data is accurate. If not, the process needs to be repeated. The formula to calculate CI is:

$$CI = \frac{(\lambda_{max} - n)}{(n - 1)}$$

From the table, we obtain $\lambda_{max} = 5.173$ and $n = 5$, thus:

$$CI = \frac{(5.173 - 5)}{(5 - 1)} = 0.043$$

For $n = 5$, the Random Index (IR) is 1.12, so:

$$CR = \frac{CI}{RI} = \frac{0.043}{1.12} = 0.038$$

Since $CR = 0.038$, which is ≤ 0.10, the results are consistent. The consistency ratio (CR) for this matrix was calculated to be 0.038, which is well below the acceptable threshold of 0.10, indicating that the data and judgments provided were consistent and reliable.

Data Processing at the Sub-Criteria Level

At the sub-criteria level, the process of data analysis closely followed the method applied at the criteria level. For each sub-criterion, a pairwise comparison was conducted by experts, and the geometric mean was calculated for each pair. This helped refine the prioritization process by evaluating the relative importance of each sub-criterion. The evaluation focused on factors such as Infrastructure Readiness, ATC Workload, Human Resources Readiness, Traffic Volume, and Number of Connections.

1. Processing of Sub-Criteria Data from Infrastructure Readiness Criteria.
   The sub-criteria of the infrastructure readiness criteria distributed to respondents contain percentages (%) of readiness conditions at the time of data collection for this study, namely: < 50% (SKI1); 50% - 70% (SKI2); > 70% - 95% (SKI3) and >95% (SKI4). From the results of the AHP method calculation, the sub-criteria results are SKI1 (<50%) = 7.6%; SKI2 (50% - 70%) = 12.7%; SKI3 (> 70% - 95%) = 27.8%; and SKI4 (>95%) = 51.8%. These results can be seen in the "priority w" column of the following table:

Table 9. Matrix Normalization and Eigenvector Calculation Infrastructure Readiness Subcriteria

Sub Kriteria	SKI1	SKI2	SKI33	SKI4	Nilai Eigen	GM	Prioritas w	λ_max
SKI1	1	0,467	0,275	0,189	0,310	0,395	0,076	0,311
SKI2	2,140	1	0,371	0,235	0,517	0,657	0,127	0,515
SKI3	3,634	2,696	1	0,437	1,110	1,438	0,278	1,125
SKI4	5,277	4,263	2,289	1	2,063	2,679	0,518	2,100
Total	12,051	8,426	3,936	1,861	4	5,169		4,051

   The sub-criteria for Infrastructure Readiness, the sub-criterion SKI4 (>95%) emerged with the highest weight of 51.8%, while SKI1 (<50%) had the lowest weight of 7.6%. This highlights the significance of robust infrastructure in ensuring the success of AIDC implementation.

2. Processing of Sub-Criteria Data from ATC Workload Criteria
   Processing of ATC Workload Criteria Sub-criteria Data
   The ATC workload criteria sub-criteria distributed to respondents contain ATC workload categories per sector/hour, namely: LIGHT (WA1); MEDIUM (WA2); HIGH (WA3) and CRITICAL (WA4). The results of the calculations up to the normalization of the matrix and the priority (eigenvector) of the sub-criteria obtained the priority weights of the sub-criteria WA1 (LIGHT) = 5.9%; WA2 (MEDIUM) = 12.7%; WA3 (HIGH) = 28.8%; and WA4 (CRITICAL) = 52.6%.

Table 10. Matrix Normalization and Eigenvector Calculation ATC Workload Subcriteria

Sub Kriteria	WA1	WA2	WA3	WA4	Nilai Eigen	GM	Prioritas w	λ_max

WA1	1	0,382	0,195	0,144	0,239	0,322	0,059	0,239
WA2	2,621	1	0,371	0,235	0,512	0,691	0,127	0,512
WA3	5,137	2,696	1	0,437	1,151	1,568	0,288	1,163
WA4	6,934	4,263	2,289	1	2,098	2,868	0,526	2.135
Total	15,69	8,340	3,855	1,816	4	5,449		4,049

3. Data Processing of Sub-criteria from Human Resource Readiness Criteria
   The sub-criteria of the HR Readiness Criteria distributed to respondents contained the number of ATC HR available at the time of data collection for this study, namely: > 70 (KS1); > 50 - 70 (KS2); ≥ 30 – 50 (KS3) and < 30 (KS4). The calculation results show the priority weight of the sub-criteria in the "priority w" column, namely: (>70) = 51.8%; (> 50 - 70) = 28.7%; (≥ 30 – 50) = 12.6%; and (< 30) = 6.9%.

Table 11. Matrix Normalization and Eigenvector Calculation Sub-criteria for Human Resource Readiness

Sub Kriteria	KS1	KS2	KS3	KS4	Nilai Eigen	GM	Prioritas w	λ_max
KS1	1	2,449	3,873	5,916	0,259	2,737	0,518	2,115
KS2	0,408	1	3	4,309	1,151	1,516	0,287	1,172
KS3	0,258	0,333	1	2,289	0,513	0,666	0,126	0,513
KS4	0,169	0,232	0,437	1	0,276	0,362	0,069	0,278
Total	1,835	4,015	8,310	13,514	4	5,281		4,078

4. Data Processing of Sub-criteria from Traffic Volume Criteria
   The sub-criteria from the Traffic Volume criteria distributed to respondents contain the annual traffic volume at the time of data collection for this study, namely: > 70,000 (JT1); > 50,000 – 70,000 (JT2); <25,000 – 50,000 (JT3) and < 25,000 (JT4). From the calculation results, the priority weight of the sub-criteria in the "priority w" column is obtained, namely: > 70,000 (JT1) = 57.2%; > 50,000 – 70,000 (JT2) = 27.4%; <25,000 – 50,000 (JT3) = 10.5% and < 25,000 (JT4) = 4.9%.

Table 12. Matrix Normalization and Eigenvector Calculation Sub-criteria Traffic Volume

Sub Kriteria	JT1	JT2	JT3	JT4	Nilai Eigen	GM	Prioritas w	λ_max
JT1	1	3	5,593	7,937	2,263	3,397	0,572	2,369
JT2	0,333	1	3,557	5,916	1,099	1,627	0,274	1,127
JT3	0,179	0,281	1	3	0,436	0,623	0,105	0,431
JT4	0,126	0,169	0,333	1	0,203	0,290	0,049	0,202
Total	1,638	4,450	10,484	17,853	4	5,938		4,130

5. Processing of Sub-criteria Data from the Number of Connections Criterion
   The sub-criteria from the Number of Connections criterion distributed to respondents contained the number of existing coordination units at the time of data collection for this study, namely: JK1 (> 10); JK2 (7–9); JK3 (4–6); and JK4 (≤ 3). After calculation, the results of the sub-criteria priority weights in the "priority w" column are as follows: JK1 (> 10) = 47.5%; JK2 (7–9) = 32.9%; JK3 (4–6) = 12.7%; and JK4 (≤ 3) = 6.9%.

Table 13. Matrix Normalization and Eigenvector Calculation Subcriteria Number of Connections

Sub Kriteria	JK1	JK2	JK3	JK4	Nilai Eigen	GM	Prioritas w	λ_max
JK1	1	2,140	3,595	4,847	1,884	2,471	0,475	1,969
JK2	0,467	1	3,557	5,192	1,317	1,714	0,329	1,360
JK3	0,278	0,281	1	2,449	0,519	0,662	0,127	0,520
JK4	0,206	0,193	0,408	1	0,281	0,357	0,069	0,282
Total	1,952	3,614	8,561	13,489	4	5,204		4,131

For consistency testing, all sub-criteria were declared consistent because the CR value was < 0.1, meaning they were acceptable and could proceed to the next calculation stage. A summary of the CR values is shown in the following table:

Table 14. Summary of Sub-Criteria Consistency Test

Sub kriteria	CI	RI	CR	Keterangan
Kesiapan Infrastruktur	0,017	0.90	0.019	Konsisten
Workload ATC	0,016	0.90	0.018	Konsisten
Kesiapan SDM	0,026	0.90	0,029	Konsisten
Jumlah Traffic	0,043	0.90	0.048	Konsisten
Jumlah koneksi	0.044	0.90	0.048	Konsisten

Final Evaluation and Ranking of Alternatives

After calculating the global weights for each sub-criterion, the next step was to evaluate each alternative (AirNav branch) based on the global weights of the criteria and sub-criteria. The final evaluation for each branch resulted in a priority ranking, as shown in Table 9. JATSC emerged as the highest priority for AIDC implementation with a global weight of 36.48%, followed by Medan (31.09%) and Palembang (30.61%).

Table 15. Final Ranking of AirNav Branches

No.	Alternative	Global Weight	Rank
1	JATSC	0.3648	1
2	Medan	0.3109	2
3	Palembang	0.3061	3
4	Pekanbaru	0.2829	4
5	Tanjung Pinang	0.2825	5
6	Pontianak	0.1585	6

This ranking provides valuable insights for AirNav Indonesia to prioritize the AIDC implementation efforts, focusing first on the branches that will benefit the most in terms of infrastructure readiness, workload reduction, and operational efficiency.

Discussion

The results of the AHP analysis indicate that AirNav Indonesia should prioritize implementing AIDC in JATSC, followed by Medan and Palembang. These locations have the highest overall global weights, suggesting that their systems are the most ready for AIDC implementation in terms of infrastructure, traffic volume, and ATC workload. Conversely, Pontianak and Tanjung Pinang, with lower global weights, should be considered for later phases of the AIDC rollout. These findings are consistent with previous studies, which emphasize the need to target areas with higher traffic and workload for the initial phases of technological implementations (Sekera & Novák, 2021; Pramono et al., 2024).

Furthermore, the prioritization of infrastructure readiness aligns with industry standards, where the successful deployment of advanced air traffic management systems like AIDC depends heavily on existing infrastructure (ICAO, 2025). The sensitivity analysis and consistency ratio further validate the robustness of the results, ensuring that the decision-making process is both reliable and systematic

CONCLUSION

The current state of the Air Traffic Services (ATS) inter-facility data communication system in six branches of AirNav Indonesia in the western region (JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang) indicates substantial progress towards the implementation of AIDC (Air Traffic Services Inter-facility Data Communication). This progress is supported by field data related to the preparation of AIDC infrastructure. The study involved experts and specialists in ATS systems, whose insights revealed key factors critical to the success of AIDC implementation. These factors included infrastructure readiness, ATC workload, human resources readiness, traffic volume, and the number of connections.

The consistency ratio (CR) for all criteria was calculated to be ≤ 0.1, indicating that the evaluations made by the respondents were consistent and reliable, allowing the analysis to proceed using the AHP method. The AHP results provided a clear ranking for the priority of AIDC implementation across the six branches. JATSC ranked highest with a weight of 36.48%, followed by Medan (31.09%), Palembang (30.61%), Pekanbaru (28.29%), Tanjung Pinang (28.25%), and Pontianak, which received the lowest priority with a weight of 15.85%.

Recommendations

Based on the findings, it is recommended that AirNav Indonesia continue its efforts to develop the AIDC infrastructure, particularly in branches such as JATSC, Medan, Pekanbaru, Palembang, Pontianak, and Tanjung Pinang. The progress made in infrastructure readiness was identified as the most significant factor for AIDC implementation, and continued investment in infrastructure will ensure smoother and more efficient integration of AIDC across AirNav Indonesia.

Furthermore, the implementation of AIDC should be carried out in phases, considering the available resources and the specific readiness of each branch. A phased approach will allow AirNav Indonesia to gradually integrate the AIDC system, ensuring that each branch is fully prepared before the next phase begins. This approach will also help mitigate any operational risks and ensure a more manageable roll-out of the system.

In addition to infrastructure development and phased implementation, it is critical that ongoing training programs for air traffic controllers and relevant personnel be prioritized. Continuous training and professional development will be vital for ensuring that staff can fully utilize the AIDC system, thus optimizing operational safety and efficiency. Training programs should be aligned with the evolving technology and procedures, ensuring that personnel are equipped with the necessary skills to adapt to new systems and technologies over time. By addressing these recommendations, AirNav Indonesia can ensure the successful and sustainable implementation of AIDC, enhancing the overall performance and safety of its air traffic management system.

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