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Design of a Remote Tower Pilot Project to Achieve Operational Excellence at Airnav Indonesia

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Abstract

The digital transformation of air navigation services has become increasingly important for improving operational efficiency, service continuity, and resource optimization, particularly in geographically dispersed areas. AirNav Indonesia faces several challenges in conventional tower operations, including high infrastructure investment, limited operational flexibility, uneven human resource distribution, security risks, and geographical constraints in Papua and Frontier, Outermost, and Disadvantaged (3T) regions. This study aims to design a Remote Digital Tower Pilot Project as an alternative air navigation service model to support Operational Excellence at AirNav Indonesia. The study employed an exploratory sequential mixed-methods approach integrating qualitative and quantitative analyses. Qualitative data were obtained through focus group discussions and brainstorming, while quantitative data included flight traffic, operational, security disturbance, personnel mutation, and project planning data. The findings indicate that Very Density Aerodrome airports are the most appropriate priority for initial implementation due to their relatively low traffic complexity and continuing requirement for Aerodrome Flight Information Services. The proposed design integrates digital camera technology, video processing, satellite-based communication networks, system architecture, and project management techniques, including the Work Breakdown Structure, Critical Path Method, schedule crashing, and Gantt Chart. Testing based on the EUROCAE ED-240A standard indicates that the proposed system meets operational requirements. The study concludes that the Remote Digital Tower Pilot Project provides a feasible framework for improving operational efficiency, resource flexibility, and sustainable digital transformation within AirNav Indonesia.

INTRODUCTION

Air navigation services have a strategic role in ensuring the safety, order, and efficiency of air traffic. As the sole provider of air navigation services in Indonesia, AirNav Indonesia is responsible for managing 7.79 million km² of national airspace covering two *Flight Information Regions* (FIRs), namely FIR Jakarta and FIR Ujung Pandang, as well as serving more than 298 airports with diverse operational characteristics. However, the implementation of air navigation services still faces challenges, especially at airports with low to medium traffic levels and Frontier, Outermost, and Disadvantaged (3T) areas. The conventional watchtower operational model leads to high infrastructure investment requirements, limited service flexibility, and challenges in the distribution of human resources due to geographical conditions, accessibility, and operational risks in certain areas (Imam, 2025; Lazarus, 2025; Sridharan, 2025; Zubkov & Aliyev, 2025).

The development of the global aviation industry encourages air *navigation service providers (ANSP*) to carry out digital transformation to improve efficiency, capacity, and quality of service (Bekier, 2023; Belkhoumani & Hakmaoui, 2026; Efthymiou, 2023; Nkabinde, 2024; Szczypiński, 2025; Tuncal, 2025). Various technologies such as *Artificial Intelligence (AI), Big Data Analytics*, *Digital Air Traffic Management*, and *Remote Digital Towers* are starting to be implemented as solutions to deal with increasing operational complexity. The *Remote Digital Tower* concept allows air traffic services to be carried out from a centralized location through the use of high-resolution digital cameras, communication networks, *real-time* data processing systems, and other supporting technologies so that it can increase operational flexibility without reducing flight safety aspects.

In Indonesia, the need for digital transformation is increasingly relevant given the broad national geographical characteristics and operational challenges in the Papua region and the 3T region (Edyanto et al., 2026; Husaini et al., 2026; Ibo et al., 2025; Lito et al., 2025; Mussanadah & Saputra, 2026). Problems in the form of operational security disturbances, imbalances in the distribution of human resources, limited access to infrastructure, and high cost of building monitoring towers show that conventional service models are not fully optimal in supporting *Operational Excellence*. This condition shows the need for alternative service models that are more adaptive, efficient, and based on digital technology (Khuntia et al., 2024; Li et al., 2022; Lito et al., 2025; Stanelyte et al., 2022; Wirtz et al., 2023).

Previous empirical research provides important evidence regarding the technical and human-performance feasibility of Remote Digital Tower operations. Papenfuss et al. (2010), using high-fidelity simulation involving tower controllers, found that a remote tower workplace using high-resolution panoramic video could provide an operationally valid working environment for smaller airports and that augmented information could reduce controllers' reliance on separate radar displays. Kearney and colleagues subsequently investigated multiple remote tower operations through approximately 50 large-scale demonstration trials ranging from single-airport operations to multiple-airport scenarios, contributing evidence regarding the feasibility of centralized remote service concepts. Heintz and Eißfeldt (2022) examined controllers operating Saarbrücken Airport remotely from the DFS Remote Tower Centre in Leipzig and concluded that remote tower operations did not fundamentally alter most mental and social ability requirements compared with traditional tower operations, although sensory requirements associated with direct visual observation naturally changed. These findings collectively demonstrate that remote tower technology has developed beyond conceptual experimentation and has become an operationally plausible alternative for selected aerodrome environments (Horváth, 2024; Khalid et al., 2024; Komiienko et al., 2024).

A substantial research gap therefore remains concerning how Remote Digital Tower technology should be translated from a technically feasible concept into a structured pilot project within the distinctive institutional and operational environment of Indonesia. Existing studies provide strong evidence concerning technical feasibility, situational awareness, controller workload, visual interfaces, and multiple-airport operations, while European and Canadian programs demonstrate increasingly mature practical implementation. However, these findings cannot automatically be transferred to AirNav Indonesia because Indonesia faces a distinctive combination of dispersed islands, remote and 3T airport locations, telecommunications constraints, personnel-distribution difficulties, different airport traffic classifications, security exposure, and substantial conventional infrastructure requirements. The manuscript itself identifies that Indonesian research addressing Remote Digital Tower implementation while simultaneously considering operational characteristics, organizational needs, geographical constraints, and project-management requirements remains limited. Consequently, the important gap is not simply whether Remote Digital Towers can function safely, but how a feasible, staged, measurable, and replicable implementation model can be designed for AirNav Indonesia under actual organizational constraints.

Addressing this gap is urgent because postponing operational transformation may perpetuate inefficient capital allocation, uneven human-resource deployment, security exposure, and dependence on airport-specific physical infrastructure, particularly at low-traffic service locations. At the same time, technological adoption without systematic implementation planning may introduce new risks associated with communication reliability, latency, system integration, cybersecurity, redundancy, controller adaptation, and operational continuity. EUROCONTROL notes that digital towers depend heavily on reliable real-time data, network robustness, backup systems, integration among sensors and communication technologies, and appropriate management of human and cybersecurity factors. International standardization is similarly important; EUROCONTROL identifies the EUROCAE ED-240 family as a major performance framework for Remote Tower Optical Systems intended to facilitate safety, efficiency, and interoperability. Accordingly, AirNav Indonesia requires more than technology procurement. It requires an implementation framework capable of connecting operational requirements, technology selection, network architecture, personnel arrangements, safety requirements, testing, scheduling, investment considerations, and project-management controls into a coherent pilot project.

Against this background, the novelty of the present research lies in designing an integrated Remote Digital Tower Pilot Project specifically adapted to AirNav Indonesia by linking digital air-navigation transformation with operational-excellence objectives and structured project-management methods. Rather than evaluating only controller performance or individual technological components, this research integrates analysis of traffic movement, security disturbances, human-resource distribution, infrastructure investment, communication-network requirements, system architecture, and implementation scheduling within a single project-design framework. The study selects AirNav Indonesia Yogyakarta Branch as a proof-of-concept environment because its accessibility and infrastructure facilitate device installation, testing, and validation, while the resulting model is intended for subsequent adaptation to more geographically challenging environments such as Papua and 3T regions. The model also considers satellite-based connectivity as an alternative communication solution for locations with limited terrestrial network infrastructure.

Therefore, this research aims to design and evaluate a Remote Digital Tower Pilot Project that can support Operational Excellence at AirNav Indonesia through a service architecture that is technologically feasible, operationally safe, resource-efficient, and suitable for staged implementation. More specifically, the research seeks to identify key limitations within the existing conventional tower service model; determine appropriate airport characteristics and priorities for Remote Digital Tower implementation; formulate the required system architecture, communication network, technology, operational mechanisms, and project implementation stages; and establish an implementation plan using systematic project-management techniques. The expected academic contribution is to extend Remote Digital Tower literature beyond technology and human-factor evaluation by integrating digital transformation, air-navigation operations, organizational constraints, and project management within an emerging-economy and archipelagic context.

METHOD

Research Approach

This study used a mixed-methods approach, which is a combination of qualitative and quantitative approaches, to obtain a comprehensive understanding of tower service operational problems and design a model for the implementation of the Remote Digital Tower pilot project at AirNav Indonesia.

The qualitative approach is used to explore in depth the existing operational conditions of air navigation services, especially related to conventional tower management, human resource utilization, and infrastructure readiness. Qualitative data was obtained through the FGD (*focus group discussion*) method, as well as brainstorming activities with related parties to identify the root of the problem and the need for system development.

Meanwhile, a quantitative approach is used to support analysis through numerical data processing, such as flight traffic data, service operational data, security disturbance data and mutation requests in the Papua and 3T regions and *project planning* data. This quantitative analysis is used to measure operational efficiency levels, identify service performance patterns, and support project implementation planning through scheduling and optimization approaches.

The mixed-methods design used in this study is exploratory sequential (qual

→ when)**,** where a qualitative analysis is carried out first to identify the main problems and relevant variables, then followed by a quantitative analysis to strengthen and validate the findings.

The choice of a mixed-methods approach is based on the need for research that not only aims to understand the phenomenon in depth, but also to produce measurable and implementable solutions. With this approach, the research is expected to be able to produce outputs in the form of an application pilot project implementation design for the Remote Digital Tower pilot project that is applicable, data-based, and supports improving the operational efficiency of air navigation services at AirNav Indonesia.

Research Design, Object/Subject

This study used a case study design with a mixed-methods approach to analyze tower service operational problems and design a model for the implementation of the Remote Digital Tower pilot project at AirNav Indonesia. The case study approach was chosen because the research is focused on the real conditions of organizations with complex and specific operational characteristics.

Research Location and Time

This research was carried out at AirNav Indonesia Yogyakarta Branch, especially in the Air Traffic Control Tower service unit which serves air traffic operations in the Yogyakarta International Airport area.

The selection of research locations is not only based on the ease of access to research, but also considers aspects of implementation and technology development. This location has relatively adequate infrastructure support that allows the implementation of tests and simulations of the implementation of the Remote Digital Tower system more effectively, including in terms of device mobilization, installation, and system testing.

In addition, the ease of distribution and delivery of equipment is a supporting factor in the implementation of the pilot project, so that the implementation process can be carried out more efficiently and controlled.

Although the research was carried out in Yogyakarta, the implementation model designed in this study is aimed at being applicable to areas with limited infrastructure, such as the Papua region and 3T (Disadvantaged, Frontier, and Outermost) areas. In this context, this study also considers the use of satellite-based communication technology, namely Starlink, as an alternative solution to support data connectivity in the implementation of Remote Digital Towers in areas with limited terrestrial networks.

Thus, the research location in Yogyakarta functions as a test environment that supports the model design and validation process, while the research results are expected to be adapted for implementation in operational areas with more complex geographical challenges.

The research implementation time was carried out in the period November 2025 to July 2026 which included the stages of data collection, analysis, and design of the Remote Digital Tower implementation model.

Population and Sample

In a qualitative approach, this study uses key informants who are purposively selected based on experience and direct involvement in air navigation service operations.

Meanwhile, in the quantitative approach, the data used comes from operational data and historical data of the company, such as flight traffic data, tower operational data, and project planning data, so it does not use a sample of respondents in a statistical sense.

Research Flow

The design flowchart in Figure 1 illustrates the systematic flow in the process of preparing a model for the implementation of the Remote Digital Tower pilot project on AirNav Indonesia. The design flow began from the stage of identifying operational problems with conventional Air Traffic Control Tower services related to the efficiency of air navigation services, infrastructure limitations in remote and 3T areas, and the high operational costs of conventional towers.

Based on these problems, the design goal was set, namely to design a pilot project implementation model for the Remote Digital Tower that is able to support the increase in the effectiveness and efficiency of air navigation services at AirNav Indonesia.

The next stage is the determination of the object and subject of the design. The design object is focused on the Air Traffic Control Tower service with the location of the case study at AirNav Indonesia Yogyakarta Branch as a test environment. The selection of this location takes into account the ease of access, infrastructure support, and effectiveness in the testing and implementation process of the device. Although it was carried out in Yogyakarta, the implementation model designed to be applied to areas with limited infrastructure, such as Papua and 3T areas, with the support of satellite-based communication technology such as Starlink.

Figure 1 Research Flow
Source : Author 2026

RESULT DAN DISCUSSION

Analysis of the Current Condition of *Air Traffic Control Service Operations*

AirNav Indonesia is the sole provider of air navigation services in Indonesia that provides services at 298 service locations with diverse operational characteristics, ranging from airports with very high flight movement rates to airports with relatively low movement rates. These differences in characteristics cause the operational needs at each airport to not always be the same, but until now the service model used still refers to the concept of conventional towers**,** namely each airport has *Air Traffic Controller* (ATC) personnel, air navigation technicians (CNS/ATM), and tower infrastructure that is physically placed at the airport location.

The operational model has met aviation safety standards, but based on the analysis of AirNav Indonesia's operational data, there are still opportunities to improve operational efficiency through the implementation of a more flexible service model. One of the indicators that shows this condition is the uneven distribution of flight traffic movements at all service locations.

Analysis of Flight Traffic Movements

One of the factors that is considered in the design of the Remote Digital Tower is the characteristics of air traffic movement at each airport. Based on the classification of AirNav Indonesia's air navigation services as shown in Table 6.1, the types of services are grouped based on the number of annual flight movements into five categories, namely *High Density* (HDA**)** with more than 100,000 movements per year, *Medium Density* (MDA) as much as 36,501–100,000 movements per year, *Low Density* (LDA) as much as 3,651–36,500 movements per year, *Very Density* (VDA) with 1,201–3,650 movements per year, and *Extremely Density* (XVA) with less than 1,200 movements per year.

Table 1 Service Type

AREA	TYPE	CODE	REFERENCES	REMARKS
Upper Level	*High Complexity*	HCU	> 31 movements during peak-hours	
	Medium Complexity	MCU	11-30 movements during peak-hours	
	Low Complexity	LCU	1-10 movements during peak-hours	
Lower Level	*High Complexity*	HCL	> 31 movements during peak-hours	
	Medium Complexity	MCL	11-30 movements during peak-hours	
	Low Complexity	LCL	1-10 movements during peak-hours	
	Advisory	ADL	*Uncontrolled airspace*	-
Aerodrome	*High Density*	HDA	> 100,000 movements/year	Tower Services
	Medium Density	MDA	36,501-100,000 movements/year	Tower Services
	Low Density	LDA	3,651-36,500 movements/year	Tower Services

	Very Density	VDA	1,201-3,650 movements/year	AFIS Services
	Extremely Density	XVA	$\leq$1,200 movements/year	CTAF Services

Source : RIJP 2025-2029 AirNav Indonesia (*data processed*)

Based on Figure 2, the number of AirNav Indonesia service locations based on *the traffic movement* category in the 2022–2025 period shows that the composition of the airport category is relatively stable. The *High Density Aerodrome (HDA) category* was recorded as many as 4 *airports*, *Medium Density Aerodrome (MDA)* as many as 13 *airports*, *Low Density Aerodrome (LDA)* increased from 59 *airports* in 2022–2023 to 60 *airports* in 2024–2025, while the *Very Density Aerodrome (VDA) category* increased from 72 *airports* In 2022, it will become 74 *airports* in 2024–2025. Meanwhile, the *Extremely Density Aerodrome (XVA) category* is the category with the highest number of service locations, which has increased from 145 *airports* in 2022 to 147 *airports* in 2024–2025.

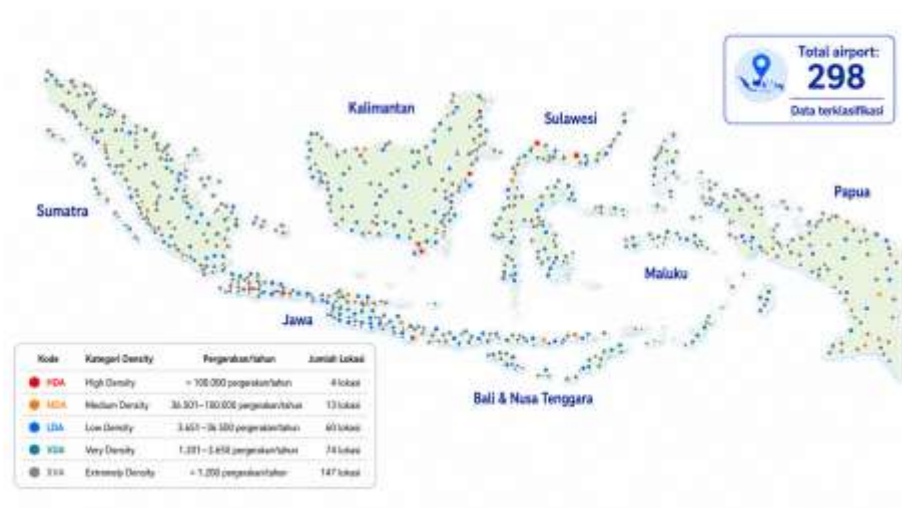

Figure 2 Number and Distribution of Airports by Traffic Movement Category
Source : AirNav Indonesia Operations Data

The increase in the number of *airports* in the *LDA*, *VDA,* and *XVA* categories shows a change in service classification influenced by the development of the number of flight movements at several airports. However, the overall composition of AirNav Indonesia's air navigation services is still dominated by airports with low to very low traffic density. This condition shows that most service locations have operational characteristics with a relatively lower level of complexity than *HDA* and *MDA* category airports. Most of the airports in the *Very Density Aerodrome (VDA)* and *Extremely Density Aerodrome (XVA)* categories are pioneer airports spread across the eastern region of Indonesia, especially Papua and the Frontier, Outermost, and Disadvantaged (3T) regions. In this region, air transportation is the main mode of transportation that connects the community with government centers, health services, education, and logistics distribution.

Therefore, despite having a relatively low rate of flight movement, the existence of air navigation services still has a very important role in ensuring connectivity between regions.

From the operational side, each category has different service characteristics. The *HDA*, *MDA*, and *LDA* category airports still use *Air Traffic Control (ATC)* or *Tower* services, while the *VDA* category uses *the Aerodrome Flight Information Service (AFIS)* and the *XVA* category uses *Common Traffic Advisory Frequency (CTAF)*. These different types of services affect the needs of operational personnel, service facilities, and infrastructure that must be provided at each airport.

Although *the XVA category* has the most airports, this category is not a priority for the implementation of *Remote Digital Towers* because the services provided use *CTAF* so that it does not require air traffic service personnel or *tower* buildings as operational facilities. Therefore, the implementation of *Remote Digital Towers* in the *XVA* category does not provide significant benefits to the optimization of operational resources.

On the other hand, the *Very Density Aerodrome (VDA)* category is seen as the most suitable initial stage for the implementation of *the Remote Digital Tower Pilot Project*. Airports in this category still have *tower* buildings and provide *AFIS* services that require operational officers. In addition, the relatively low level of flight movement makes operational complexity simpler than *LDA*, *MDA*, and *HDA category* airports, so that the risk of implementing new technology can be minimized.

If the implementation in the *VDA* category has gone well and meets the safety and operational performance aspects, then the implementation model can be developed gradually at airports in the *Low Density Aerodrome (LDA)* category that still use *Air Traffic Control (ATC)* or *Tower* services with a higher level of operational complexity.

Based on the results of the analysis, this design sets the airport in the *Very Density Aerodrome (VDA) category* as the priority for the implementation of *the Pilot Project Remote Digital Tower*, while the *Low Density Aerodrome (LDA)* category is projected as the next stage of implementation development after the concept, technology, and operational procedures are proven to run optimally.

Table 3 Priority Analysis of Remote Digital Tower Implementation

Category	Type of Service	Tower Building	Implementation Priorities
HDA	Air Traffic Control (Tower)	There	No
MDA	Air Traffic Control (Tower)	There	No
LDA	Air Traffic Control (Tower)	There	Stage II
VDA	Aerodrome Flight Information Service (AFIS)	There	Tahap I (Pilot Project)
XVA	Common Traffic Advisory Frequency (CTAF)	No Required	No

Source : Processed by the Author based on AirNav Indonesia's Service Classification, 2026.

Security Intrusion Analysis

Operational safety is one of the most important aspects in the implementation of air navigation services. In addition to ensuring the safety of personnel and operational facilities, security conditions also affect the continuity of air traffic services, the reliability of air navigation infrastructure, and the continuity of airport operations. For AirNav Indonesia, security challenges are of particular concern, especially at airports located in the eastern region of Indonesia and the Frontier, Outermost, and Disadvantaged (3T) regions, considering the geographical characteristics, limited access, and security conditions in some of these areas still require more comprehensive risk management.

Based on Figure 3, the number of security disturbances at AirNav Indonesia's operational facilities during the 2021-2025 period was recorded as many as 94 incidents. The number of disturbances increased from 10 incidents in 2021 to 21 incidents in 2022, then reached a peak of 31 incidents in 2023. Furthermore, the number of disturbances decreased to 26 incidents in 2024 and 6 incidents in 2025. Despite showing a downward trend in the last two years, security disturbances are still one of the factors that need to be considered in maintaining the operational sustainability of air navigation services.

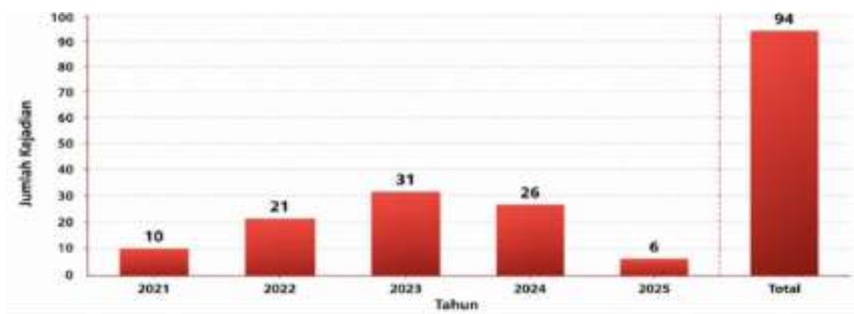

Figure 3 Total Security Disturbances in 2021-2025

Source : Directorate of Security of AirNav Indonesia, 2026 (Data processed)

Based on the results of the evaluation of the Directorate of Security of AirNav Indonesia, most incidents of security disturbances occurred at airports located in the eastern region of Indonesia, especially Papua and the Frontier, Outermost, and Disadvantaged (3T) areas. The region has challenging geographical characteristics, limited transportation access, and security conditions that require special attention in the implementation of air navigation services.

These security disturbances not only have an impact on operational facilities, but also have the potential to affect the safety of personnel on duty at the airport, such as *Air Traffic Control (ATC)* officers, *Aerodrome Flight Information Service (AFIS)* officers, and air navigation technicians (*CNS/ATM*)). In addition to increasing risks to personnel safety, these conditions can also hinder air navigation facility maintenance activities, logistics distribution, and extend recovery time in the event of a disruption to operational equipment.

From the perspective of operational management, these conditions indicate that the implementation of air navigation services in areas with a high level of security risk requires a more adaptive operational approach. One of the alternatives that can be applied is the concept of *Remote Digital Tower*, which is the separation between service locations and airport locations through the use of digital technology and reliable communication networks. With this concept, operational personnel do not always have to be at the airport location so that potential exposure to security risks can be minimized without reducing the quality of service and aviation safety standards.

In this design, the implementation of *the Remote Digital Tower Pilot Project* was carried out at AirNav Indonesia Yogyakarta Branch as a *proof of concept* to test the readiness of technology, operational procedures, and system integration. The resulting implementation model is expected to be gradually applied to airports in *the Very Density Aerodrome (VDA) category* in the Papua region and the 3T region by utilizing satellite communication infrastructure such as *Starlink* to support sustainable service connectivity.

Based on the results of the analysis, the operational security aspect is one of the main considerations in designing the *Remote Digital Tower* implementation model. The implementation of this technology is expected not only to support the digital transformation of air navigation services, but also to improve personnel safety, maintain service continuity, and support operational sustainability at airports in areas with high security risks.

Table 4 Analysis of the Impact of Security Disturbances on the Implementation *of Remote Digital Towers*

Aspects	Existing Conditions	Impact on Operational	Planning Implications *Remote Digital Tower*
Personnel safety	There is a risk of security disturbances at airports in Papua and the 3T region	Increase risk to the safety of operational personnel	Operational personnel can be stationed at *the Remote Tower Center* Safer
Continuity of service	Security disruptions have the potential to hamper bookmaker operations air	Air navigation services could potentially be disrupted	Services can continue through the concept of *remote operation*
Facility maintenance	Mobilization of technicians to the location takes time	Recovery *time* Become Longer	Monitoring and early diagnosis of the system can be done from the center
	and high costs		Control
Efficiency	Still operational	Flexibility	Operational to
Operational	depending on	pengelolaan	more flexibility through
	The presence of	operational to	centralized

	personnel in		management
	Airport Location	Limited	(*centralized operation*)

Source : Results of the author's analysis, 2026.

HR Distribution Analysis

Human resources are one of the main components in the implementation of air navigation services. Operational success is determined not only by the readiness of infrastructure and technology, but also by the availability of competent personnel at each airport. For AirNav Indonesia, managing personnel distribution is a challenge in itself, especially at airports in the Papua region and the Frontier, Outermost, and Disadvantaged (3T) areas. Difficult geographical conditions, limited supporting facilities, and security conditions in some of these areas cause the placement of personnel at operational locations to require special attention.

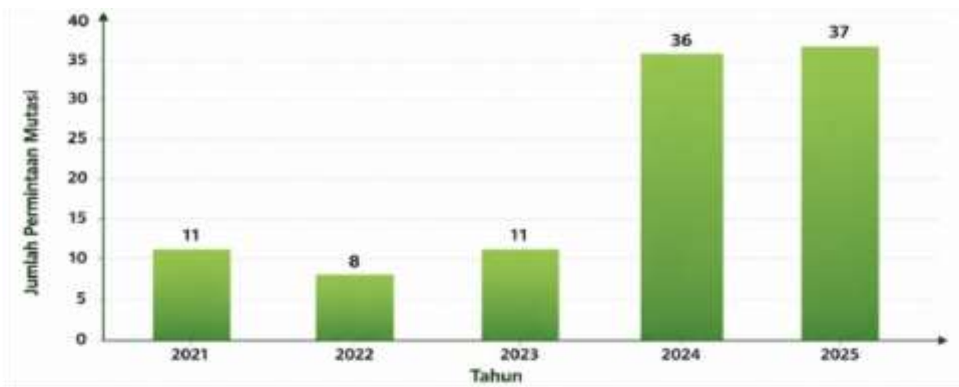

Figure 4 Employee Mutation Requests for Papua Region and 3Q 2021-2025

Source : Directorate of Human Resources and General Affairs of AirNav Indonesia, 2026 (Data processed)

Based on Figure 4, the number of personnel mutation requests from the Papua region and the 3T region during the 2021–2025 period shows an increasing trend. In 2021, there were 11 requests for mutations, then decreased to 8 requests in 2022. Furthermore, the number of requests increased again to 11 requests in 2023 and experienced a significant increase to 36 requests in 2024 and 37 requests in 2025.

The increase in the demand for mutations shows that the placement of personnel in the Papua region and the 3T region is still a challenge for AirNav Indonesia. In addition to being influenced by geographical conditions and limited supporting facilities, security factors and limited accessibility are also one of the considerations for personnel in applying for a move to another area. This condition has the potential to cause a high need for personnel rotation and increase complexity in human resource management.

From an operational perspective, the high demand for mutations can affect the stability of air navigation services. Relatively frequent personnel changes require a process of regeneration, training, and adjustment to the new operational environment. In addition, the distribution of personnel becomes less optimal if each airport still requires the permanent placement of operational officers even though it has a relatively low level of flight movement.

One of the alternatives that can be considered to overcome these challenges is the application of *the Remote Digital Tower* concept. Through this concept, air navigation services are no longer completely dependent on the presence of personnel at airport locations. Operational personnel can be placed in *Remote Tower Centers* that have more adequate work facilities, while services to the airport are still carried out remotely through the support of digital cameras, visual systems, and reliable communication networks.

In this design, the implementation of *the Remote Digital Tower Pilot Project* was carried out at AirNav Indonesia Yogyakarta Branch as *a proof of concept* to produce an implementation model that can then be applied gradually to airports in the *Very Density Aerodrome (VDA)* category in the Papua region and the 3T region. With this approach, the distribution of personnel is expected to be more flexible, the risk of high mutations can be minimized, and operational needs at airports with low traffic levels can still be met without reducing service quality and flight safety aspects.

Based on the results of the analysis, the management of human resource distribution is one of the important factors that support the need for the implementation of *Remote Digital Tower* as part of the digital transformation of air navigation services at AirNav Indonesia.

Table 5 Analysis of Human Resources Distribution on the Implementation *of Remote Digital Tower*

Aspects	Existing Conditions	Impact on Operational	Planning Implications *Remote Digital Tower*
HR Distribution	The high demand for personnel mutations in Papua and the 3T region	Increased personnel rotation needs	Personnel can be placed on *the Remote Tower Center*
Operational Stability	Personnel turnover is relatively high	Adaptation of new personnel requires Time	Operational stability is better maintained through centralized management
Personnel Competencies	Training must be carried out on every Location	Effectiveness of human resource development Not Optimal	More centralized competency development
Efficiency HR Management	Personnel placement still based on airport location	Low personnel distribution flexibility	Personnel distribution is more flexible through concepts *remote operation*

Source : Source: Results of the author's analysis, 2026.

Infrastructure and Investment Cost Analysis

The provision of infrastructure is one of the main components in the implementation of air navigation services. To provide *Air Traffic Control (ATC)* and *Aerodrome Flight Information Service (AFIS)* services, each airport needs *tower* facilities, flight communication devices, communication networks, electrical systems, and various other supporting infrastructure. These needs cause development investment and operational costs to be relatively large, especially at airports in the Papua region and the Frontier, Outermost, and Disadvantaged (3T) areas that have geographical and logistical challenges.

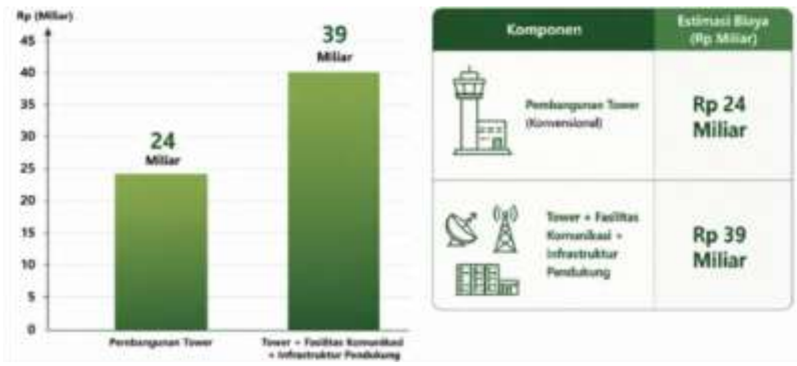

Figure 5 Estimated Investment Cost of Conventional Tower Construction
Source : Directorate of Engineering AirNav Indonesia, 2026 (Data processed)

Based on Figure 5, the estimated investment in the construction of one unit of conventional tower requires a budget of around IDR 24 billion. This value can increase to around IDR 39 billion if the tower construction is equipped with communication facilities and other supporting infrastructure. The large investment needs show that the provision of air navigation facilities requires careful planning, especially at airports with *relatively low* traffic movement levels.

This condition is a challenge for AirNav Indonesia in realizing the equitable distribution of air navigation services throughout Indonesia. On the one hand, every airport still requires air navigation services to ensure flight safety. On the other hand, the investment needs for the construction and operation of conventional *towers* are relatively high when applied to all airports, especially in the Papua region and the 3T region which have a lower level of flight movement than the main airport.

In addition to development investment, the location of airports in remote areas also increases the cost of delivering materials, mobilizing personnel, maintaining facilities, and distributing spare parts. This condition causes the cost of providing air navigation services to be higher because all infrastructure and resources must be available at each airport independently.

Through the *Remote Digital Tower* concept, the need for *tower* construction at each airport can be optimized by focusing services on *the Remote Tower Center*. This approach allows multiple airports with low *traffic movement* levels to be served from a single control center, so that the need for new infrastructure development, operational costs, and resource management can be done more efficiently without compromising aviation safety standards.

In addition to providing efficiency in terms of investment, *the Remote Digital Tower* concept also supports the optimization of the utilization of assets that AirNav Indonesia already has. Communication infrastructure, digital visual devices, and control centers can be used together to serve more than one airport, so that the level of infrastructure utilization is more optimal than the conventional operational model which requires each airport to have separate operational facilities and personnel.

In this design, the implementation of *the Remote Digital Tower Pilot Project* was carried out at AirNav Indonesia Yogyakarta Branch as a *proof of concept* to test technology readiness, system integration, and operational procedures. The selection of Yogyakarta is based on the ease of access to logistics, infrastructure readiness, and efficiency in the implementation of installation and testing of devices. The resulting implementation model is expected to be gradually replicated at airports in *the Very Density Aerodrome (VDA) category* in the Papua region and the 3T region by utilizing satellite communication media such as *Starlink* as the main connecting network between the airport and *the Remote Tower Center*. Based on the results of the analysis, investment and infrastructure aspects are one of the main considerations in designing *Remote Digital Towers*. With an estimated investment in conventional *tower* construction reaching IDR 24-39 billion for each airport, the implementation of *Remote Digital Tower* is not only a technology transformation solution, but also a long-term investment strategy that allows AirNav Indonesia to expand the scope of air navigation services more effectively, efficiently, and sustainably. Through this approach, the need for new infrastructure development can be optimized, asset utilization is maximized, and the implementation of air navigation services at airports in *the Very Density Aerodrome (VDA)* category in the Papua region and the 3T region can be done at a more cost-efficient cost without reducing the aviation safety aspect.

Synthesis of Current Conditions

Analysis of the existing condition of AirNav Indonesia has been carried out through four main aspects, namely *traffic movement* analysis, operational security disturbances, distribution of human resources, and infrastructure and investment. These four aspects were chosen because they are closely related to the implementation of air navigation services, especially at airports in the Papua region and the Frontier, Outermost, and Disadvantaged (3T) areas.

The results of the analysis show that each aspect presents different challenges, but they are interrelated in influencing the effectiveness of the implementation of air navigation services. Airports with relatively low *traffic movements* still require the provision of operational facilities and personnel, while security conditions, human resource distribution, and high investment needs are factors that further increase the complexity of operational management.

To provide a comprehensive overview of the relationship between these problems, the results of the analysis on each aspect are summarized in Table 6.5. This synthesis is the basis for identifying the root of the problem which is then analyzed using the *Fishbone Diagram* method and *5 Why Analysis* as the basis for the preparation of the *Remote Digital Tower implementation model* at AirNav Indonesia.

Table 6 Results of Analysis of Existing Conditions

Analysis Aspect	Analysis Results	Impact on Operations	Implications for note Digital Tower ***Planning***
Traffic Movement	The majority of airports AirNav Indonesia Be in the category *Very Density Aerodrome (VDA)* dan *Extremely Density Aerodrome (XVA)* with level pergerakan Relative Flight low.	Utilization of facilities and Personnel on the city low air framing not optimal, while the service Air navigation must still be available.	Airports Category *Very Density Aerodrome (VDA)* is a priority Pilot implementation *Project Remote Digital Tower* as an initial stage operational transformation.
Security Intrusion	During the period 2021–2025, there were 94 incidents of security breaches, most of which occurred at airports in the Papua region and 3T area.	Increase risks to personnel safety, disrupt service continuity, and slow down the maintenance process of navigation facilities penerbangan.	The *Remote Digital Tower* concept allows operational personnel to be placed in *the Remote Tower Center* so that exposure to security risks can be reduced.
Human Resource Distribution	The demand for personnel mutations in the Papua region and the 3T region shows an increasing trend, especially in 2024–2025.	Personnel distribution becomes less than optimal, increases the need for human resource rotation, and affects operational stability at airports secluded.	Personnel management can be carried out more centrally so that the distribution of human resources becomes more flexible and efficient.
Infrastructure and Investment	The construction of *conventional towers requires an investment of around IDR 24 billion and can reach around IDR 39 billion if equipped with communication facilities and supporting infrastructure.*	The high cost of construction and operations is a challenge in the equitable distribution of air navigation services, especially at airports with *low traffic movement*.	The utilization of *Remote Tower Centers* can optimize infrastructure investments, increase asset utilization, and support the efficiency of air navigation service implementation.

Source : Author's Analysis Results 2026

Remote Digital Tower Pilot Project Planning

Based on the results of the system needs analysis, the Remote *Digital Tower Pilot Project* Design requires a structured project plan so that all stages of work can be carried out effectively, efficiently, and in accordance with the set targets. Project planning is an important stage to ensure that each implementation activity has a clear scope of work, a systematic execution sequence, and optimal time allocation.

In this study, implementation planning is prepared by referring to project management principles which include the preparation stage, location survey, preparation of the scope of work, project scheduling using *the Critical Path Method (CPM),* analysis of schedule acceleration (*Crashing*), and the preparation of *Gantt* Charts. This approach is used to ensure that the implementation of *the Remote Digital Tower Pilot Project* can be carried out in a planned manner and is able to minimize potential delays during project implementation.

CONCLUSION

Digital transformation is an important strategy for AirNav Indonesia in improving the quality of air navigation services through the implementation of *the Pilot Project Remote Digital Tower* as a solution to support *Operational Excellence*. This study identifies various obstacles to the operation of conventional watchtowers, such as the high need for infrastructure investment, limited operational flexibility, suboptimal distribution of human resources, and geographical challenges in the Papua and Frontier, Outermost, and Disadvantaged (3T) regions. The results of the study show that the *Remote Digital Tower concept* is able to be an alternative solution through the use of digital camera technology, *video stitching*, Starlink *Business-based communication networks*, video processing servers, and *display systems* to support air traffic services centrally without reducing safety aspects. This research resulted in the design of *the Remote Digital Tower Pilot Project* which includes system architecture, communication network design, device specifications, operational mechanisms, and implementation stages based on project management through *Work Breakdown Structure (WBS), Critical Path Method (CPM), Network Diagram*, *Crashing*, and *Gantt Chart*. The test results based on *the EUROCAE ED-240A standard* show that the system meets operational needs and is suitable as an initial implementation model at AirNav Indonesia. This research provides practical contributions as a reference for the development *of Remote Digital Towers* to improve operational efficiency, optimization of human resources, and flexibility of air navigation services, as well as academic contributions through the integration of digital transformation concepts and project management. As a strategic step, implementation is recommended to be carried out in stages starting from Yogyakarta Airport, followed by the preparation of operational standards, system evaluation, expansion to airports with appropriate characteristics, and integration with AirNav Indonesia's digital transformation programs such as Jarkompenas, *Digital Air Traffic Management (Digital ATM), System Wide Information Management (SWIM)*, and other supporting technologies to realize more effective, efficient, and sustainable air navigation services.

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