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AAM을 활용한 인도네시아 Kepulauan Riau의 지속 가능한 연결 교통 구축에 관한 연구

A Study on the Construction of Sustainable Connected Transportation in Kepulauan Riau, Indonesia Using Advanced Air Mobility (AAM)

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[요 약]

인도네시아 케풀라우안 리아우(Keplauan Riau) 지방은 군도적 성격, 예산 제약, 부지 부족으로 인해 연결교통 인프라 개발의 한계에 봉착해 있다. 말라카 해협 비즈니스 삼각지대에 있는 전략적 위치와 싱가포르와 말레이시아에서 많은 관광객 방문으로 교통 수요가 증가하고 있다. 그러나 많은 섬 간을 연결해야 하는 특성으로 교통인프라 구축이 이루어지지 못하고 있는 상황이다. 본 논문에서는 인도네시아 Kepulauan Riau 지역의 실제 상황 분석과 적용 고려를 통해서 전기 수직 이착륙(e-VTOL) 시스템을 갖춘 AAM(advanced air mobility)의 도입이 가져 올 수 있는 혁신을 예측해 보고자 한다. 또한, AAM을 활용한 혁신적 교통인프라 구축에 대한 국가차원의 검토와 정책 수립, 인프라 구축 계획에의 반영, 적극적인 글로벌 협력 등의 촉진에 기여하고자 한다.

[Abstract]

Indonesia's Keplauan Liau region is facing limitations in the development of connected transportation infrastructure due to its archipelago nature, budget constraints, and lack of land. Transportation demand is increasing due to its strategic location in the Malacca Strait Business Triangle and many tourist visits from Singapore and Malaysia. However, due to the nature of connecting many islands, the establishment of transportation infrastructure has not been achieved. This paper aims to predict the innovations that can be brought about by the introduction of advanced air mobility (AAM) with an electric vertical take-off and landing (e-VTOL) system through analysis and application consideration of the actual situation in Indonesia's Kepulauan Liau region. In addition, it intends to contribute to national-level review and policy establishment on the establishment of innovative transportation infrastructure using AAM, reflection in infrastructure construction plans, and active global cooperation.

Key word : Advanced air mobility, Geographic challenges, Environmental sustainability, International collaboration, Kepulauan Riau.

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Ⅰ. Introduction

In Indonesia's 'Kepulauan Riau', In the form of island provinces, connectivity remains a major issue, making connectivity development difficult if solely reliant on road and bridge infrastructure construction. Moreover, the minimal contribution of around 15% of the total national spending budget to infrastructure exacerbates the challenge of connectivity infrastructure development in these areas. Both central and regional governments are not without strategies for addressing this issue.

The Riau Archipelago heavily relies on maritime and air transportation, while accessibility by sea and air to and from some cities in the archipelago remains quite limited. For maritime and air transportation, connections are only available to a few major cities (Augustian 2023). For instance, 28 ports have been built to serve human and/or cargo traffic, with 7 of them serving international routes. Additionally, the central government, through national strategic projects, has constructed integrated ports with the Tanjung Sauh Batam industrial area and developed the Kuala Riau Port. Besides governmental intervention, regional governments have undertaken efforts to enhance connectivity by constructing HDPE (High-Density Polyethylene) floating pioneer ports in five locations. As for air transportation, the Riau Archipelago is currently served by 8 airports, including two international airports—Hang Nadim Airport in Batam and Raja Haji Fisabilillah International Airport in Tanjung Pinang, with data indicating 1.1 million arrivals and departures on domestic flights to the Riau Archipelago. Ground transportation such as railways and toll roads in the Riau Archipelago is not a top priority for development alongside limited land availability and a concentrated population on the main islands, which poses further challenges. However, with a motor vehicle count of around 1,073,265 units, congestion persists at several points in the main cities of Batam and Tanjung Pinang. The Indonesian Central Government has also implemented a strategy to strengthen connectivity between nearby islands through the construction of the Balerang Bridge (Batam − Rempang − Galang) with a cumulative length of approximately 54 km, with a budget of over 1 billion USD during the period from 1992 to 1998. Currently, the Indonesian government is planning the construction of a bridge connecting Batam Island and Bintan Island spanning 14.75 km, with an estimated budget of 850 million USD, and is currently offering cooperation in the development to various partners.

As one of the provinces proposed to become a priority industrial zone in Western Indonesia, the main issue of connectivity in the Riau Archipelago has yet to be resolved with the best solution. The implementation of advancements in transportation technology could provide an alternative to improve the diversification of transportation modes, one of which is advanced air mobility (AAM) with electric vertical take-off and landing (e-VTOL) systems. Given the limitations of geography, infrastructure, and budget, it is hoped that this approach can solve the transportation problems of the Riau Archipelago. Therefore, we now require a new approach.

The integration of aircraft designs in advanced air mobility (AAM) involves cutting-edge technologies in propulsion and automation. Emerging propulsion systems, such as electric and hybrid motors, are currently in development for aircraft applications. Electric motors, with their simplicity and reduced moving parts compared to internal combustion or turbine engines, are expected to reduce single points of failure and potential malfunctions. Moreover, the adoption of electric propulsion technologies has the potential to significantly reduce aircraft noise and environmental impacts, while also decreasing reliance on traditional carbon-based aviation fuels.

However, AAM utilization extends beyond intercity, suburban, or inter-island travel. Various countries, including South Korea, have conducted AAM flight trials. For instance, the K-UAM 'OPPAV', developed by South Korean researchers, recently completed its first public flight demonstration. This air taxi, capable of carrying one person and reaching speeds up to 240 km/h with reduced noise compared to helicopters, marks the commencement of the Korean UAM Demonstration Project [9]. This project aims to test aircraft safety and infrastructure for future commercialization, with the government aiming to streamline UAM regulations for operational urban skies by 2025. Similarly, Hignett, K. (2023). Scotland's "MedicXpress" initiative, led by HIAL, Loganair, and Skyports, facilitated swift medical deliveries in the Highlands and Islands, in the U.S., a collaborative effort by the FAA and Matternet showcased AAM's potential in streamlining healthcare logistics, particularly in remote locales, by expediting medical supply transport.

Moreover, the widespread adoption of AAM is anticipated to address mobility challenges prevalent in congested urban environments, particularly in megacities with underdeveloped infrastructure. As cities increasingly embrace AAM solutions, the global mobility industry stands to undergo a paradigm shift, unlocking new opportunities for growth and innovation. To realize the full potential of AAM, collaboration and partnership across diverse stakeholders are imperative. AAM is actively pursuing strategic alliances along the entire value chain, encompassing parts suppliers, ecosystem stakeholders, and regulatory bodies. By fostering collaboration and innovation, AAM aims to usher in a new era of urban air mobility, revolutionizing transportation on a global scale.

Ⅱ. Main subject

2-1 Transportation issues in Kepulauan Riau

Although both the central and local governments emphasize inter-regional connectivity in the Riau Archipelago through maritime transportation, with budget and human resource constraints, only 28 ports have been constructed across the 8 main islands in the Riau Archipelago thus far. These include ports built and operated by the government on islands such as Anambas, Batam, Bintan, Karimun, Lingga, Natuna, and Tanjung Pinang. However, in terms of port classification, few are designated as cargo and vehicle ports. Out of the total operational ports, only 1 (4%) is designed for passenger and vehicle shipment, 4 ports (14%) have passenger shipment capabilities, while the remainder are ports equipped with passenger delivery facilities.

In addition to the need for proficient maritime transportation, which also entails considerable costs, Ginting (2013) conducted an in-depth discussion with stakeholders in the Riau Islands. It was found that the cost of transporting 100 passengers by land requires approximately 1 billion Indonesian Rupiah to build a bus, while constructing a fiberglass boat with a capacity of 100 passengers for short distances between islands costs approximately 5 billion Rupiah. Meanwhile, the cost of building an iron ship with a capacity of 100 passengers to reach the outermost islands and open seas requires approximately 20 billion Rupiah. This is not to mention the additional costs for building docks and other supporting facilities.

This is also evident in air transportation, where currently only 7 airports are operational, including two international airports−Hang Nadim airport in Batam and Raja Haji Fisabilillah international airport in Tanjung Pinang. Additionally, there are domestic airports such as Ranai airport, Dabo airport, Sei Bati airport, Matak airport, and Letung airport in the Anambas islands. Furthermore, there are several issues faced in the management of island regions. First, most of the islands are considered underdeveloped areas and many are uninhabited. Second, there are limitations in administrative government services, economic and socio-cultural empowerment, communication and transportation infrastructure, including maritime transportation connecting small and large islands. Third, Fourth, the limitation of equipment, frequency, and skilled human resource. other issues arise in air transportation. For instance, despite Batam and Bintan having international airports, there are limited direct regular operators serving this route. Despite the relatively short distance of approximately 50.5 kilometers, in terms of cost-benefit analysis, this route is not profitable for small to medium aircraft (approximately 500 kg). Challenges such as the absence of direct regular flights to and from the main islands extend the time required for shipping goods.

Table 1. List of seaport in Kepulauan Riau.

No.	Sea Port Name	City	Port Type	Route
1	Seaport Sri Bintan Pura	Tanjungpinang	Passenger	Dometic and Intenasional
2	Seaport Roro Dompak	Tanjungpinang	Passanger and Vehicle	Dometic
3	Terminal Ferry Telaga Punggur	Batam	Passenger	Dometic
4	Seaport Roro Telaga Punggur	Batam	Passanger and Vehicle	Dometic
5	Terminal Ferry Domestik Sekupang	Batam	Passenger	Dometic and Intenasional
6	Internasional Ferry Terminal Harbour Bay Batam	Batam	Passenger	Dometic and Intenasional
7	Internasional Ferry Terminal Batam Center	Batam	Passenger	Internasional
8	Nongsa Pura Ferry Terminal	Batam	Passenger	Internasional
9	Seaport Bulang Linggi Tanjung Uban	Bintan	Passenger	Dometic
10	Seaport BBT Lagoi	Bintan	Passenger	Internasional
11	Seaport Sri Bayintan Kijang	Bintan	Passenger and Logistic	Dometic
12	Seaport Tanjung Balai Karimun	Karimun	Passenger	Dometic and Intenasional
13	Seaport Tanjung Makom	Karimun	Passenger	Dometic
14	Seaport Roro Parit Rempak	Karimun	Passanger and Vehicle	Dometic
15	Seaport Roro Selat Beliah	Karimun	Passanger and Vehicle	Dometic
16	Seaport Sri Tanjung Gelam	Karimun	Passenger	Dometic
17	Seaport Tanjung Batu	Karimun	Passenger	Dometic
18	Seaport Moro	Karimun	Passenger	Dometic
19	Seaport Tanjung Berlian	Karimun	Passenger and Logistic	Dometic
20	Seaport Sei Tenam	Lingga	Passenger	Dometic
21	Seaport Tanjung Buton	Lingga	Passenger	Dometic
22	Seaport Jagoh	Lingga	Passenger	Dometic
23	Seaport Roro Jagoh	Lingga	Passanger and Vehicle	Dometic
24	Seaport Letung	Anambas	Passenger	Dometic
25	Seaport Tarempa	Anambas	Passenger	Dometic
26	Seaport Sedanau	Natuna	Passenger & Logistic	Dometic
27	Seaport Selat Lampa	Natuna	Passenger and Logistic	Dometic
28	Seaport Ranai Penagi	Natuna	Intergrated all	Dometic

Table 2. List of flight routes in Kepulauan Riau.

Airport to departure	Airport Destination	Route	Operator	Note
Bandar Udara Internasional Hang Nadim, Batam	Jakarta (HLP)	inter-provincial	Batik Air	Domestik
	Jakarta (CGK)	inter-provincial	Batik Air, Citilink (SEO), Garuda Indonesia (SEO), Lion Air, Sriwijaya	
	Padang (PDG)	inter-provincial	Cililink, Lion Air	
	Pekanbaru (PKU)	inter-provincial	Cililink, Lion Air	
	Palembang (PLM)	inter-provincial	Cililink, Lion Air	
	Pontianak (PNK)	inter-provincial	Cililink, Lion Air	
	Semarang (SRG)	inter-provincial	Lion Air	
	Surabaya (SUB)	inter-provincial	Lion Air	
	Bandar Lampung (TKG)	inter-provincial	Lion Air	
	Yogyakarta (JOG)	inter-provincial	Lion Air	
	Letung (LMU) Anambas	Intra-provincial	Wings Air	
	Pulau Jemaja (LMU) Anambas	Intra-provincial	Wings Air	
	Majalengka (KTJ)	inter-provincial	Lion Air	
	Dumai (DUM)	inter-provincial	Wings Air	
	Bengkulu (BKS)	inter-provincial	Wings Air	
	Kualanamu (KNO)	inter-provincial	Lion Air	
	Tanjungpinang (TNJ)	Intra-provincial	Wings Air	
	Natuna Ranai (NTX)	Intra-provincial	Sriwijaya Air	
	Subang / Kuala Lumpur (SZB)	Inter-National	Malindo Air	Internasional
Bandar Udara Internasional Raja Haji Fisabilillah, Tanjungpinang	Jakarta (CGK)	inter-provincial	Batik Air, Citilink Indonesia (SEO)	Domestik
Bandar Udara Raden Sadjad, Ranai, Natuna	Batam (BTH)	inter-provincial	Sriwijaya Air, Wings Air	Domestik
Bandar Udara Haji Abdullah, Karimun	Pekanbaru (PKU)	inter-provincial	Susi Air (Pioneer)	Domestik
	Dabo Singkep, Lingga (SIQ)	Intra-provincial	Susi Air (Pioneer)	Domestik
Bandar Udara Letung, Anambas	Batam (BTH)	Intra-provincial	Susi Air (Pioneer)	Domestik
Bandar Udara Mantak, Anambas	Tanjungpinang (TNJ)	Intra-provincial	Susi Air (Pioneer)	Domestik
Bandar Udara Dabo, Lingga	Tanjung Balai Karimun (TJB)	Intra-provincial	Susi Air (Pioneer)	Domestik
	Pekanbaru (PKU)	inter-provincial	Susi Air (Pioneer)	Domestik
	Jambi (DJB)	inter-provincial	Susi Air (Pioneer)	Domestik

Another issue related to domestic airports in the Riau Archipelago is that they are served by only 2-3 operators with irregular schedules, leading to island-to-island emergency situations relying more on sea transportation. As a comparison, the fast boat route from Batam to Bintan takes approximately 60 minutes.

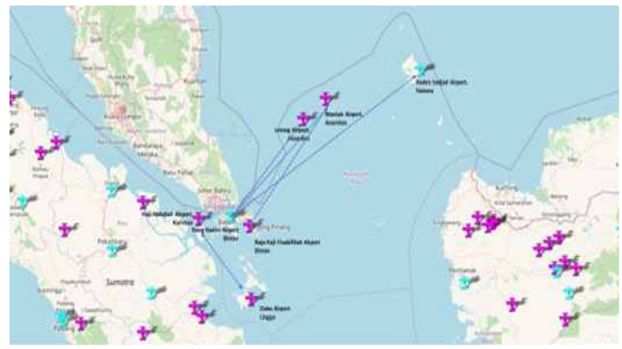

Fig. 1. Inter-Provicial Routine Route flight in Kepulauan Riau.

Susi Air
www.susiair.com
#ReachingTheUnreachable

SENIN,SELASA, RABU, JUMAT, SABTU, dan MINGGU

Rute	Keberangkatan	Kedatangan	Harga
Natuna - Pontianak	07.00 LT	08.45 LT	Rp 2.500.000
Pontianak - Natuna	12.15 LT	14.00 LT	Rp 2.500.000

SELASA dan SABTU

Rute	Keberangkatan	Kedatangan	Harga
Pontianak - Tambelan	09.15 LT	10.15 LT	Rp 1.500.000
Tambelan - Pontianak	10.45 LT	11.45 LT	Rp 1.500.000

MINGGU

Rute	Keberangkatan	Kedatangan	Harga
Natuna - Letung	12.15 LT	13.35 LT	Rp 1.950.000
Letung - Natuna	14.35 LT	15.55 LT	Rp 1.950.000

Fig. 2. Flight Schedule and price ticket of Susi Air in Kepulauan Riau November 2022.

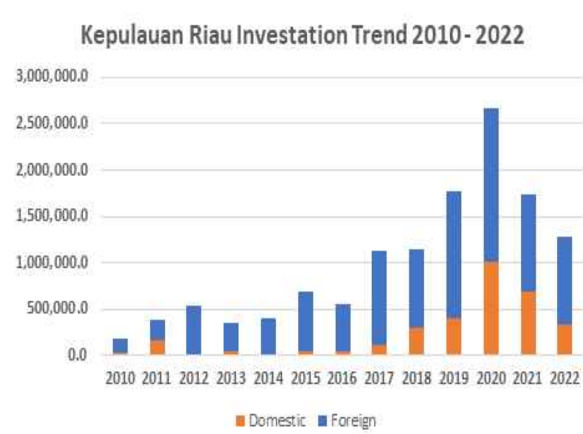

Fig. 3. Composition of Investment in Kepulauan Riau.

Table 3. Constribution of Investement in Kepuluan Riau.

Regional Investation (US$. K)	2015	2016	2017	2018	2019	2020	2021	2022
America	22,546.8	10,468.1	13,058.6	46,865.5	32,908.3	2,141.5	12,027.0	886.4
Africa	1,458.6	88.1	75,842.0	1,053.0	5,070.5	12,859.8	7,053.2	14,499.5
Australia	3,178.3	597.0	39,300.4	131,522.4	413.3	18,884.7	1,661.3	1,643.7
Asia	406,512.4	380,025.0	664,009.9	559,906.9	1,054,180.0	1,402,903.2	773,724.9	758,403.9
South Korea	783.0	14.5	2,427.7	674.4	146.4	506.9	1,474.5	212.1
People's Republic of China	5,047.0	21,318.7	9,248.4	22,967.3	35,697.9	39,771.4	101,592.0	29,260.6
Hong Kong (SAR)	106,916.4	2,868.8	55,297.1	16,749.2	149,875.8	5,004.4	7,828.6	29,811.8
runei Darrussalam		262.0	0.0	6.5	2.9	0.0	0.0	0.9
Singapore	233,635.0	317,413.5	444,994.3	474,103.8	694,983.9	1,307,226.5	585,005.2	600,036.1
Malaysia	12,141.5	12,987.6	140,439.4	28,442.0	147,194.3	15,264.3	28,167.2	44,700.9
Taiwan	102.0	2,315.6	3,507.9	472.7	17,819.7	22,484.2	20,496.3	41,392.6
Bangladesh	150.0			35.0			25.5	51.0
India	267.5	146.6	223.4	3,119.2	128.0	239.1	619.4	2,256.2
Myanmar		9.8	500.0					
United Arab Emirates				0.0			0.0	245.4
The Philippines			0.0		3.3	0.0	0.0	
Thailand	0.0	610.3	1,696.7	3,549.0	1,245.6	859.3	1.4	0.0
Japan	47,441.2	21,127.6	5,675.0	9,787.8	7,082.2	11,547.1	28,514.8	10,436.3
Afghanistan	28.8	0.0	0.0	0.0	0.0	0.0		
Pakistan		950.0						
Europe	20,871.0	127,899.5	239,327.9	91,900.1	270,792.9	212,576.0	249,219.1	158,607.8
Other	185,854.2							
Total Foreign Investatio	640,421.3	519,077.7	1,031,538.8	831,247.9	1,363,365.0	1,649,365.2	1,043,685.5	934,041.3

In addition to the aforementioned challenges and based on data from the Central Statistics Agency (2023) show several economic potentials that can be tapped into in the Riau Archipelago, which the economic structure of Riau Islands is primarily formed by manufacturing processing industries (27.00%), followed by agriculture, forestry, and fisheries (25.70%), mining and quarrying (19.46%), and trade (11.37%). Ministry of Investment Indonesia. (2024), Nasional Single Window Investment Data show investment in the Riau Islands from 2010 to 2022 has consistently shown an increasing trend, reaching its peak in 2020 with a total investment of 1.625 billion USD, making it the largest in the Sumatra regional area and ranking sixth nationally. Foreign investment dominates investment in the Riau Islands, contributing more than 81% of the total investment in the region. Upon closer examination, foreign investment flowing into the Riau Islands is predominantly from Asian countries, namely Singapo re, China, Malaysia, Taiwan, and Hong Kong

Based on data from the Ministry of Tourism and Creative Economy (2019), beyond the industrial sector, the region boasts a burgeoning tourism sector, which serves as a focal point for the local government's promotional efforts. Foreign tourist arrivals in the Riau Islands totaled approximately 2,864,795 individuals, representing 17.3% of Indonesia's overall foreign tourist visits. The composition of visits to the Riau Islands is dominated by tourists from Singapore, accounting for 48.5% of the total, followed by Malaysia with 10.6%.In addition to tourism for leisure, some tourists also visit private luxury

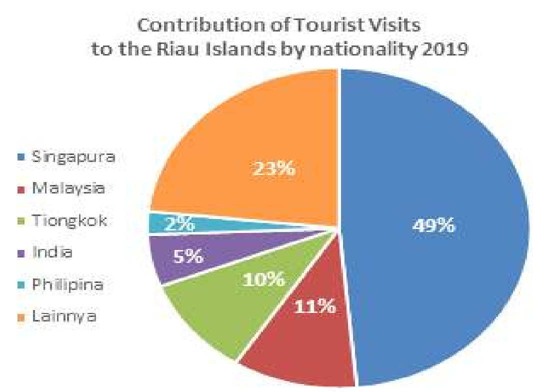

Fig. 4. Marine Fisheries Production Volume by Province 2022

islands such as Pulau Bawah and Pulau Nirup. Currently, access to these islands can only be done using helicopters or sea planes. Apart from the potential for luxury tourism, there are visits by engineers and experts to oil refineries around the Anambas Sea and Natuna Islands. This indicates an expanded tourism target sector, where they also visit and work in oil refineries around the Anambas Sea and Natuna Islands.

Given the extensive maritime expanse defining the Riau Islands, it stands as the second-largest contributor to marine catches in Sumatra. Specifically, it yielded 310,051 tons, constituting 22.5% of Sumatra's total marine catch. However, since 2018, there has been no significant increase in the export of fresh fish from the Riau Islands to surrounding regional countries, as indicated by graph 2 on Production and Export of Marine Fishery Products from the Riau Islands.

Fig. 5. Pulauh Nirup and Pulau Bawah, Kepulauan Riau.

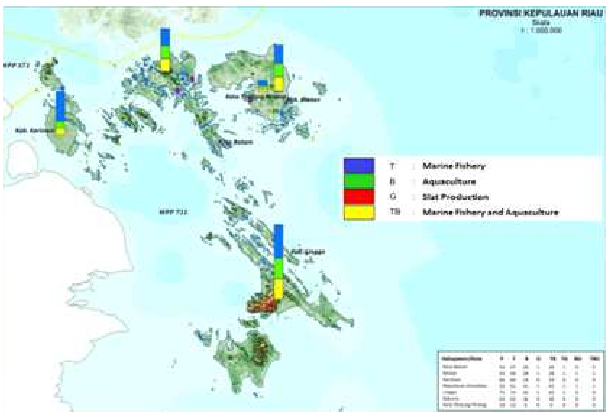

Fig. 6. Contribution of Fish product in Kepulauan Riau.

This may be attributed to the quality of fish, which deteriorates due to the long supply chain and the lack of cold storage facilities, leading to a decline in the quality of high-value marine products such as lobster, crab, shellfish, and some fresh fish.

Emergencies can also arise due to natural disasters, and transportation flexibility becomes crucial during such emergencies. In early 2023, an earthquake occurred in the Natuna Islands. Issues arose when the airstrip was damaged due to the quake, limiting the delivery of medicine and medical personnel, which could only be carried out via sea or airdrops.

Currently, the National Search and Rescue Agency (Badan Nasional Pencarian dan Pertolongan Bencana alam) has approximately 18 helicopters to serve emergency responses throughout Indonesia, despite around 3,500 natural disasters occurring in Indonesia each year (Data Bencana Informasi Bencana Indonesia, 2024). Geographically, the Riau Archipelago also serves as the forefront in safeguarding Indonesia's sovereignty in the South China Sea, where conflicts are currently occurring in several countries in the ASEAN region. Budgetary constraints, fleet limitations, and personnel shortages also pose challenges for maritime security along the borders, which are also experienced by the Indonesia Coast Guard in border surveillance. Both of these issues, the lack of emergency fleet and security, are currently supplemented by assistance from the Air Force, local governments, and/or private entities. However, this situation cannot be considered a permanent strategy; There needs to be a solution that can address the gaps in multifunctional emergency transportation in Indonesia

The development of connectivity based on physical infrastructure often requires significant financial investment and time, leading to potential delays and budget overruns, particularly for large-scale projects. Budget allocation is also necessary annually for maintenance and upkeep. The limitation in budget spending determines the direction of development in each period, based on the prioritization of cost impact and benefits. As an illustration, the realization of total infrastructure budget absorption in the Riau Islands reached Rp751.88 billion, or 33.89% of the total regional expenditure. In 2020, land connectivity in the Riau Islands was allocated Rp158.22 billion (21.0%), while maritime connectivity amounted to Rp84.4 billion (11.22%), and air connectivity was allocated Rp36.74 billion (4.88%). The majority of these budgets were focused on the improvement and capacity enhancement of existing infrastructure (Ministry of Finance Indonesia, 2021). This indicates that despite the significant allocation of funds for infrastructure development and connectivity in the Riau Archipelago, it has not been able to solve issues such as loss coverage of development and geographical challenges.

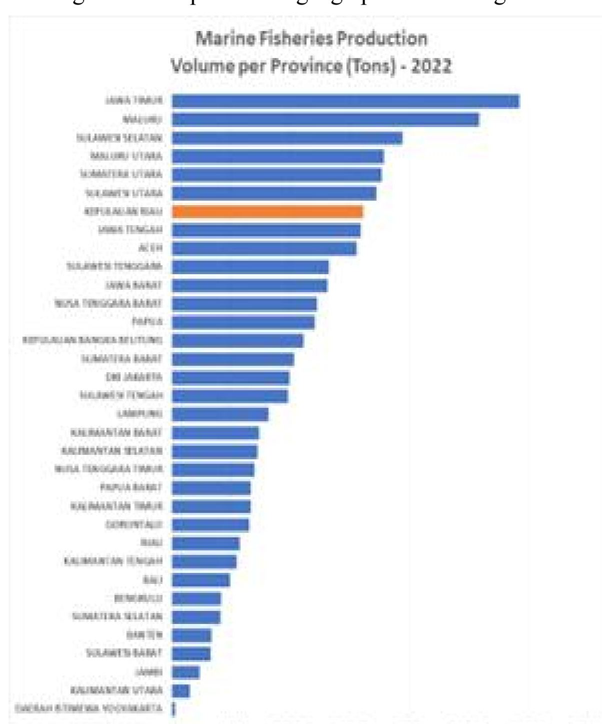

Fig. 7. Marine Fisheries Production Volume by Province 2022.

Fig. 8. Production and export of Marine Fisheries in Kepulauan Riau

The development approaches for water/seaports and the expansion of transportation modes in both sectors have not met the transportation needs, emergencies, and security requirements in the Riau Archipelago. On the other hand, economic growth has led to increased demand for transportation with lower initial purchase costs, broad coverage, easy maintenance, and operational requirements that do not necessitate expensive and extensive infrastructure.

Advanced air mobility (AAM) could serve as an alternative solution to address the missing gaps in the "Kepuluan riau"s logistic transportation system by serving as environmentally friendly, competitive logistic and passage cost, easy-to-operate and maintain transportation options with broader coverage, this includes reducing congestion through spot-to-spot connectivity, providing last-mile connectivity, ensuring accessibility to remote or underdeveloped areas, and serving as emergency response and disaster relief vehicles.

2-2 Advances in aviation technology

AAM is an expanding domain, concentrated on the advancement of aerial transportation systems tailored for integration into urban landscapes, offering swifter, more effective, and eco-friendlier transportation alternatives.

The overarching goal of AAM is to furnish a rapid, more streamlined, and environmentally sustainable mode of transportation, particularly within densely populated urban regions. Although still in its nascent phase, AAM technology has garnered significant interest from numerous enterprises, including major aerospace companies and start-ups, as well as standards (IEEE,2023), are investing in the development of e-VTOL vehicles and related infrastructure, such as charging stations and landing pads [5].

The advanced air mobility (AAM) technology is the beginning of life of product, with numerous companies and research actively involved in the development and testing. These innovative aircraft are engineered to surpass traditional helicopters and airplanes in terms of speed, safety, and efficiency. Emerging propulsion technologies, including electric and hybrid motors, are currently being researched and developed for aircraft. Electric motors offer a simpler design with fewer moving parts compared to traditional internal combustion or turbine engines. This reduction in complexity is anticipated to minimize single points of failure and the potential for malfunctions or fatal accidents. Modern aircraft designs are integrating multiple electric motors with redundant power sources to enhance overall safety [4].

Furthermore, electric propulsion systems have the potential to significantly decrease aircraft noise pollution and lessen reliance on carbon-based aviation fuels. Alongside these advancements, hydrogen engine concepts are also under exploration. They incorporate electric propulsion systems, cutting-edge materials, and autonomous technologies. Automation plays a crucial role in reducing operator workload and optimizing air traffic management. For instance, aircraft autopilot systems have substantially enhanced operational safety by mitigating the risk of mid-air collisions. Despite the portrayal of fully autonomous vehicles in the media, in the foreseeable future, most aircraft will continue to be piloted by FAA-licensed pilots within the existing airspace management and operational framework (U.S Department of Transportation, 2023). Nevertheless, numerous companies developing AAM vehicles aspire to eventually operate their vehicles remotely, leveraging highly automated systems. Promising a revolutionary level of mobility that could reshape transportation in the years ahead. In the future, these air mobility vehicles aim to offer swift and efficient transportation solutions in urban settings, particularly for short-to-medium distances. Various types of such vehicles are under development.

These designs represent fundamentally different design concepts. Multiple publications provide overviews of the different technical specifications and characteristics associated with eVTOL aircraft (e.g., see Roland Berger, 2018; Porsche Consulting, 2018). The Vertical Flight Society (VFS) provides one of the more thorough overviews of the different types of eVTOL aircraft and maintains a database of known eVTOL designs. According to VFS, as of March 5, 2020, there were a total of 260 aircraft6 that included 99 vectored thrust, 39 lift + cruise, 26 wingless multicopters, 46 hover bikes/ flying devices7 and 20 eHelos and eGyros. Across these designs, there are large variations in the number of seats, speed, and range.

The adoption of AAM is anticipated to yield advantages such as alleviating traffic congestion, enhancing connectivity and accessibility, and mitigating carbon emissions stemming from ground transportation. Moreover, Concerns regarding the safety and noise levels of AAM vehicles, as well as their influence on urban environments, are also prevalent. The vehicle mostly considered for AAM operations is an e-VTOL aircraft capable of carrying passengers and air cargo with a limited capacity. Like any other flying platform with humans on board and flying over human living areas, AAM vehicles necessitate a robust and sophisticated communication, navigation, and surveillance (CNS) system [2]. To ensure safe operations and to avoid life-threatening accidents. When it comes to autonomous and beyond visual line of sight (BVLOS) flights in future, the reliability and robustness of the communication link between the AAM vehicle and ground control stations is the key factor in safe AAM operations. The AAM vehicle flies through controlled and uncontrolled airspace. When flying through controlled airspace, The vehicle must maintain communication with ground-based air traffic management (ATM) entities and adhere to their directives.

Table 4. AAM vehicle type base on energy source.

Vehicle Type	Range (Km)	Payload Capacity (Kg)	Max Speed (Kmh)	Altitude (m)
Electric Multicopper	50	100	160	2000
Hybrid Tiltrotor	400	1000	300	4000
Electric Fixed-Wing	100	500	200	3000
Hydrogen Fuel-Cell Multicopper	200	150	120	2500
Gasoline Combustion Fixed-Wing	500	1000	300	5000

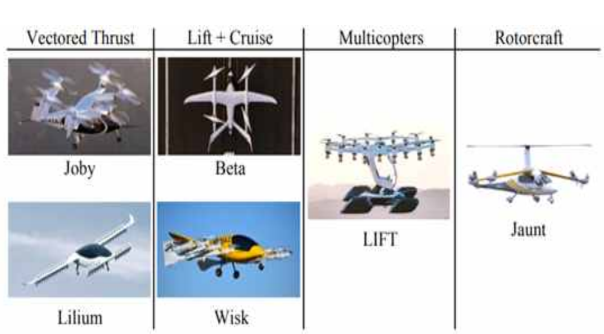

Fig. 9. Type of AAM base on Type of rotor.

For reference and comparison, the following table presents a comparison of established modes of transportation in Kepuluan Riau used for inter-island connectivity, with the comparison limit being transportation modes for a maximum of 4 passengers. Infrastructure development utilizes historical data, while travel speeds are measured in kilometers per hour.

Advanced air mobility (AAM) technology, particularly with electric-Vertical Takeoff and Landing (e-VTOL) capabilitie s, is its applicability in island regions. This technology enables aircraft to perform vertical takeoffs and landings, eliminating the necessity for extensive runway infrastructure. This aspect proves particularly advantageous in island environments where land availability may be limited and constructing lengthy runways is impractical or prohibitively expensive. Furthermore, AAM vehicles equipped with VTOL capabilities can easily access remote and inaccessible areas. In island regions, where certain areas may be rugged or inaccessible via traditional modes of transportation, VTOL aircraft offer efficient and swift transportation alternatives. Moreover, AAM technology facilitates point-to-point connectivity, enabling direct and efficient travel between various islands or remote locations. This has the potential to significantly reduce travel durations and enhance accessibility in island regions, where inter-island travel may presently be time-consuming and inconvenient. In summary, the versatility, flexibility, and efficiency of AAM technology with VTOL capabilities render it well-suited for addressing the unique transportation challenges encountered in island regions.

As an archipelago area and with budget constraints, AAM with e-VTOL can serve as an alternative solution to enhance transportation services in the Riau Archipelago, offering a variety of options and the best modes for each case.

Table 5. Comparison table of current transportation in Riau Islands.

Transportation Mode (Passager)	Infrastructure Cost (Portin.000USD)	Price Cost (.000USD)	Emission Production (per litter fuel, kg CO^2)	Speed (kmh)	Noise (dB)
Small Airplane (1-8)	750~2.500	600~ 3.500	20~34	250~ 500	70~90
Helicopter (1-8)	0~150	1.500~ 7.000	3.16	200~ 250	80~110
Speed Boat (1-30)	0~80	0.35~ 160	7~8	20~65	70~140
AAM (electric) (1-4)	0~150	500~ 1.000	0	100~300	40~65

AAM technology has the potential for point-to-point connectivity, offering several advantages in problem-solving: (1) Providing efficient transportation for fishery products, enabling quick and direct delivery of seafood from remote islands to markets or processing facilities. This can reduce transportation time and costs, ensuring fresh and high-quality products reach consumers. (2) Facilitating the transportation of raw materials and finished goods between islands and main manufacturing facilities. This can streamline supply chains, reduce logistics costs, and support the growth of manufacturing activities in the region. (3) AAM services can cater to the transportation needs of the luxury tourism sector, offering exclusive and efficient travel options for high-end tourists visiting the islands. This can enhance the tourism experience and contribute to the development of luxury tourism infrastructure in the region. (4) Enhancing border surveillance and security operations in the South China Sea region by providing aerial reconnaissance and monitoring capabilities. Rapid deployment of e-VTOL aircraft can support maritime patrols, border surveillance, and emergency response efforts, bolstering security measures in the area. (5) Providing rapid transportation of personnel, equipment, and supplies to affected areas. e-VTOL aircraft can access remote and inaccessible locations, enabling swift and efficient emergency response operations.

From the connectivity issues previously outlined in Kepulauan Riau, including budget limitations for infrastructure, difficulties in ground infrastructure development, limitations and lack of diversity in transportation modes, coupled with the scarcity of routine inter-island routes, can be resolved by leveraging the advantages of various transportation modes. These include infrastructure development that doesn't require extensive land or large budgets, the ability to conduct spot-to-spot connectivity without the constraints of routine flight route permissions, such as the advantages offered by helicopters, low maintenance costs due to operational simplicity, fast access speeds to facilitate logistics, and multi-purpose adaptability for various needs, as seen in small-capacity aircraft. Additionally, as a commitment to environmental preservation and transportation sustainability , this new form of transportation must utilize environmentally friendly energy sources and exhibit low air pollution. In this regard, AAM possesses nearly all the advantages required by the Riau Islands to expand inter-regional connectivity, especially inter-island transportation.

As a branch making in the development of the ecosystem of the Indonesian Government or more specifically Local government of Kepulauan Riau, referring to airworthiness authorities negara lain yang sudah lebih dulu meluncurkan strategy pengembangan industri AAMnya such as the United States Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) are currently in the process of establishing safety standards, or utilizing interim standards, for certain aircraft. With the aviation sector being relatively nascent, it is anticipated that commercialization will commence by 2025, with full-scale expansion projected between 2030 and 2035.

This timeline accounts for the necessary adherence to safety standards encompassing aircraft, flight operations, and infrastructure, alongside the requisite certification processes. Additionally,August 2019, the Ministry of Land, Infrastructure, and Transport (MOLIT) of South Korea established the 'Future Drone Traffic Officer,' conceived as a venture entity tasked with identifying and advancing innovative initiatives as part of the government's innovation agenda.

This organization is dedicated to urban air transportation and has convened a technical committee comprising experts from industry, academia, research institutions, and governmental bodies. The committee's objective is to identify emerging issues and tasks within the realm of air transportation. Through this strategic roadmap, the government has outlined its primary objective of introducing commercial services within the next 25 years. It has also delineated a phased approach, beginning with flight demonstrations in 2024 and progressing towards full-scale commercialization by 2030.First of all, focus on the action plan to introduce the first service connecting the base and the base in 2025, Leap to a leading country in urban air transportation.

Looking ahead, both the FAA, EASA and MOLIT are focused on advancing the regulatory framework for UAM and AAM to enable safe and efficient integration of these technologies into urban environments. This includes ongoing collaboration with industry stakeholders, continuous refinement of certification standards, and the development of scalable air traffic management solutions capable of handling the increased complexity of urban airspace. As UAM and AAM technologies mature, regulatory agencies will play a crucial role in ensuring that these innovations deliver on their promise of enhancing urban mobility while upholding the highest standards of safety and reliability.

Build a new paradigm of time and space, Accelerate creation of future connectivity methods by presented three visions, (1) Government support for privately-led initiatives, (2) Construction of a new institutional framework rather than the existing safety and transportation system framework, and (3) Application of global standards to induce advancement and growth in advanced industries. The main promotion contents according to the three basic directions are as follows.

2-3 Provide comments for application

Since AAM is a 'new concept of air transportation' that requires the development of almost everything, it suggests that development through international cooperation is efficient. Advanced Air Mobility, specifically e-Vertical Takeoff and Landing, is a novel global technology. It is vital to assess infrastructure readiness, including Vertiports, air traffic control, charging systems, and power supply. Additionally, the preparedness of human resources and the formulation of policies for AAM and e-VTOL development are crucial. Cybersecurity should also be considered as a key element for autonomous technology readiness. Diversifying air transportation not only opens up investment opportunities but also fosters collaboration in research and development. Indonesia, with its market and infrastructure, can play a significant role in the global aerospace industry.

Presenting efficiency measures through cooperation with Korea (K-UAM), which is actively promoting utilization and commercialization at the national level. Assistance, guidance and comparative studies in conducting research and piloting projects, Indonesia aspires to be a partner and branch maker country like South Korea due to South Korea already having a trihelix ecosystem of Advanced Air Mobility from the Ministry Land, Infrastructure, and Transport's announcement of the "Korean urban air mobility (K-UAM) Roadmap" outliners a step‑by-step goal for preparing for the full scale commercialization of UAM in the long term and transfer knowledge through research and development are being carried out by various institutions such as the Korea aerospace research institute (KARI), electronics and telecommunications research institute (ETRI), Korea Transport Institute (KOTI).

Ⅲ. Conclusion

Advanced air mobility (AAM) with electric vertical take-off and landing (e-VTOL) systems presents a compelling alternative to traditional transportation methods, especially in island regions like Kepulauan Riau, Indonesia. The advantages of AAM over conventional modes of transportation are manifold. AAM offers swift, efficient, and environmentally friendly transportation options, overcoming the challenges of budget constraints that governments often face in island regions, leading to the need for prioritization and limitations on infrastructure development . By utilizing e-VTOL capabilities, AAM enables direct point-to-point connectivity, reducing travel durations and enhancing accessibility to remote or underdeveloped areas that require large-scale and high-cost infrastructure and fill the gaps where traditional transportation modes may be impractical or unavailable. Moreover, the versatility of AAM technology provides solutions for various transportation needs, including passenger transportation, logistics and luxury tourism

Positioning AAM within the Kepulauan Riau highlights its potential as a pivotal solution to enhance transportation services in the region. Integrating AAM with existing transportation modes can improve inter-island connectivity through point-to-point transportation, which is expected to have a domino effect supporting economic growth. Additionally, AAM can serve as a multipurpose transportation mode facilitating emergency response and strengthening border security. This integration also offers cost-effective, easy-to-maintain, and environmentally friendly transportation options compared to small aircraft and helicopters that still rely on fossil fuels, thereby aligning with the region's sustainability goals. Furthermore, the adoption of AAM can drive innovation and job creation in the aerospace industry, further solidifying the positioning of the Kepulauan Riau as a hub for advanced transportation technologies in Southeast Asia.

Create a novel framework for understanding time and space, hasten the development of future connectivity approaches through three proposed visions, Encourage governmental backing for privately-driven ventures, Establish a new institutional structure instead of relying on the current safety and transportation system framework, and Implement international standards to stimulate progress and expansion in advanced industries. The primary promotional themes aligned with these three fundamental directives are outlined below. To fully realize the potential of AAM, governments at both national and provincial levels should prioritize the readiness and development of AAM infrastructure, such as communication networks, airspace systems, radar, sensors, battery charging facilities, power supply, hangars, public vertiport construction, and so forth. Additionally, regulations need to be formulated, including safety and cybersecurity standards, technical specifications for vertiports, certification of operations, and flexible route licensing .

Collaboration with international partners, such as South Korea, the US, and the EU, can facilitate knowledge exchange, operational preparedness projects, and regulatory alignment to expedite AAM adoption and commercialization. Furthermore, investment in AAM research, development, and operational projects should be encouraged to evaluate feasibility, safety, and scalability in island regions like the Kepulauan Riau .

Looking ahead, future research should delve deeper into the feasibility and impact of AAM integration in island regions, exploring infrastructure requirements, operational models, economic viability, and environmental sustainability . Studies should also assess the socio-economic benefits of AAM adoption, including job creation, tourism growth, supply chain optimization, and disaster resilience. Collaboration between academia, industry, and government stakeholders will be essential to drive innovation in AAM technology, airspace management, safety standards, and regulatory frameworks. Overall, embracing AAM technology presents a transformative opportunity for Kepulauan Riau to overcome transportation challenges, enhance connectivity, and foster sustainable development in the region, paving the way for a brighter future for island communities.

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