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The Effect of Undelivered Air Traffic Service Inter-Facility Datalink Communication Messages on Air Traffic Controller Workload

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Abstract:

This study discusses the importance of ATS Inter-facility Data Communication (AIDC) in reducing the workload of Air Traffic Controllers (ATC) at the Approach Control Unit (APP) of Airnav Denpasar Branch. The function of AIDC is to exchange flight data between different ATC systems to facilitate coordination. However, several factors can cause AIDC Message Not Sent issues, such as differences in coordination calculations over points, aircraft performance databases, waypoint and route databases, human adaptation, and the use of serial cables. These failures can lead to increased workload for ATC and decreased efficiency. The research aims to evaluate the implementation of AIDC in APP, determine the workload of ATC, analyze the impact of AIDC optimization on workload, and identify factors causing AIDC failures. This study employs a quantitative method including observation, interviews, and document analysis. Data will be analyzed using statistical techniques such as Pearson Product Moment correlation and linear regression analysis. The findings of this research will provide insights into the effectiveness of AIDC optimization in reducing ATC workload and enhancing air traffic management in the Denpasar area. The analysis concludes that there is a very strong and significant relationship between AIDC Message Not Sent and ATC Workload, with a Pearson Product Moment correlation significance value of 0.971, indicating a very strong correlation. The AIDC Message Not Sent variable influences ATC Workload by 94%.

Keyword: AIDC, Air Traffic Controller, Air Traffic Service, Datalink Communication Messages

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Introduction

Aviation is an integrated system encompassing the utilization of airspace, aircraft, airports, air transportation, air navigation, safety and security, environmental considerations, and other public facilities (Kemendephub, 2009). The Bali Approach Control (APP) provides airspace guidance services to ensure the safety, orderliness, and efficiency of flight traffic within its jurisdiction, as outlined by AirNav Indonesia (AirNav Indonesia, 2019):

1. Preventing collisions between aircraft operating within its area of responsibility.
2. Preventing collisions between departing and arriving aircraft.
3. Ensuring the smooth and orderly flow of flight traffic.
4. Providing essential information for the safety and efficiency of flight operations.
5. Furnishing information to the National Search and Rescue Agency (BNPP) regarding aircraft requiring search and rescue.

The high volume of traffic at I Gusti Ngurah Rai Airport in Denpasar places significant responsibility on Air Traffic Control (ATC) personnel. These professionals, particularly those in Bali's Approach Control (APP) and Terminal Maneuvering Area (TMA), manage both Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) flights. For instance, Bali APP/TMA handles VFR operations such as training flights conducted by the Bali International Flight Academy (BIFA) and tourist flights operated by Fly Bali.

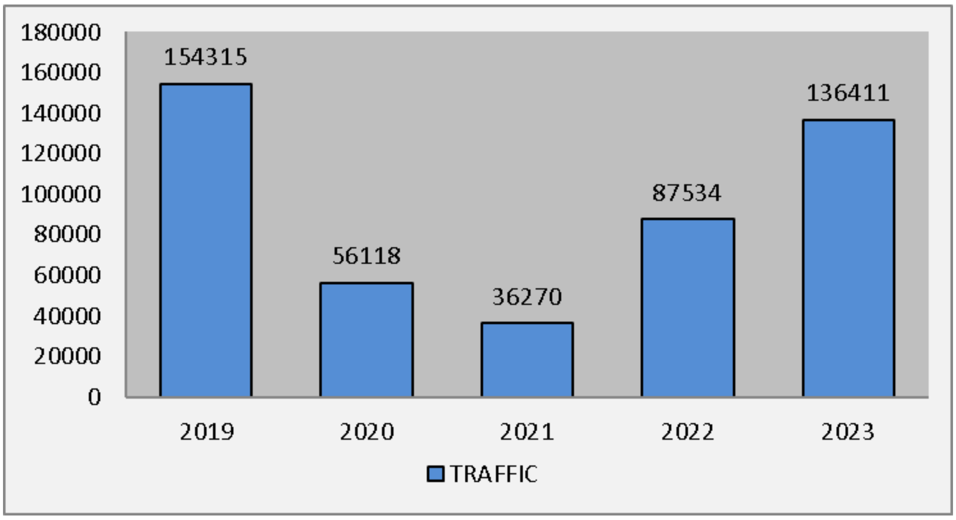


Figure 1. Movement Traffic 2019-2023

The high volume of air traffic directly correlates with increased workload for Air Traffic Controllers (ATC) responsible for guiding aircraft. Maintaining effective coordination is crucial for ATC, particularly during periods of heavy traffic. This heightened workload necessitates greater focus on managing existing traffic, potentially reducing attention to coordination tasks, especially during peak hours. Managing diverse types of traffic further amplifies the workload associated with providing air traffic control services. Key tasks involved in ATC workload include:

1. Coordination tasks
2. Communication tasks
3. Scanning tasks
4. Planning tasks
5. Flight management tasks

As traffic volume increases, the workload related to coordination also escalates, potentially affecting the quality of control services offered. To mitigate workload and optimize air traffic control services, the Bali Approach Control Unit utilizes ATS Inter-facility Data Communication (AIDC). AIDC facilitates the exchange of flight data between different ATC systems using a datalink method (ICAO, 2017). Implementing AIDC significantly reduces the coordination workload for ATC, thereby enhancing control services. A primary function of AIDC is to coordinate between ATS units without relying solely on voice communication.

Despite its benefits, AIDC can experience failures. In such cases, coordination must revert to manual methods using DS telephones, which increases the ATC workload. For instance, in January 2024, the Denpasar ATS Unit sent 5,492 AIDC messages to MATSC, but 1,798 messages were not delivered (32.74%).

Here are some causes of AIDC failures:

1. Differences in Coordination Over Point Calculation Systems: AIDC relies on Coordination Over Point (COP), an estimated coordinate point where aircraft pass FL245. Bali APP/TMA uses the "Tern System," while Ujung Control ACC uses the "Topsky System," resulting in different COP calculations. If the COP calculation from Bali APP/TMA differs significantly from Ujung Control ACC's tolerance area, AIDC fails.
2. Differences in Aircraft Performance Database: Variances in aircraft performance databases between ATS Units can lead to AIDC failures.
3. Differences in Waypoints and Route Database: Flight plans include routes and waypoints aircraft use to reach destinations. If new route or waypoint names are not registered in the ATC system's Waypoint & Route Database, AIDC may fail.
4. Human Adaptation: Deviations from standard operating procedures (SOP) for AIDC increase the risk of failure.
5. Use of Serial Cable: AFTN at Bali APP/TMA employs a serial cable, which has slower flight message transmission speeds. High message queues due to heavy traffic can overwhelm the ATC system in Ujung Pandang, exceeding its message reception limit and causing AIDC message failures.

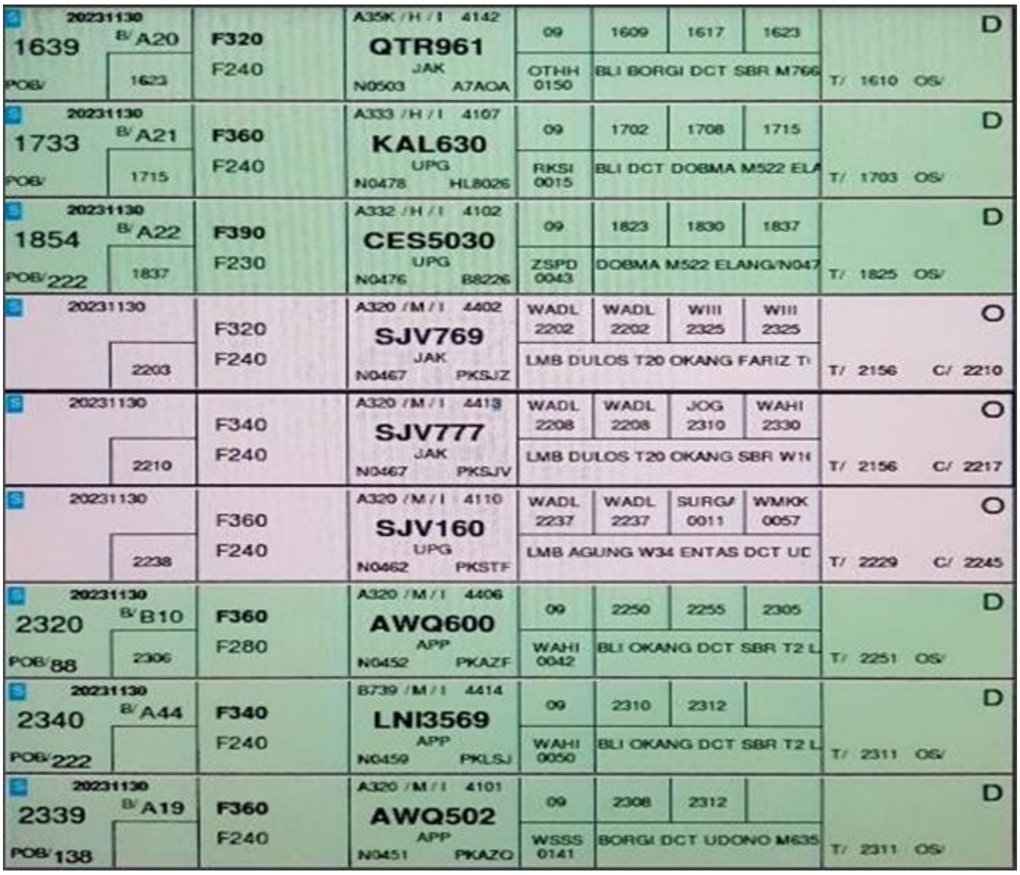


Figure 2. AIDC Messages Undelivered

AIDC is a system used by ATC to coordinate with adjacent units via datalink, eliminating the need for voice communication and enabling highly effective and efficient coordination. Emphasizing a higher level of automation to support air traffic controllers' workload and alleviate stress is crucial for a resilient ATM (Air Traffic Management) system (SESAR, 2020). The implementation of AIDC aims to diminish ATC workload associated with coordination tasks, thereby improving overall ATC performance in delivering air traffic control services.

Table 1. State of The Art

NO	RESEARCH TITLE	AUTHOR & YEAR OF RESEARCH	FINDING
1.	The AIDC Messaging Between Bali APP/ TMA, Surabaya APP/ TMA & Ujung Pandang ACC	(ICAO, 2017)	This paper presents the experience of AIDC messaging between APP/TMA units and ACC units. Typically, AIDC messaging is implemented between FIRs. Indonesia uses AIDC messaging to reduce workload and improve coordination quality between APP/TMA and ACC units.
2.	Impact of AIDC on trajectory-based operations in air traffic management. International Journal of Aviation Systems	(Lee & Kim, 2019)	Trajectory-Based Operations (TBO) greatly benefit from the implementation of AIDC, as it allows for real-time updates and 4D trajectory coordination across various ATC units. This ensures that aircraft follow optimized flight paths, reducing fuel consumption and delays. Research shows that the use of AIDC in TBO improves the predictability and efficiency of flight operations, leading to more sustainable air traffic management.
3.	Training programs for the integration of AIDC in ATC operations. Aviation Education and Training	(Gonzalez & Fernandez, 2019)	The introduction of AIDC (Automatic Identification and Data Capture) requires adequate training for ATC (Air Traffic Control) personnel to ensure they are proficient in using the new system. Adaptive training programs that simulate real-world scenarios help controllers become accustomed to AIDC operations and develop the necessary skills. Studies show that comprehensive training programs are essential to maximize the benefits of AIDC and ensure smooth integration into existing ATC workflows.
4.	Data link communication systems in air traffic control. FAA Technical Report.	(FAA, 2019)	Data link communication systems, such as Controller-Pilot Data Link Communications (CPDLC) and ATS Interfacility Data Communication (AIDC), facilitate efficient and reliable information exchange between controllers and adjacent units. These systems reduce the need for voice communication, thereby decreasing communication workload and minimizing errors.
5.	Measuring workload in air traffic control: A review. Journal of Air Traffic Management	(Wickens et al, 2019)	Several methods are used to measure ATC workload, including subjective assessments (e.g., NASA-TLX), physiological measurements (e.g., heart rate variability), and objective metrics (e.g., number of aircraft managed, communication frequency). Recent advancements have integrated these methods to provide a comprehensive understanding of workload dynamics.
6.	Enhancing coordination efficiency in air traffic control. Eurocontrol Report Series.	(Eurocontrol, 2020)	Several challenges can increase ATC workload during coordination with adjacent units, including communication delays, inconsistent information, and varying procedures between units. These challenges can lead to increased cognitive load, potential errors, and reduced efficiency. Research has shown that standardized procedures and enhanced communication technologies can mitigate these challenges..
7.	Real-time information sharing in collaborative decision making with AIDC. Journal of Aerospace Operations	(Johnson et al, 2020)	Collaborative Decision Making (CDM) is enhanced by AIDC through real-time information sharing among ATC units, airlines, and other stakeholders. AIDC enables the automatic exchange of flight data, weather information, and traffic flow updates, facilitating informed decision-making. The implementation of AIDC in CDM has been shown to improve flight schedule coordination and rerouting decisions during disruptions.
8.	Enhancements in AIDC for efficient air traffic	(Zhang & Wang, 2020)	AIDC supports various functions, including control message transfer, flight plan coordination, and surveillance data

NO	RESEARCH TITLE	AUTHOR & YEAR OF RESEARCH	FINDING
	management. Journal of Air Traffic Control		exchange. These functions are essential for maintaining situational awareness and ensuring smooth transitions between different ATC sectors. Recent advancements in AIDC systems have improved the accuracy and timeliness of data exchange, contributing to more efficient air traffic management.
9.	Machine learning-based conflict detection and resolution using AIDC. Aviation Technology and Innovation.	(Smith et al, 2021)	Automated conflict detection and resolution (CDR) using AIDC involves continuous monitoring of aircraft trajectories and the exchange of relevant data between ATC units. Modern CDR algorithms integrated with AIDC systems utilize machine learning techniques to predict potential conflicts and propose resolution strategies. Research has shown that integrating AIDC with advanced CDR algorithms significantly reduces the likelihood of mid-air collisions and enhances overall airspace safety..
10.	Human-machine interface design for AIDC systems. Journal of Ergonomics and Human Factors.	(Chen & Li, 2021)	Effective human-automation interaction is crucial for the successful deployment of AIDC. Designing intuitive human-machine interfaces (HMI) that facilitate easy interpretation of AIDC messages is essential. Advances in HMI design focus on providing controllers with clear and concise information, reducing cognitive load and enhancing situational awareness. Research on HMI for AIDC systems has demonstrated improved controller performance and reduced error rates.
11.	Global harmonization of air traffic management procedures. ICAO Technical Bulletin.	(ICAO, 2021)	The future of ATC workload management involves integrating advanced technologies such as artificial intelligence (AI) and machine learning (ML) to predict and mitigate workload spikes. Research is also focused on developing more sophisticated human-machine interfaces (HMI) that adapt to controller needs and enhance situational awareness. Additionally, the implementation of standardized global procedures will play a key role in reducing workload associated with coordination between adjacent units.

Research has demonstrated that the implementation of Automatic Identification and Data Capture (AIDC) systems provides numerous significant benefits in air traffic management. Originally designed to reduce workload and enhance coordination between Air Traffic Control (ATC) units, AIDC messages have been shown to improve flight operation efficiency, reduce fuel consumption, and minimize delays through Trajectory-Based Operations (TBO).

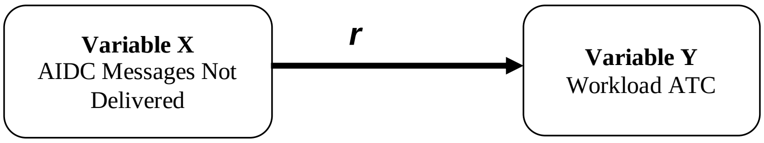
The integration of AIDC systems necessitates adaptive training programs to ensure that ATC personnel achieve adequate proficiency. Data link communications, such as Controller-Pilot Data Link Communications (CPDLC) and AIDC, minimize the reliance on voice communication, thereby reducing errors and enhancing coordination efficiency. The application of AIDC in Collaborative Decision Making (CDM) processes enhances real-time information sharing, leading to better decision-making during flight disruptions.

Furthermore, research underscores the importance of intuitive human-machine interface (HMI) design in reducing controllers' cognitive load and improving performance. Advancements in machine learning algorithms for conflict detection and resolution, along with the harmonization of global procedures, further bolster the contributions of AIDC to enhanced safety and efficiency in air traffic management.

Method

The research methodology used in this study is the Quantitative Method, which addresses research problems through numerical data and statistical analysis. In quantitative research, data collection tools are developed based on research variables derived from the theory being tested (Pillers Dobler, 2018). This study examines two primary variables: the Independent Variable and the Dependent Variable. They are defined as follows:

1. Independent Variable: This variable influences or causes changes in the dependent variable (Pace, 2021). In this study, the independent variable is Unsent AIDC Messages, represented by the symbol X.
2. Dependent Variable: This variable is influenced by or is a result of changes in the independent variable (Hossan et al., 2023). In this study, the dependent variable is the ATC Workload at the Approach Control Unit (APP) AirNav Denpasar Branch, represented by the symbol Y.



r = relationship between Variable X and Variable Y

Figure 3. Research Paradigm

Data collection in this study was carried out using several techniques:

1. Observation
   According to Lo et al (Lo et al., 2020), observation involves using human senses to gather information about the surrounding world. In this study, structured observation was used to observe and calculate the ATC workload according to the KP 265 formula of 2017.
2. Interview
   Chamberlain explains that an interview is a data collection technique involving questions posed by the researcher to respondents to gain an in-depth understanding of a topic (LaMarre & Chamberlain, 2022). In this study, interviews were conducted to explore the factors causing unsent AIDC messages and to identify solutions for optimizing AIDC.
3. Documentation Study
   Leavy describes a documentation study as a research method that uses documents as primary, secondary, or tertiary data sources (Blanchflower, 2018). The study included an examination of Standard Operating Procedures (SOP), Aeronautical Information Publications (AIP), AIDC message logs, and aircraft movement data to obtain information related to the research objectives. Additionally, local documents and previous research papers on the role of AIDC in reducing ATC workload at AirNav Denpasar Branch were reviewed.

ATS Inter-facility Data Communications (AIDC) is a data link application that facilitates the exchange of data between air traffic services units during the notification, coordination, and transfer of aircraft between flight information regions. It is an automated system that enables routine coordination by providing reliable and timely data exchange between ATS units, allowing for accurate information to be obtained directly from the system. This reduces the controller's workload and minimizes human error (ICAO, 2017).

Document 9806 Annex 1 Chapter 2 point 42 explains that workload relates to the amount of work expected from an individual (ICAO, 2002). Air traffic controller workload is defined as the time spent completing all tasks within a specific time interval (Bauer & Langr, 2017). According to the AirNav Indonesia Manual on Airspace Capacity Calculation, workload is the time required by an ATC officer to complete all tasks within a certain period, usually measured in minutes. The methods for measuring ATC workload, as outlined in the AirNav Indonesia Manual on Airspace Capacity Calculation (Airnav Indonesia, 2015), include the following: observation. interviews, and documentation study

$$\mathbf{WL = tC1*Oc1+tF1*OF1+tCnf*Cnf}$$

Explanation:
WL: Workload
OF1: Occurrence of Routine Task
OCnf: Occurrence of Climb/Descent Task
OC1: Occurrence of Conflict Task
tF1: Duration of Routine Task
tCnf: Duration of Climb/Descent Task
tC1: Duration of Conflict Task

Routine tasks are regular ATC activities, including communication with aircraft, coordination with adjacent units or assistants/planners, and manual activities such as moving flight progress strips, etc.

Climb/Descent tasks involve ATC activities such as issuing climb or descent instructions.

Conflict tasks consist of ATC activities like providing traffic information and issuing instructions to avoid conflicts.

Results and discussions

Based on the observations, the highest recorded traffic was 31 aircraft, with a corresponding workload of 53.4 minutes. The lowest recorded traffic was 24 aircraft, with a workload of 33.3 minutes. Additionally, the average workload from these observations falls into the Overload category.

Table 2. Workload Data Recapitulation for January 2024

NO	ATC	DATE	TIME	TRAFFIC	WORKLOAD ACTUAL	CATEGORY
1	WA	01/01/2024	04.00-05.00	31	53.48	Overload
2	SL	02/01/2024	04.00-05.00	29	48.43	Overload
3	IF	03/01/2024	04.00-05.00	31	49.03	Overload
4	NS	04/01/2024	04.00-05.00	25	35.6	Heavy Load
5	ME	05/01/2024	04.00-05.00	29	46.95	Overload
6	RD	06/01/2024	04.00-05.00	30	48.41	Overload
7	OV	07/01/2024	04.00-05.00	31	49.45	Overload
8	AS	08/01/2024	04.00-05.00	31	48.61	Overload
9	MF	09/01/2024	04.00-05.00	28	45.81	Overload
10	SC	10/01/2024	04.00-05.00	31	48.36	Overload
11	AI	11/01/2024	04.00-05.00	33	52.05	Overload
12	NA	12/01/2024	04.00-05.00	28	42.8	Overload
13	RY	13/01/2024	04.00-05.00	27	38.56	Heavy Load

14	PD	14/01/2024	04.00-05.00	28	48.33	Overload
15	IM	15/01/2024	04.00-05.00	29	46.45	Overload
16	KT	16/01/2024	04.00-05.00	28	42.18	Overload
17	EL	17/01/2024	04.00-05.00	29	47.11	Overload
18	KA	18/01/2024	04.00-05.00	24	33.3	Heavy Load
19	RP	19/01/2024	04.00-05.00	25	34.08	Heavy Load
20	PA	20/01/2024	04.00-05.00	26	36.31	Heavy Load
21	BJ	21/01/2024	04.00-05.00	26	37.2	Heavy Load
22	NW	22/01/2024	04.00-05.00	25	33.81	Heavy Load
23	A	23/01/2024	04.00-05.00	28	42.38	Overload
24	HS	24/01/2024	04.00-05.00	28	43.81	Overload
25	DA	25/01/2024	04.00-05.00	28	41.8	Heavy Load
26	HE	26/01/2024	04.00-05.00	28	40.98	Heavy Load
27	FA	27/01/2024	04.00-05.00	25	32.43	Heavy Load
28	CO	28/01/2024	04.00-05.00	29	38.75	Heavy Load
29	AW	29/01/2024	04.00-05.00	28	39.16	Heavy Load
30	PS	30/01/2024	04.00-05.00	26	36.86	Heavy Load
31	KS	31/01/2024	04.00-05.00	23	33.55	Heavy Load

The term optimization implies that all AIDC messages were successfully sent during the previous actual workload data collection period. AIDC Optimization data is obtained by subtracting the time associated with unsent AIDC messages from the actual workload data. The data indicates that if all AIDC messages are sent, there is a significant reduction in workload. Specifically, the average actual workload, initially categorized as Overload, decreases to the Heavy Load category. The distribution shifts to 16 instances of Heavy Load, 1 instance of Overload, and 3 instances of Medium Load.

Table 3. AIDC Optimal Workload Data Recapitulation for January 2024

NO	WORKLOAD ACTUAL	AIDC UNDELIVERED		WORKLOAD AIDC OPTIMAL	CATEGORY
		OCCURRENCE	TIME		
1	**53.48**	4	160	**50.81**	Overload
2	**48.43**	2	80	**47.09**	Overload
3	**49.03**	8	320	**43.69**	Overload
4	**35.6**	4	160	**32.93**	Heavy Load
5	**46.95**	7	280	**42.28**	Overload
6	**48.41**	6	240	**44.41**	Overload
7	**49.45**	2	80	**48.11**	Overload
8	**48.61**	6	240	**44.61**	Overload
9	**45.81**	4	160	**43.14**	Overload
10	**48.36**	11	440	**41.02**	Heavy Load
11	**52.05**	7	280	**47.38**	Overload
12	**42.8**	5	200	**39.46**	Heavy Load
13	**38.56**	4	160	**35.89**	Heavy Load
14	**48.33**	5	200	**44.99**	Overload
15	**46.45**	8	320	**41.11**	Heavy Load
16	**42.18**	8	320	**36.83**	Heavy Load
17	**47.11**	5	200	**43.77**	Overload
18	**33.3**	5	200	**29.96**	Medium Load
19	**34.08**	1	40	**33.41**	Heavy Load
20	**36.31**	3	120	**34.31**	Heavy Load
21	**37.2**	6	240	**33.2**	Heavy Load
22	**33.81**	4	160	**31.14**	Medium Load
23	**42.38**	4	160	**39.71**	Heavy Load
24	**43.81**	7	280	**39.14**	Heavy Load
25	**41.8**	7	280	**37.13**	Heavy Load
26	**40.98**	3	120	**38.98**	Heavy Load
27	**32.43**	7	280	**27.76**	Medium Load

28	**38.75**	9	360	**32.75**	Heavy Load
29	**39.16**	6	240	**35.16**	Heavy Load
30	**36.86**	8	320	**31.52**	Medium Load
31	**33.55**	6	240	**29.55**	Medium Load

1. Normality Test

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
PESAN AIDC TIDAK TERKIRIM	.097	31	.200*	.972	31	.567
WORKLOAD ATC	.128	31	.200*	.942	31	.091

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 4. Normality Test Results

Based on the results of the Shapiro-Wilk normality test, it can be concluded that the data for both the UNSENT AIDC MESSAGE variable (statistic value of 0.972 and significance value of 0.567) and the ATC WORKLOAD variable (statistic value of 0.942 and significance value of 0.091) are normally distributed, as the significance values are greater than 0.05.

2. Correlation Test

Correlations

		PESAN AIDC TIDAK TERKIRIM	WORKLOAD ATC
PESAN AIDC TIDAK TERKIRIM	Pearson Correlation	1	.971**
	Sig. (2-tailed)		.000
	N	31	31
WORKLOAD ATC	Pearson Correlation	.971**	1
	Sig. (2-tailed)	.000	
	N	31	31

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 5. Pearson Product Moment Correlation Test Results

Based on the results of the Pearson Product Moment correlation test, it can be concluded that there is a very strong and significant relationship between the UNSENT AIDC MESSAGE variable and the ATC WORKLOAD variable. The correlation value is 0.971 with a significance value of 0.000, indicating that an increase in one variable tends to be followed by a significant increase in the other variable.

3. Simple Linear Regression Test

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.971[a]	.942	.940	1.51551

a. Predictors: (Constant), PESAN AIDC TIDAK TERKIRIM

Figure 6. Simple Linear Regression Test Results

Based on the results of the simple linear regression test, it can be concluded that the model shows a very strong and significant relationship between the independent variable (UNSENT AIDC MESSAGE) and the dependent variable (ATC WORKLOAD). The R value is 0.971, and the R Square value is 0.942, explaining 94.2% of the variation in the dependent variable. The Adjusted R Square value is 0.940, indicating that this model is reliable for prediction with relatively small deviation.

Conclusion

The analysis reveals a very strong and significant relationship between Unsent AIDC Messages and ATC Workload. The Pearson Product Moment correlation test shows a correlation value of 0.971, indicating a very strong relationship. The simple linear regression analysis further supports this, with Unsent AIDC Messages accounting for 94% of the variation in ATC Workload, as evidenced by an R Square value of 0.942 and an Adjusted R Square value of 0.940.

Based on these findings, it is clear that AIDC optimization is closely linked to ATC workload. An increase in unsent AIDC messages significantly raises ATC workload. Therefore, to effectively manage air traffic controller workload, it is crucial to focus on optimizing AIDC messages.

Recommended Actions:

1. Improve AIDC Efficiency: Adopt advanced technologies and methods to enhance AIDC optimization, thereby managing ATC workload more effectively.
2. Training and Development: Provide ongoing training for ATC personnel on the latest AIDC technologies to improve their effectiveness and efficiency.
3. Continuous Monitoring: Regularly monitor the relationship between AIDC and ATC workload to ensure that improvements in AIDC optimization continue to have a positive impact.
4. Policy Development: Develop and implement policies that support AIDC optimization as a key component of ATC workload management strategies.

By implementing these steps, it is possible to achieve better management of ATC workload, leading to enhanced performance and operational efficiency in air traffic management.

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