

Revolutionizing Remote Logistics: Cargo Drones for 3T and Disaster-Prone Regions in Indonesia

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Abstract. The increasing relevance of unmanned aircraft technology, or "drones," has opened new avenues for enhancing logistics in hard-to-reach areas. This study addresses the **main problem** of limited transportation infrastructure in Indonesia's 3T (remote, outermost, and disadvantaged) regions and disaster-affected zones, which hampers the timely delivery of essential goods and services. To explore solutions, the study employs simulation-based **methods** to evaluate the feasibility of cargo drone deployment by analyzing six critical parameters: logistics demand, drone type, routing, infrastructure readiness, regulatory environment, and implementation timeline. **Results** of the simulations demonstrate strong potential for drone-based logistics, particularly for the delivery of medical supplies, vaccines, and pharmaceuticals across islands. While operational constraints remain especially related to altitude performance in mountainous terrain, the viability of cargo drones in disaster response has been confirmed through multiple real-world cases. Furthermore, analysis suggests that a multimodal drone logistics network can be effectively supported by fewer than seven major drone hubs nationwide within the next five years. In **conclusion**, the study affirms that cargo drones offer a promising and scalable solution for enhancing logistics in underserved and crisis-affected regions of Indonesia, paving the way for future development of an integrated, drone-enabled transportation system.

Keywords: Drone; Cargo; Rural Area; Disaster Zone; Multi-Mode Transportation

INTRODUCTION

Indonesia as an archipelagic country with a geography dominated by waters makes Indonesia have the potential to become the world's maritime axis. Nevertheless, several regions in Indonesia are still hundreds of 3T (Disadvantaged, Frontier and Outermost) areas. These areas are generally located in areas that tend to be far from the larger island or mainland, thus making them isolated areas. The lack of access to transportation experienced by these areas makes them face serious obstacles in their efforts to meet their needs. Due to difficult logistics supply chain activities, which also have an impact on economic growth and regional development are hampered.

The challenges of transportation access to these areas are also caused by geographical circumstances, which then force access in and out and logistics delivery lines can only depend on one or two types of transportation modes. Some of the challenges faced in accessing these regions are the lack of essential infrastructure, so there are not many modes of transportation that can be used. The types of transportation modes that are generally used for access to this area are generally in the form of sea transportation such as ships and air transportation such as airplanes or helicopters. However, geographical constraints are still more of an operational challenge than these types of transportation. The high cost of shipping and the high need for experienced operators are also obstacles that cause difficulty in accessing this area.

The development of unmanned aircraft (UAV) technology has opened new paths in various fields around the world, both in the military realm and as a means of transportation, one of which is in the logistics sector. The use of this technology has great potential in the future as a mode of future transportation. The use of unmanned aerial vehicles (UAVs) for cargo delivery and logistics purposes has also started to become a new trend recently. The technology, which offers advantages in lower operating costs and the lack of need for experienced operators, has made drones have great potential in the future.

The use of UAV drones as a mode of transportation to send logistics cargo also has the potential to help increase the delivery of aid to disadvantaged, frontier and outermost areas that have limited accessibility and can help disaster-affected areas. Unlike other modes of air transportation that have high operational costs and long crew training, modes of transportation such as UAV drones can allow the delivery of goods such as medical equipment and emergency needs to be carried out more quickly and efficiently without depending on the often minimal ground infrastructure in these locations. The use of drones in a multimodal transportation system that can be arranged through a mobile command center provides convenience in the organization and management of aid deliveries in real time. The ability of drones to pass through difficult areas and various geographical obstacles, the response to emergency situations in the 3T area and disaster zones can be carried out more precisely and effectively so as to speed up the handling of problems and rescue for those affected.

LITERATURE REVIEW

Along with the times, unmanned aircraft (UAV) or drone technology has now become a new trend in the logistics delivery service industry, this technology is expected to be a new solution for transportation and logistics needs in the future. Basically, the key technologies of drones today and in the future can be classified for the following needs: transportation, construction, logistics, inspection and surveillance, and agriculture (Nouacer et al., 2020). In a country that has many isolated areas such as Iceland, the delivery process by *drones* (AHA and Flytrex) significantly reduces the delivery time of packages (Kellermann et al., 2020). UPS together with Gavi and the Vaccine Alliance explored the delivery of medical supplies to remote areas of Rwanda, in collaboration with *drone* startup Zipline. Amazon has also developed a *special drone* for the delivery of medical supplies called Parcelcopter (Jeong et al., 2019).

This new mode of transportation is considered not only to reduce operational costs, but also to minimize the occurrence of security and safety risks for the operators themselves. With the *GPS-based Autonomous system, drones are now also starting to become an alternative transportation that is more efficient and effective in the logistics delivery process in 3T areas and in areas affected by natural disasters*. The use of drones in Indonesia is certainly very effective and efficient because Indonesia is an archipelagic country that has a very wide sea, mountains, hills and also dense cities. Shipping goods by car can take up to two days and is also expensive. Meanwhile, using a drone, goods can be delivered in at least 15 minutes. Not only delivering goods but drones are usually used for military purposes, just as a hobby, or for documentation. In Indonesia itself, the government already has regulations regarding the use of *drones* contained in (Peraturan Menteri Perhubungan Nomor PM 47 Tahun 2016 Tentang Pengendalian Dan Pengoperasian Pesawat Udara Tanpa Awak (Unmanned Aircraft System/UAS) Di Ruang Udara Yang Dilayani Indonesia, 2016) the Regulation of the Minister of Transportation Number PM 47 of 2016 .

However, even so, the use of drones (UAVs) in Indonesia, especially in 3T areas and the need to overcome natural disasters also still have its own challenges, some examples are; inadequate regulations, limited range and flight duration, and communication and control. These three challenges are still limiting the potential of logistics drone (UAV) operations, especially in efforts to deliver goods to 3T areas affected by disasters.

Basically, human activities for logistical needs include the need to deliver things (components of goods, hardware, food, beverages, etc.) quickly and safely, as well as emergency needs such as medical conditions (requiring sample tests from laboratories that are far away). These needs are in line with the Regulation (Peraturan Menteri Perdagangan Nomor 53 Tahun 2020 Tentang Penetapan Harga Acuan Pembelian Di Petani Dan Harga Acuan Penjualan Di Konsumen Untuk Komoditas Cabai Dan Bawang Merah, 2020) as the Minister of Trade regulation No. 53 of 2020, where food and beverages as well as health/emergency services are public service obligations for the transportation of goods to and from the 3T area.

METHOD

Recent research highlights the integration of prospective study design with parametric analysis and simulation techniques across both biomedical and engineering domains. (LaMonica et al., 2025) conducted a prospective simulation study using magnetic resonance imaging (MRI)-based mathematical models to investigate tumor growth predictability. Their work involved a ten-day simulation with twelve distinct parameter combinations, demonstrating how parametric sensitivity can influence model accuracy and clinical forecasting. Similarly, (Sabourishirazi et al., 2025) applied computational fluid dynamics (CFD) simulations and neural network-based parametric analysis to assess thermohydraulic performance in pillow-plate heat exchangers. This study provided a foundation for future design optimization through forward-looking simulation and structural parameter modeling. Together, these studies underscore the power of prospective simulation and parametric methods in advancing predictive modeling in both health and thermal systems.

The prospective study method combined with parametric analysis and simulation is highly suitable for evaluating the future performance, feasibility, and impact of cargo drone deployment in remote and disaster-prone regions of Indonesia. Therefore, this research uses the concept of prospective studies through parametric analysis and simulation of the use of drones to mobilize the needs of goods in 3T areas and disaster-affected areas. Based in waters in Indonesia. The area is used as a case study for geographical observation, then important points in the area are used as a basis for parametric simulations. Data collection was carried out through literature review and database selection from *cargo* drones. The technical specifications of the *drone* are obtained through one of the international databases for medical cargo drones. The data and information to review the geographical conditions in the territory of Indonesia, especially the 3T area which is the object of research, were obtained through the Google Earth page (<https://earth.google.com/web/>).

There are seven main parameters used in this study, namely: 1)Water-based areas categorized as 3T; 2)Logistics/cargo needs; 3)Drone Type; 4)Mobile Hub platform vehicle type; 5)Operation Route; 6)Regulation, and: 7)Timeline of realization.

RESULTS AND DISCUSSION

The seven parameters above will be described in more detail in the next discussion:

A. 3T water areas (Disadvantaged, Frontier, Outermost)

The interpretation of disadvantaged areas in Indonesia is the coverage of areas in certain administrative areas that meet the category of less developed compared to other regions when examined on a national scale. The 3T region is generally plagued by limitations in physical infrastructure (roads, electricity, water), digital infrastructure (network connectivity), local government capacity (fiscal capability), and social services (health & education). Normatively, the determination of disadvantaged regions is regulated by Presidential Regulation Number 63 of 2020, this regulation is the parent that contains a mechanism for determining national disadvantaged regions which is updated periodically every five years. Presidential Regulation Number 63 of 2020 also indicates that the determination of disadvantaged regions **must meet the elements of six criteria linked to quantitative** and qualitative coverage, namely: 1) Community economy; 2) Human resources; 3) facilities and Infrastructure; 4) Regional financial capability; 5) Accessibility; and 6) Regional characteristics

The Aru Islands are a group of islands located in the southeastern part of Maluku Province, at the confluence of the Arafuru Sea and the northern waters of Australia. Administratively, this cluster forms Aru Islands Regency, with main islands such as Tanahbesar (Wokam), Kola, Kobroor, Maikoor, Koba, and Trangan. The center of economic activity and the main port is in Dobo. The location and composition of the islands make Aru strategic for marine activities and affect inter-island logistics needs. The Aru Islands are dominated by lowlands, swamps, and hills, some areas are composed of corals, limestone, and alluvial sediments, causing the depth of the coast to be at a shallow level. This morphology causes the infrastructure of the road network to be unable to be integrated between the point of awakening and the point of attraction, and the phenomenon of settlement patterns scattered along the coast and river mouths also hinders accessibility. Consequently, inter-island access capabilities for logistics delivery and urgent circumstances have been highly dependent on local modes of sea transportation such as small boats.

The livelihood of the Aru Islands residents relies on marine natural resources. The economy of the Aru Islands is supported by commodities based on the marine sector, agriculture or small farming, fishery cultivation, and seaweed cultivation. Indonesia is one of the largest producers of seaweed in the world. The Aru Islands region also has superior wealth of economic value in addition to its agricultural commodities, the waters of the Aru Islands hold the potential for high-standard pearls, tuna catches, and crabs that can increase the added value of exports. With the many potential for economic exploration development with natural resources, the Aru Islands need a qualified supply chain system, and is also supported by effective, fast logistics mobility to meet regional and national market standards, so that downstream it can spur Aru Islands' income.

B. Logistics/cargo needs

Table 1. The item type, main regulatory basis and urgency of delivery to the 3T region

No	Item Type	Main Regulatory Basis	Urgency of Delivery to the 3T Region
1	Medicines, vaccines, blood plasma, medical supplies	PM 79/2017 (Peraturan Menteri Keuangan Nomor 79/PMK.03/2017 Tentang Kriteria Dan/Atau Rincian Jasa Lain Sebagaimana Dimaksud Dalam Pasal 23 Ayat (1) Huruf C Angka 2 Undang-Undang Pajak Penghasilan, 2017) ; PM 10/2024; Permendag 53/2020	Emergency needs for health services and medical emergency situations; Prompt delivery is essential so that the stock does not run out and maintains the safety of life.
2	Fresh food (fish, meat, vegetables, fruits, milk)	Perpres 71/2015; Permendag 53/2020	Perishable goods with short shelf life; Rapid distribution is needed to maintain food security on islands and remote areas.
3	Staple foodstuffs (rice, sugar, cooking oil, salt, flour)	Perpres 71/2015; PM 79/2017; Permendag 53/2020	The main consumption materials that if arrived late have an impact on local inflation and socio-economic stability.
4	Household and hygiene items (soap, detergent, diapers, toothpaste)	Permendag 53/2020	It is important for the basic hygiene and health of the community, especially vulnerable groups in remote areas with limited access.
5	Educational and communication tools (books, computers, stationery, telecommunication devices)	PM 79/2017; KP 206/2024 Kemenhub	Supporting education and communication which are key to social well-being in remote communities.
6	Seeds, fertilizers, animal feed, fish feed, locally superior agricultural & livestock products	Perpres 71/2015; Permendag 53/2020	Supporting food security and local economies; On-time delivery is important to maintain farm and livestock productivity.
7	Return cargo (copra, nutmeg, seafood, dried)	Permendag 53/2020; PM 79/2017	Supporting a two-way economy, reducing logistics costs and increasing the income of local communities.

No	Item Type	Main Regulatory Basis	Urgency of Delivery to the 3T Region
	fish, local handicrafts)		

Strategic goods such as medicines, fresh food, staples, as well as household and educational needs are categorized as urgent needs in the 3T area. The delivery of these goods is considered very important to ensure the welfare of the community. The conventionally difficult geographical terrain in the Aru Islands leads to the need for innovative solutions in distribution.

Emergency needs for health services and medical emergency situations demand rapid and reliable systems to ensure patient survival and effective care delivery. For instance, the *Penn Cancer Cavalry* model illustrates how home-based urgent care can rapidly respond to critical oncology symptoms, minimizing hospital visits while enhancing patient safety through prompt symptom management (Kucharczuk et al., 2025). Similarly, a collaborative care model in Western Sydney demonstrated that integrated commissioning of urgent care services enabled timely delivery of non-life-threatening but essential treatments, showing improved outcomes and system efficiency (Messom, 2025). On a broader scale, the public health crisis in Ecuador underscored how disruptions in energy and medical supply chains critically impair emergency service delivery, with life-threatening consequences, highlighting the need for robust infrastructure to maintain continuity of care (Ortiz-Prado & López-Cortés, 2025).

The distribution of perishable goods with short shelf life is a critical challenge for maintaining food security, especially in island economies and remote regions where supply chain disruptions can lead to severe shortages. (Zhang et al., 2023) emphasize that building resilience in the food supply chain for island economies demands rapid, adaptive logistics to mitigate the risks posed by delayed deliveries and environmental constraints. In support, (S. Kumar & Joshi, 2022) highlight the vital role of agile cold chain systems in ensuring that time-sensitive food items reach remote communities without loss of quality or nutritional value. Similarly, (Maity & Pan, 2021) argue that risk pooling and responsive distribution models are essential during crisis periods such as pandemics to reduce spoilage and maintain continuous access to essential perishable goods.

Delays in the arrival of main consumption materials can significantly disrupt local inflation rates and compromise socio-economic stability, particularly in vulnerable regions. For instance, (Das & Ghosh, 2022) demonstrated that disruptions in essential commodity supply chains during India's COVID-19 lockdown led to heightened regional inflation and deepened economic disparities. Similarly, (Chong & Ramachandran, 2023) found that delays in food imports in island economies such as Fiji and the Maldives triggered sharp local price increases, exposing the fragility of their dependency on external supplies. On a broader continental scale, (Bellemare & Novak, 2021) showed how volatile food prices driven by inconsistent supply were statistically linked to civil unrest and conflict across Sub-Saharan Africa, revealing the critical role of timely delivery in preserving social and economic order.

Basic hygiene and health services are crucial for safeguarding vulnerable populations in remote areas where access to infrastructure and education is limited. (Jackson & Ahmed, 2021) identified systemic barriers such as lack of clean water, inadequate sanitation, and cultural resistance that directly hinder hygiene practices in rural communities,

disproportionately affecting children, women, and the elderly. Supporting this, (Latu & Williams, 2023) demonstrated that community-based WASH interventions in isolated regions like Papua New Guinea significantly improve hygiene outcomes when tailored to local needs and involving local participation. (Rivera & Toloa, 2024) further emphasized that hygiene education programs targeted at maternal health in remote Indigenous communities not only reduced preventable infections among mothers and newborns but also fostered sustainable health practices critical to long-term well-being.

Supporting education and communication is essential for promoting social well-being in remote communities, where isolation and lack of resources often undermine development. (Miura et al., 2025) showed that structured, ICT-based group conversations significantly improved cognitive function and social connectedness among older adults during the COVID-19 pandemic. Similarly, (Castro-Rojas & Blanco-Molina, 2025) found that digital tools could foster emotional resilience and health literacy in rural elderly populations, proving that communication technologies are powerful mediums for social support. Complementing these findings, (Koichi et al., 2025) evaluated the Six Universities Initiative Japan-Indonesia (SUIJI), demonstrating how cross-border educational programs enhanced local capabilities and community sustainability in underserved areas, reinforcing that education and communication are foundational to long-term well-being.

Ensuring on-time delivery of agricultural inputs and services plays a vital role in supporting food security and sustaining local economies, particularly in rural and vulnerable regions. (A. Kumar et al., 2022) emphasized that delayed access to perishable agricultural inputs in smallholder systems severely hampers productivity and directly undermines local food availability. In East Africa, (Ouma & Abebe, 2023) demonstrated that the timely distribution of livestock feed during drought emergencies was critical in preventing large-scale herd losses and maintaining household incomes. Similarly, (Fernandez & Moore, 2024) highlighted how localized logistics improvements during post-pandemic recovery programs helped farmers stabilize output and protect food systems from collapse. Together, these findings affirm that efficient and prompt delivery systems are essential to safeguard both agricultural productivity and the broader socio-economic stability of rural communities.

Developing a two-way economy that supports both inbound and outbound logistics is crucial for reducing costs and enhancing the income of local communities, particularly in rural or underserved regions. (Ghimire, 2025) illustrates how Nepal's decentralized Female Community Health Volunteer model not only improved public health outcomes but also stimulated local economic participation, creating income-generating roles while lowering distribution costs through community-based networks. Similarly, (Musoke et al., 2023) found that integrated transport planning involving rural communities enabled two-way flows of people and goods, effectively reducing logistics barriers and supporting inclusive rural economic growth in Sub-Saharan Africa. (He et al., 2022) further reinforced that decentralized logistics hubs in Southeast Asia increased local employment and improved cost-efficiency by enabling reverse logistics, demonstrating that community centre logistics models are both economically and socially transformative.

The use of drones as a mode of cargo transportation combined with command ships is proposed. The command ship functions as the fleet's flagship, providing communication infrastructure, office spaces, and accommodations for the fleet commander and staff to coordinate maritime activities. As a dedicated command vessel, it includes specialized compartments for the assault commander to support tactical

decision-making in operational settings (Dewanga Aradea Widjatmiko., et. al). In this way, the delivery of goods can be done faster, as drones can reach remote areas with minimal time, while command ships function as portable ports that support the efficient distribution of goods. It is hoped that the combination of these modes can shorten supply chains, reduce logistics costs, and increase the effectiveness of the distribution of essential goods in remote island areas, especially the Aru Islands. This kind of system is expected to be able to overcome existing geographical and infrastructure limitations, while strengthening national connectivity.

C. Drone Type

There are three types of drones that will be reviewed in this study, including *Multicopter* VTOL, STOVL, and STOL. In this study, the drone model chosen as a reference for typical specifications is

Table 2. Technical Specifications of *T-150 drone* (VTOL)

	Technical Specifications	
	Manufacture	Malloy Aeronautics
T-150	Type Drone	Multicopter
	Maximum Range	37,5 Km
	Maximum Payload	68 Kg
	Maximum Speed	108 Km/H

Table 3. Technical Specifications of *Chaparral Drone* (STOL)

	Technical Specifications	
	Manufacture	Elroy Air
Chaparral	Maximum Range	483 Km
	Maximum Payload	200 Kg
	Maximum Speed	125 Km/H
	Wingspan	8 m

Table 4. Technical specification of *drone Black Swan* (STOL)

	Technical Specifications	
	Manufacture	Dronamics
Black Swan	Maximum Range	2500 Km
	Maximum Payload	350 Kg
	Maximum Speed	200 Km/H
	Wingspan	16 m

D. Mobile Hub platform vehicle type

The mode of transportation that will be used as a mobile hub platform is designed in the form of a sea ship with a large main deck to support the drone take-off and landing process. Mobile hubs are used for the consolidation and distribution of goods in local supply chains, enabling more efficient last-mile delivery by reducing transport miles and optimizing delivery routes (Isabela. T. S, et.al. 2021). The ship must also have a large carrying capacity, so that it can function as a walking warehouse for cargo storage and logistics before being forwarded using drones in order to increase access flexibility.

Self-loading and unloading capabilities on ships are also needed so that operations can be carried out autonomously in various locations. In addition, well deck facilities must be available to support land mobilization, and the ship must be able to operate anywhere and act as a portable port as needed. Thus, this ship can be a strategic and flexible distribution center to support efficient logistics management in the Aru Islands region, especially in the face of geographical challenges and limited infrastructure.

The following is an example of a ship transportation mode that can be used as a mobile hub platform:

Table 5. Technical Specification of Transporter / Mobile Hub

	Technical Specifications	
	Manufacture	AAL
	Type	Multipurpose Dry Cargo Ship
	Maximum Lift	20.000 Tones
	Speed	14,55 Knot
SUPER B-CLASS HL MPV	Tonnage	32.000 Tones

Table 6. Technical Specification of Transporter / Mobile Hub

	Technical Specifications	
	Manufacture	CSL
	Type	Hybrid self-loading/unloading vessel
	Displacement	11.000 Tones
	Speed	14,55 Knot
MV CSL FLEXVIK	Tonnage	18.000 Tones

E. Operation Route

Given the constraints in fiscal funding and the readiness of supporting infrastructure and facilities, diversification of operational routes is essential to achieve optimal objectives for delivering goods to hard-to-reach areas. The synchronous multi-modal approach represents a strategic method for goods transportation that can be implemented by integrating primary vehicles, such as drones, with complementary land-based transport vehicles that form an integral component of the system. Examples include light commercial vehicles and two-axle light trucks with a total vehicle weight under 5 tons, which can also serve as mobile platforms for drones to access take-off and landing points.

Main Benefit	Explanation
Flexibility	Real-time mode switching enables easy adaptation to changing conditions.
Cost Efficiency	Automation reduces logistics delivery costs to hard-to-reach locations.
Sustainability	Promotes a shift toward low-emission transport modes and ensures operational continuity.
System Resilience	Withstands disruptions and responds effectively to variations.

This operational modeling approach necessitates synchronization of movements between the supporting vehicle and its primary drone, ensuring that the supporting vehicle

does not need to wait for the drone's return before proceeding to subsequent delivery points. In this study, such routes are still categorized alongside conventional multimodal systems.

The primary challenges lie in the human resource capacity within operations, where field personnel must perform dual roles as both land transport vehicle drivers and drone operators during the final delivery phase. Another constraint affecting delivery effectiveness relates to the level of drone system automation; drones require a high degree of autonomy to fly independently to the delivery destination and return to the take-off point without disrupting ground transport operations. Synchronous multi-modal transportation offers operational advantages through modal integration, flexibility, and continuity. Successful implementation hinges on collaboration, data integration, and supportive infrastructure that enables efficient modal transitions. Rotterdam in the Netherlands serves as a notable example of this concept's successful application.

Delivery of goods to hard-to-reach areas can also be facilitated through multi-modal operational strategies, combining drones with other transport modes, such as trucks. In this framework, a central logistics hub can leverage additional modes to access regions beyond the drone's flight radius. The reverse pattern is also feasible, with drones handling deliveries from the central hub while trucks or other modes manage transport from distribution points (hubs) to final destinations.

Routes of this type can be implemented by having one mode, such as a truck, carry the drone along with its take-off and landing platform to a specific location (a plug-and-play module), after which the drone is launched from that point to reach targets inaccessible by the initial mode.

Nevertheless, multi-modal route systems demand thorough upfront planning, particularly in scheduling between ground mode deliveries and final-stage drone flights. Additional challenges include the fact that not all goods transported by land modes align with drone payload capacities or specifications. Any mismatches could lead to delivery failures and disruptions in the overall distribution schedule.

F. Regulation

Several regulations have been issued by the Indonesian Government as a form of supervision and maintenance of safety related to drone operations, both specifically and within the broader context of general aviation regulations. This is particularly relevant in the development of mobile drone systems for remote, border, and outermost regions, such as the Aru Islands in Indonesia, where such regulations are essential to ensure safe and integrated operations.

Peraturan Menteri Nomor 63 Tahun 2021, which replaces Peraturan Menteri Nomor 163 Tahun 2015, has been formulated to address the main provisions concerning unmanned small aircraft. The provisions cover aspects of operation, operator certification, and registration of such small unmanned aircraft systems. Furthermore, Peraturan Menteri Nomor 34 Tahun 2021, as the most recent regulation issued by the Ministry of Transportation, has been designed to explain airworthiness standards for remotely piloted aircraft systems, internationally known as Remotely Piloted Aircraft Systems (RPAS). This regulation refers to the latest international standards for similar vehicles, namely the Civil Aviation Safety Regulations (CASR) Part 22. In addition, Peraturan Menteri Nomor 34 Tahun 2021 also addresses the oversight mechanisms for the certification process delegated to the Directorate General of Civil Aviation, including audits, inspections,

observations, monitoring, and testing.

Peraturan Menteri Nomor 37 Tahun 2020, issued to replace Peraturan Menteri Nomor 47 Tahun 2016 and Peraturan Menteri Nomor 180 Tahun 2015, focuses on controlling the operation of unmanned aircraft in Indonesia's serviced airspace. This regulation details the operation of unmanned aircraft, from serviced airspace, operational procedures and protocols, approval mechanisms, operational supervision, to the application of sanctions. From an operational perspective, Peraturan Menteri Nomor 37 Tahun 2020 regulates in detail based on categories including vehicle weight, operational principles, and operational areas (both in populated and non-populated regions). For drones weighing less than 55 lbs, the applicable provisions are compliance with CASR Part 107 or classification as small unmanned aircraft. Meanwhile, for drones weighing more than 55 lbs, the certification follows CASR Part 21. These regulations are expected to support the development of adaptive mobile drone systems for areas like the Aru Islands, emphasizing safety and compliance with national and international standards.

G. Timeline of realization

The determination of the implementation timeline has been based on parameters such as the type of drone, supporting infrastructure, and applicable regulations. The explanation of this is compiled as follows:

In the current period (less than 1 year), the implementation of cargo drones has been able to be carried out by utilizing the available technology and regulations. The main obstacles faced include regulations that are not completely perfect, the level of acceptance of existing regulations, and considerations related to profit margins that can be obtained. Initiatives in this period have been largely driven by voluntary operators and are relatively independent.

In the short term (1-5 years ahead), private operators are expected to be able to run the drone cargo business in a sustainable manner, thus giving rise to competition to dominate the market in similar sectors. In this period, regulations have been able to accommodate drone business operations, including aspects outside of technology such as business, labor, insurance, taxation, and others. However, the obstacles that are still faced are the limitation of regulations that are exclusive to the drone business locally, as well as the unavailability of operating schemes that are integrated with other modes of transportation at the national level.

In the long term (more than 5 years), the implementation of *Unmanned Traffic Management* (UTM) is expected to be realized, so that the difference between national airspace for manned and unmanned aircraft is minimal. One example of the UTM concept has been developed by *the Federal Aviation Administration* (FAA) and *the National Aeronautics and Space Administration* (NASA). In addition, during this period, the performance of the battery is estimated to have improved by approximately 47% compared to current conditions, allowing for more efficient remote operation. This implementation is expected to support the development of optimal mobile drone systems for the needs of remote areas such as the Aru Islands, taking into account operational efficiency and integration with national transportation systems.

Table 7. Timeline of Realization for drone operation, regulation and integration

Phase	< 1 Year (Current)	1-5 Years (Short Term)	> 5 Years (Long Term)
Operations	Limited, feasible ops with existing rules.	Sustainable ops emerge as competition grows.	Wireless UTM implemented; minimal manned/unmanned airspace gap.
Regulation & Tech	The regulatory framework exists but is evolving.	Regulations expand to cover insurance, tax.	Battery performance improves (~47%), enabling efficient remote ops.
Integration	Profit margins uncertain; initiatives are independent.	Regional-based exclusive schemes; no national multimodal yet.	Integrated with national transport systems; optimal mobile drones for remote areas.

H. Prospective study based on Time horizon, core condition, Regulatory , Barriers and strategic outlook.

Table 8. Prospective study based on Time horizon, core condition, Regulatory, Barriers and strategic outlook.

Prospect	Time Horizon	Core Condition	Regulatory & Market Readiness	Main Barriers	Strategic Outlook
1st Prospect — Current Stage	< 1 year	Operations already feasible using existing tech & partial rules	Regulation exists but incomplete; business mostly voluntary and non-commercial	Regulatory maturity low, low adoption pressure, unclear profit margin	Proof-of-concept era driven by pioneers, not by market pull
2nd Prospect — Short-Term Stage	1-5 years	Private operators become sustainable and begin competing	Regulation covers business, labor, insurance, tax but only local scope	Not yet integrated nationally; multimodal linkage absent	Commercialization era market competition begins but fragmented
3rd Prospect — Long-Term Stage	> 5 years	UTM reduces gap between manned vs unmanned airspace; tech efficiency increases	Full integration with national systems expected; battery +~47% enables long-range efficiency	Standardization & national alignment still needed	Scaled national ecosystem drones embedded into mainstream logistics

Source : Research (2025)

I. Prospective studies based on Simulation

The Aru Islands have been chosen as a prospective study area due to their strategic position in the southeast of Maluku Province, right at the confluence of the Arafuru Sea and the northern waters of Australia. Administratively, this area forms the Aru Islands Regency which consists of main islands such as Tanahbesar (Wokam), Kola, Kobroor, Maikoor, Koba, and Trangan. Inter-regional transportation access in this region is still relatively limited

because the small islands around it are only served by small ports. Rar Gwamar Airport in Dobo is the only airport in the region, which only serves the Dobo–Ambon route with limited frequency. The geographical conditions dominated by shallow waters and coral reef zones have made the construction of large ports impossible, so that the logistics distribution chain in this region runs inefficiently and is highly dependent on weather factors and small capacity sea modes.



Figure 1. Map of the Aru Islands

The limited infrastructure also has an impact on the lack of inter-island and inter-village transportation modes in the Aru Islands. This often causes difficulties in meeting basic needs and distributing medical medicines in remote areas. The reliance on air transport such as small aircraft and helicopters to supply logistics has led to a significant increase in distribution costs, which ultimately triggers price inequality as well as the risk of scarcity in some villages.



Figure 2. Operational Radius of Cargo Drone from Command Ship

Based on these conditions, the Aru Islands are considered the most relevant location for the implementation of an integration-based logistics model between cargo drones and command ships as a *moving hub*. This concept was developed with the main goal of cutting and shortening the logistics distribution chain, both in the main archipelago region and in remote villages. In its implementation, the command ship functions as a drone operational center as well as a take-off and landing point, so that the distribution of important goods can be carried out directly to areas that are difficult to access without dependence on the existence of large ports or airports. Simulated, the command ship will depart from a large port on the island around the destination to carry out the cargo loading and unloading process, at the same time, the cargo drone will also move along with the ship to the destination location. Using the *Synchronous Multi Capital* route model, the drone will take off and land on the command ship, simultaneously, this operation will provide flexibility and effectiveness in the operational radius of cargo drone delivery. Thus, drones do not

need airports or ports to be used as logistics centers (hubs), but can move and operate directly through the flight deck of a command ship.



Figure 3. Ilustrasi pengiriman logistic ke desa Popjetur & Marafenfen dengan drone tipe VTOL

At the first prospect of cargo drone operations in the region, simulating the mission of distributing vaccines and medical drugs. The command ship will function as a mobile logistics center or moving hub, the drone used is a Multicopter type with Vertical Take-Off & Landing (VTOL) capability. That way the drone will be able to take off and land vertically, so it can provide high accessibility, as well as flexibility because it does not require a lot of space to fly and park when flying at the destination location.

In this prospect, it is simulated if the delivery uses a *Malloy Aeronautics* T-150 drone with a maximum payload capacity of 68 kg. The multicopter drone will be perfect for fast delivery options and high-priority batches of goods such as medical necessities that require fast delivery times. The priority medical packages included vaccines, antibiotics, intravenous fluids, first aid kits, and personal protective equipment to support basic public health services. The temperature and stability of the goods are maintained using a cold box and special insulation during the flight. This delivery is carried out to reach several villages in one day, so that access to health services can be improved in areas with limited transportation infrastructure. Thus, fast and reliable medical distribution can be realized in 3T regions such as the Aru Islands.

In **Figure 3**, the simulation depicts the T-150 drone departing with priority cargo, such as high-priority medical supplies, destined for the villages of Marafenfen and Popjetur. These locations were selected due to their proximity to the coastal areas of the Aru Islands, which suffer from limited accessibility, compounded by the extended travel times required to reach the nearest main port. Consequently, the T-150 drone is employed to distribute logistics via aerial routes. With an average distance of 13-15 km and a total payload capacity of up to 68 kg, the delivery process for each shipment requires approximately 8 minutes, while a complete round trip takes around 20 minutes.



Figure 4. Illustration of logistics delivery to Lorang & Manjau villages using a STOVL type drone

The second prospect in the parametric simulation employs a fixed-wing drone with Short Takeoff and Vertical Landing (STOVL) capabilities, specifically the Chaparral model produced by Elroy Air, which offers a payload capacity of 200 kg and an average speed of 125 km/h. This drone was selected for its ability to transport larger loads while maintaining high economic efficiency, making it ideal for delivering items such as telecommunications equipment, staple foodstuffs, and household goods. Its flexibility is enhanced by short takeoff and vertical landing features, which broaden accessibility, particularly in the Aru Islands archipelago. The Chaparral drone is particularly suited for deliveries to densely populated areas and villages, addressing basic community needs with an operational range of up to 480 km, rendering it highly appropriate as a transport mode in the Aru Islands.

In **Figure 4**, the simulation illustrates the Chaparral drone departing with heavier cargo, including telecommunications devices, essential food supplies, and household items, bound for inland regions of the Aru Islands. For this simulation prospect, the targeted areas are the villages of Lorang and Manjau, chosen for their central location within the Aru archipelago. These sites also face significant accessibility constraints, relying solely on transportation via small rivers, alongside prolonged travel times to the nearest main port. As a result, the Chaparral drone is utilized to distribute logistics through aerial means. Given an average distance of 50-60 km and a maximum payload of 200 kg, each delivery process requires approximately 24 minutes, with a full round trip taking around 20 minutes. This approach is markedly faster than river-based delivery by boat, which can take several hours.

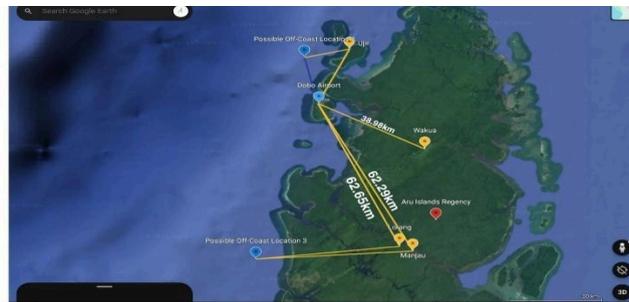


Figure 5. Illustration of logistics delivery to all islands using STOL type drones

The third prospect in the simulation was carried out using a Black Swan drone produced by Dronamics, which is a Short Take-Off and Landing (STOL) type drone. This drone has a carrying capacity of 350 kg and an operational range of up to 2,500 km, so its mileage can match that of a short haul type aircraft with efficiency as a drone that is maintained. Shipping goods to islands with larger logistics centers is the main target of the use of these drones. The effectiveness of increasing economic growth in the Aru archipelago is believed to be achieved through the use of drones. The assumed cargo includes natural products and local products of high economic value that require fast shipping such as conventional air transportation. In addition, this drone is designed to be able to take off and land from a command ship, and the loading and unloading process is carried out at Dobo Airport. Its licensed performance for commercial flights, speeds of up to 200 km/h, and long-range capabilities make this drone a cost-effective and environmentally friendly modern logistics solution.

In **Figure 5**, the Black Swan drone is simulated as a medium-distance heavy-lift transport mode, anticipated to facilitate the delivery of economically valuable return cargo. The drone is assumed to operate solely between the command ship and Dobo Airport, where Dobo Airport serves as a central logistics hub for transiting goods, including return cargo derived from the natural resources and local products of the Aru Islands. The Black Swan drone is expected to provide an alternative solution for transporting cargo from the Aru Islands to other airports, such as Surabaya (SUB) or Makassar (UPG). In this figure, it is further assumed that drones like the Chaparral will carry cargo from various locations within the Aru archipelago to Dobo Airport (DOB), followed by transit and onward transport beyond the islands.

In addition, other areas such as Ujir and Wakua emerge as promising sites for this third prospect, where Chaparral and T-150 drones would help interconnect regions within the Aru Islands via the command ship or Dobo Airport (DOB), prior to external shipment. **Figure 5** also illustrates the operational route simulation under a multi-modal model. This third prospect aims to bolster the Aru Islands' economy by introducing an aerial cargo transport solution through drone-based modes integrated with command ship transportation.

The prospects for cargo drones in disaster-affected areas

This study evaluates the 2018 Lombok earthquake case, drawing on reports from the National Disaster Management Agency (BNPB) regarding the series of seismic events in West Nusa Tenggara Province. The most severe quake struck on August 5, 2018, registering a magnitude of 7.0 on the Richter scale and inflicting economic losses estimated at Rp12.15 trillion alongside 564 fatalities. North Lombok bore the brunt of the destruction due to its proximity to the epicenter.

The earthquake severed electrical grids, telecommunications networks, and several ground transportations routes, severely impeding logistics distribution efforts. In response, BNPB dispatched 21 tons of aid via cargo aircraft, while the National Search and Rescue Agency (Basarnas) deployed three helicopters to reach refugees in isolated zones. Drones were also employed to expedite aid delivery in areas near command posts, highlighting their emerging utility in such crises.

Analytical data were sourced from BNPB records, encompassing conditions at evacuation sites and damage assessments as depicted in Figure 8, as well as the "NTB Emergency Operations 2018" report from the Integrated Joint Task Command Post Volunteer House (POSKOGASGABPAD) NTB 2018.



Figure 7. Illustration of logistics delivery for aid for the 2018 Lombok natural disaster using cargo drone mode

The first prospect for deploying cargo drones in this context involves multicopter platforms, exemplified by the T-150 system. The distribution of relief supplies would

concentrate on the northern West Lombok Regency, where the number of evacuees substantially exceeds the capacity of the limited aid posts identified as logistics distribution centres in **Figure 7**.

According to the National Disaster Management Agency's (BNPB) 2020 technical specification for ready-to-eat food packages, each parcel contains 400 g of rice, side dishes, three packs of instant noodles, 150 ml of soy sauce, and 4 L of drinking water, yielding a total weight of roughly 6 kg and meeting the agency's 2 100 kcal-per-person-per-day standard. For aerial delivery, these parcels may be re-configured to increase coverage per sortie such as substituting lightweight 900 kcal military rations weighing 400 g each thereby optimising the T-150's 68 kg payload capacity.

Although this route demands multiple drones pre-positioned at various nodes, operational efficiency can be enhanced through a multimodal scheme in which drones coordinate with complementary transport assets, notably a command ship acting as a moving hub when shore-based infrastructure is inadequate.

The second prospect employs a synchronous multimodal concept: the command ship navigates coastal waters off Lombok as the primary mode, while drones execute last-mile deliveries to settlements beyond the reach of damaged arterial roads, as illustrated in **Figure 7**. A key innovation of this approach is that the command ship doubles as a take-off and landing platform effectively a mobile logistics hub thereby reducing the number of drones required and enabling near-term implementation.

A notable innovation in the synchronous multimodal framework is the command ship's dual role as both a takeoff and landing platform for drones and a dynamic mobile hub, which facilitates streamlined operations in fluid environments like disaster zones. This configuration not only minimizes the fleet of drones required by centralizing launches and recoveries at sea but also supports rapid deployment over short- to medium-term horizons, making it particularly viable for archipelagic responses where fixed infrastructure may be compromised.

The third prospect addresses longer ranges and complex geography by integrating Vertical Take-Off and Landing (VTOL) drones similar to the T-150 with Short Take-Off and Vertical Landing (STOVL) platforms such as the Chaparral. This configuration permits direct delivery from logistics centres to target sites, either via parachute drops or by landing at evacuation areas, mirroring cargo air-drop practices employed by U.S. Air Force C-17 aircraft during the 2010 Haiti earthquake, which released forty pallets of food and water from 600 ft. By circumventing strategic infrastructure airports and seaports that typically anchor conventional supply chains, the VTOL/STOVL model can also mitigate pilot fatigue-related risks that have historically contributed to fatal accidents, such as those recorded during the 2004 Aceh tsunami response.

Collectively, these integrative approaches are expected to improve logistics efficiency in Indonesia's 3T (remote, frontier, outermost) regions by shortening distribution times and expanding inter-island accessibility. Employing a ship-based drone operations hub should enable more effective and sustainable provision of essential goods, thereby accelerating regional development and strengthening connectivity across the Aru Islands within the broader framework of integrated maritime development.

This integrative approach is seen as able to improve the efficiency of logistics systems in the 3T region through reducing distribution time and increasing inter-island accessibility. With the implementation of a system that combines ships as the base of drone operations, the distribution of basic needs of the community is expected to run more

effectively and sustainably. Through this model, the acceleration of regional development and the improvement of connectivity in the Aru Islands are believed to be optimally realized in the context of the development of an integrated maritime region.

CONCLUSION

In this article, a prospective study has been conducted through parametric analysis and simulation regarding the potential of a new model of using and integrating drones with marine transportation modes in the 3T water area, in Indonesia. Seven parameters related to the operation, namely regional criteria, logistics needs, drone type, moving hub platform type, operation route, regulations and realization timeline, have been simulated in several 3T water areas, precisely in the Aru islands. From this study, four prospects for cargo drone operations involving supporting modes of transportation, namely command ships as moving hubs, which allow the shortening of the logistics chain, which originally depended on the presence of infrastructure such as airports and ports, can now be replaced by a command ship and cargo UAV drones. In addition, this study also needs to be strengthened with trials in various 3T areas, as well as technical trials of cargo drone operations from the deck of the ship, before the real implementation, in order to realize the use of cargo drones for alternative modern transportation and logistics systems in Indonesia.

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