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Original Article

Development in Airport Runway Expansion: The Rendani Airport Case Study, Papua

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Abstract *- The research examines the runway development at Rendani Airport in West Papua to determine essential strategic elements for expansion. The current 2300-meter runway at Rendani Airport serves only limited operations because it cannot accept bigger aircraft. The research fills an infrastructure gap by analyzing how a longer runway would help airlines use bigger planes and increase airport operations while boosting regional development. A SWOT analysis of runway development connects its strengths and weaknesses with its external opportunities, threats, and internal variables. The information gathered from interviews combined with field observations and secondary data sources yielded complete insights into present airport conditions. The airport benefits from its dominant position as the top regional airport, which creates substantial grounds for business progress and tourism expansion. The airport faces crucial obstacles made up of inadequacies regarding land availability, interference from local groups and persistent crosswind conditions. The research outcome suggests the airport should increase its runway length to 2500 meters and double down on safety improvements while forming a land solution strategy by uniting stakeholders with governmental backing. The recommendation involves introducing environmentally friendly operations to build Rendani Airport into a sustainable, nature-friendly aviation facility. The evidence studied shows that proper collaboration between relevant parties ensures the proper development of the airport according to its master plan design.*

Keywords *- Airport, Extension, Indonesia, Papua, Runway.*

1. Introduction

Air transportation functions as a vital industry that allows regional people and goods transportation through its vital speed advantage over alternative transport methods [1]. The pivotal position of airports in air transportation development supports the aviation sector with the infrastructure needed to manage aircraft operations and services for passengers and cargo activities [2]. The national aviation regulations define an airport as an area built either on land or water with specific purposes for aircraft operations as well as passenger transfer and cargo handling and intermodal connection between transportation systems [3]. The definition demonstrates the multiple layers of airport development because it focuses on both physical site arrangements and airport economics, sustainable environmental agendas, and transportation network coordination. All elements form a cohesive system that mandates authorities implement an integrated airport management method [4].

Airports throughout Indonesia receive management through the combined efforts of Airport Business Entities (BUBU) and Airport Operation Units (UPBU). Commercial airport management falls under BUBU jurisdiction, but UPBU handles airport operations at all facilities still under government leadership. The UPBU controls Rendani Airport, located in Manokwari, which functions as a facility for the Directorate General of Civil Aviation within the Ministry of Transportation. Rendani Airport enables regional expansion by delivering connection services to several local destinations [5]. Rendani Airport gained its establishment under Dutch rule in Papua. The facility has progressed throughout time to become a vital regional infrastructure asset. The airport stands in four different geographical settings which include coastal regions with mangroves together with artificial land areas along with residential hill communities and densely inhabited plains. Several environmental constraints make constructing this site difficult [6].

Presently, Rendani Airport receives around 20 aircraft each day while serving regular flights between Sorong, Jayapura, Biak, Makassar, Jakarta, and Surabaya and conducting unscheduled and pioneering routes [7]. The

2,000-meter runway at Rendani Airport cannot support Boeing 737-900ER aircraft operations when they approach maximum load capacity. Safety requirements force payload limitations, which demonstrate the necessity to extend the runway to comply with the 2,470-meter requirement from Aeroplane Reference Field Length (ARFL) [8]. The main requirement for runway extension involves proper adherence to runway strip specifications. The runway strip needs a structural expansion from its present width of 140 meters to reach 280 meters according to the 2022 master plan specifications. Running installation facilities while procuring new lands constitutes the essential step for this expansion process. The procedures to address land acquisition problems through negotiations and agency coordination with local communities have not resolved all issues, which continue to cause difficulties during development [9].

Two potential extensions exist for the runway at Samos International Airport through either sea expansion at Runway Threshold 35 or residential expansion at Runway Threshold 17. The second option emerged as the preferred choice because it matched the master plan of the airport following extensive research. Evaluation of this decision depends on social effects and environmental aspects as well as cost and operational feasibility and assessment of environmental conditions. Operational challenges at this airport become more complicated due to its position along with unpredicted weather patterns in addition to recurrent tailwinds. Historical incidents reveal that these safety and reliability issues must receive immediate attention because they enhance operational security.

The development blueprint for Rendani Airport needs 151.13 hectares, while the existing certified holdings amount to 135.3 hectares, together with the recent 5.5-hectare donation from the Manokwari Regency Government. Progress is continuing for additional land acquisitions, yet the land ownership disputes have caused implementation delays.

The development of Rendani Airport depends heavily on road access upgrades and utility switching services, which require active collaboration between different community members. Sustainable growth of the airport requires simultaneous protection of environmental ecosystems in coastal zones. Operations and construction plans need sustainable practices for sustained compliance and long-term ecological sustainability.

This study employs a SWOT analysis to evaluate the strengths, weaknesses, opportunities, and threats associated with the runway extension project. Additionally, in-depth interviews with relevant stakeholders and secondary data analysis provide insights into actionable strategies for developing Rendani Airport in alignment with safety standards and sustainable development goals.

Global efforts toward sustainable infrastructure growth through Eco Airport development have not bridged the knowledge gap while dealing with regions requiring distinct geographical and social along with economic considerations. Most literature about Eco Airports exists for developed cities in regions with solid basic infrastructure and effective governance systems. Very little research exists about the particular obstacles and advantages that arise from developing infrastructure in remote settings such as Papua. The analysis investigates the growth of Eco Airports in Papua, where its specific features make this Indonesian region unique compared to other national territories. The physical makeup of Papua creates major problems for transporting goods and protecting the environment. Papua transforms into a complex development territory because it contains extensive mountain regions, dense rainforests, and restricted passage routes. The complex nature of Papua development avoids major urban construction methods because the region demands revolutionary solutions to sustainable growth. The airport development process requires special caution because of Papua's abundant biodiversity to maintain balance in local ecosystems.

Development in Papua brings distinctive features due to its socio-cultural environment. Indigenous communities in this area show deep ties to their land and natural resources because of their cultural heritage. Papua's infrastructure initiatives, particularly those of airports, need to factor in traditional practices and property patterns and active community involvement for development standards that fully benefit the local people. Large-scale projects encounter community opposition in many situations because they fail to respect local values and community requirements. Papua must overcome serious economic obstacles that create difficulties in obtaining infrastructure funds that ensure long-term sustainability.

Due to its status as one of Indonesia's regions with limited economic development, the financial and technological support needed to implement Eco Airport initiatives has become more restricted than in other parts of the country. The necessity emerges to develop specified solutions which address Papua's economic conditions yet continue pursuing sustainable and environmentally conscious airport development.

The present research investigates optimal implementations of the Eco Airport concept to address its local adaptation in Papua through the mentioned considerations. The research addresses geographical, socio-cultural and economic challenges to supply recommendations supporting sustainable practices, environmental protection, and local development necessities. By achieving this goal, the study adds to the complete framework of sustainable airport development across different challenging environments.

2. Literature Review

2.1. Overview of Airport and Runways

Assets known as airports perform an essential function in the national transportation system because they enable both people and freight to travel by air. Within the framework of transportation infrastructure, government agencies collaborate with private entities to deliver public facilities, which include roads, railways, and seaports alongside airports, to promote connectivity and economic expansion. Airports carry out various essential roles by operating as interconnecting points of transportation infrastructure alongside economic entry points and transit points for multipurpose transportation and drivers of industrial and commercial expansion. Border areas gain significant development through their features, and the nation serves its sovereignty through airport infrastructure during disasters [10].

The annual passenger volume shapes how airport facilities belong to different classification levels. Secondary hub airports receive more than five million annual passengers as they serve National Activity Centers (PKN). Secondary hub airports welcome passengers in numbers ranging from one to five million per year and maintain services for both PKN and Regional Activity Centers (PKW). In contrast, tertiary hubs support passengers traveling between 500,000 and 1,000,000 per year. Spoke airports function exclusively for local needs while sustaining restricted economic development together with their service for hub airports. Austin Bergstrom International Airport and other facilities get their type through operational capacity assessments, which determine their limit for aircraft types and annual passenger numbers. Code numbers indicate runway length through Reference Field Length (ARFL), while code letters connect to the aeroplane wingspan alongside the landing gear's maximum reach [6].

The airport functions through two separate operational areas named landside and airside. All airside features are flight operation facilities with restricted entry for authorized personnel through mandatory security protocols [11]. All passenger and freight activity occurs at the passenger terminals, cargo terminals, control towers, administrative spaces, and parking facilities that connect the rest of the world with the airside through the landside facilities. The landside facilities contain necessary facilities for fuel storage alongside maintenance capabilities and waste management mechanisms [12].

At air facilities, runways represent essential rectangular zones that serve as landing and takeoff areas for aircraft. They are divided into two categories based on instrumentation where instrument runways provide visual and non-visual approach assistance during all weather conditions [13]. Non-precision approach runways exist as one segment of instrument runways, while precision approach runways split into three categories, I, II and III, depending on their decision height and runway visual range minimums. The non-instrument category of runways operates for both visual approaches and intermediate procedures between instrument-based approaches and visual meteorological conditions [14]. The runway strip, consisting of the runway and applicable stopway segments, safeguards aircraft overruns while providing safety protection during flight takeoff and landing operations. Security requirements determine all strategic elements of the strip through the runway code. Operating facilities at airports rely on declared distances to communicate essential safety parameters that comprise Takeoff Run Available (TORA) along Takeoff Distance Available (TODA), Accelerate-Stop Distance Available (ASDA), and Landing Distance Available (LDA). The parameters act as key pieces of information that create safe operational conditions while also making airports function better [15].

2.2. Sustainable Development Goals (SDGs)

The SDGs organize a complete system for attaining sustainable development by maintaining harmony between economic expansion and societal fairness while safeguarding natural resources and delivering sound administrative oversight. The objectives focus on maintaining durable enhancements in quality of life between different worldwide generations [16]. The sustainability concept underlies the SDGs, which require joint economic and social development treatment with environmental priorities to promote prolonged development. The world community united behind seventeen universal goals that outline solutions for urgent worldwide problems to create lasting and fairer societal infrastructure. The SDGs set the elimination of poverty in its entirety as their core priority because poverty elimination creates necessary conditions for achieving broader development objectives. The accessibility of enough nutritious food must be promoted through hunger elimination and food security enhancement with sustainable agricultural practice advancement [17]. The initiative promotes universal healthcare service accessibility and advances well-being throughout the lifespan for all ages. Education functions as a transformative instrument that receives attention through actions that deliver inclusive and equitable quality education while ensuring lifelong learning chances for everyone [18].

SDGs declare gender equality essential to development by demanding stronger empowerment of women together with girls. Clean water access alongside proper sanitation facilities together with sustainable water management systems lies essential for maintaining public health while securing environmental protection [19]. Accessible, reliable, sustainable, modern, and affordable energy sources serve as a promotional factor for economic growth, together with enhanced living standards. Economic growth with inclusive

features, together with the generation of productive work opportunities and the provision of decent jobs, serve as fundamental elements for diminishing social gaps and enhancing community resistance. Sustainable development depends heavily on infrastructure development since it enables resilient and sustainable practices with inclusive industrial models while motivating the advancement of new ideas [20]. Fighting both internal and international inequality stands as the fundamental step for establishing balanced societies that are based on justice. The SDGs establish a fundamental goal to create inclusive, safe, sustainable urban areas because globalization continues to generate urban populations at an accelerating pace. Sustainable production, together with consumption patterns, receives support to reduce environmental destruction and maximize resource productivity [21].

The advancement of the United Nations Sustainable Development Goals relies on immediate action against climate change alongside its effects because of worldwide warming requirements [22]. The goals focus on marine resource conservation for ecosystem protection and the need to protect land ecosystems through biodiversity restoration, sustainable forest management, and combating land degradation [23]. The SDGs support creating peaceful, inclusive communities through the establishment of accountable institutions together with access to justice systems. Global partnerships need strengthening according to the recognized need to unite resources with knowledge and technology toward achieving these objectives. The SDGs unite different priorities through a unified framework, which creates a substantial development plan that ensures both human progress and environmental sustainability.

2.3. Eco-Airport

A proper Eco Airport features environmental management practices by systematically measuring environmental factors that affect its surroundings. The approach protects the airport zone environment through dedicated measures for addressing essential environmental issues. The planning process of Eco Airports focuses on pollution prevention, which integrates sustainability goals to develop and operate transportation facilities while supporting environmental care [10]. Different elements support the Eco Airport framework, including noise reduction, air pollution control and water pollution management, soil contamination mitigation, waste management, energy efficiency and adherence to aviation safety zones [24].

The reduction of noise relies on technological advances together with soundproofing materials and aircraft flight path optimization to decrease airport-related disturbance for nearby residents. Traffic control strategies at airports work to reduce pollution from aircraft together with ground traffic in addition to airport-related activities through sustainable fuel usage, renewable energy deployment, and operational optimization. The implementation of water and soil pollution management focuses on treating wastewater correctly and preventing dangerous spills that harm local ecosystems. The waste management approach of Eco Airports includes responsible hazardous waste management combined with recycling operations and a reduced landfill disposal rate. Eco Airport's central priority focuses on energy management because it implements renewable sources together with efficient technologies and sustainable building methods to decrease airport emissions [25].

The core component of an Eco Airport embraces safety measures through the establishment of Aviation Safety Zones referred to as "Kawasan Keselamatan Operasi Penerbangan" (KKOP). The airport maintains three designated territories that protect safe flight operations through KKOP. The Kawasan Keselamatan Operasi Penerbangan (KKOP) contains various elements that consist of the approach and takeoff zones together with crash hazard zones, transitional surfaces, and horizontal and conical surfaces. The flight path zones operate with specific safety guidelines that manage potential threats from obstacles and environmental threats through height and distance regulations protecting aviation performances. The management tasks of KKOP include protecting both airspace and water and ground usage, which affect aviation operations. Utilizing these zones should avoid damaging navigation signals and, creating visual hazards for pilots and causing either glare or reducing airport visibility areas. The process requirements serve as essential elements to guarantee operational efficiency along with safety performance [6].

Eco Airports combine complete airport development practices with environmental sustainability together with safe aviation performance and functional efficiency. Sustainable development of aviation services occurs through environmental challenge resolution and preventive procedures at Eco Airports that produce safer transportation with greater operational efficiency.

2.4. Research Gap and the Challenges of Papua

The literature review of airport infrastructure, including airports, runways, and eco-airports, demonstrates an academic deficiency in implementing these systems, particularly in Indonesian and Papuan territories. Airport infrastructure development has failed to match increasing travel needs in various Indonesian zones, especially distant regions such as Papua. The inadequate development goes past fundamental infrastructure to incorporate questions about safety practices, accessibility requirements, and environmental responsibility [25]. The airport development challenges in Papua become harder to overcome because of its difficult terrain, poor infrastructure, and remote geographical position. The repeated problem lies in airport

runways when many Papua airports lack international certification standards because their installations do not meet specifications for bigger airplanes, thus restricting economic and accessibility potential. Installing eco-airports as sustainable facilities using energy-efficient and waste-reduction practices remains challenging to achieve at present [26].

Implementing eco-friendly airports is limited in Papua since environmental needs compete against necessary development priorities [27]. The shortage of research about Papua's airports creates additional problems as specialists need to develop customized solutions that handle environmental issues together with socio-economic needs. Solving this infrastructure deficit necessitates upgrading facilities and improving knowledge of sustainable airport planning and construction, considering the distinct obstacles Papua's airports must handle.

Numerous investigations have studied how conservation affects Indigenous Peoples and local communities, but a substantial gap exists between the planned policy objectives and the implementation procedures in the field [28]. Local Papua Province residents feel mistreated, dissatisfied, and confused because park managers have failed to consult them over many years of conflicting development projects that lack proper funding. Research must focus on precise examinations of actual conservation policy effects on social groups residing near protected territories [29]. Several investigations indicate that the OTSUS Special Autonomy policy achieved limited success regarding a better socio-economic framework and improved trust relations between Papuans and the Indonesian government. The OTSUS policy faces criticism because it does not effectively interact with local needs, and customary leaders receive no say in decision-making roles. Studies lack sufficient research to demonstrate how effective these policies prove toward their desired results. The transmigration program launched across different regions has encountered opposition because of its negative environmental effects, together with its social consequences [30].

Soil erosion and deforestation represent harmful environmental consequences connected to the transmigration program, as the scheme has drawn criticism for its insensitivity toward local cultural land ownership [31]. Additional, comprehensive research is needed to fully measure transmigration's long-lasting negative effects on environmental conditions and native populations. Studies have yet to adequately study the wellness differences between local residents and new residents in Papua [32]. Research demonstrates that newcomers report lower well-being results compared to local populations, but the foundation of this and possible remediation methods remain unclear. Research ought to explore the fundamental causes behind this inequality between native and immigrant groups because it necessitates studies that suggest methods to build stronger social alliances and equal rights. Research shows that limited investigation exists about how Papua's local communities are affected by actual policy execution [33].

Additional research requires examination of actual policy implementation and their associated effects on target populations because current research only analyzes documents. The closing of these gaps will lead to the development of superior conservation approaches and governance mechanisms that deliver actual benefits to Indigenous populations throughout Indonesia particularly in Papua territory.

The research presents an innovative approach to developing Eco Airports by applying them to Papua's specific situation since this region lacks detailed studies about sustainable airport development. The research hinges on sustainability principles for Eco Airport development in a secluded setting with limited infrastructure compared to previous research. The originality of this study emerges from how it brings environmental concerns together with socio-cultural elements and economic factors during Eco Airport development to produce sustainability practices that match local requirements.

The emphasis on novelty focuses on developing Eco Airports with both environmental sustainability and resistance to Papua's geographic limitations and logistical challenges. The research investigates different minimal-impact airport development methods instead of traditional building techniques that require clearing large land areas and extensive construction. The research examines modern construction methods together with renewable power alternatives and waste handling systems that function suitably within Papua's isolated and limited resource zone.

New research demonstrates that indigenous involvement together with cultural integration, must be central elements for developing sustainable airports. Implementing infrastructure projects throughout Papua has struggled because they do not fit native cultural practices and community requirements.

The research intends to create a development framework that integrates traditional wisdom with indigenous land ownership while permitting community involvement throughout the entire Eco Airport planning and management process. By adopting this strategy sustainability becomes defined through environmental factors together with approval by local communities and benefits which extend beyond short-term intervals.

The research helps sustain the economic lifecycle of Papua Eco Airport projects by finding financial approaches

and policy solutions to implement them. Researchers examine affordable solutions together with funding possibilities to enable Eco Airport development without compromising sustainability requirements within the economic limitations of the region. The assessment includes opportunities for public-private partnerships as well as green financing mechanisms and government incentive programs designed for underdeveloped regions.

Through its focus on research gaps, the study brings new insights into Eco Airport development that serve as the groundwork for upcoming investigations and practical implementations for other isolated ecological areas.

The research outcome provides important knowledge to policymakers and airport developers while sustainability advocates for developing infrastructure that upholds environmental responsibility, social inclusivity, and economic sustainability.

3. Materials and Methods

This research adopts a qualitative descriptive approach, chosen specifically to offer a detailed, transparent, and in-depth account of the observed phenomena in the field. The main objective is to describe the conditions and issues related to the development of Rendani Airport, particularly focusing on the runway extension. Based on the data from the Aeronautical Information Publication (AIP), the airport's Aerodrome Reference Point (ARP) is located at coordinates 00° 53' 38"S (South) and 134° 03' 01"E (East), with the thresholds for Runway 35 and Runway 17 positioned at distinct coordinates. The research includes primary data from field observations, interviews, and collecting relevant documents about the airport's development. Secondary data were gathered from official reports and documents from relevant institutions. This includes aviation data such as flight diversions and go-arounds from Airnav's Manokwari Branch and meteorological data regarding wind and rainfall from the BMKG Manokwari station.

Fig. 1 Location of rendani airport

The SWOT analysis methodology serves as the tool for evaluating both the internal elements and external influences that determine the successful development of the airport. The internal variables consist of strengths and weaknesses that need strengthening and minimizing weaknesses. The SWOT analysis evaluates projects through external elements, which consist of growth possibilities and potential security risks that stakeholders should accelerate their advantages while protecting their defensive positions. A matrix will present strategic directions that result from how strengths connect with weaknesses and opportunities to encounter threats.

In-depth interviews are essential tools for obtaining stakeholder perceptions regarding strategic development issues in Rendani Airport, with a special emphasis on safety aspects. Positional interviews will explore how non-physical conditions impact infrastructure development yet identify the challenges during construction times. The research will analyze secondary data through various reports while

investigating environmental records, aviation regulations, and accident data to determine the trends that enhance sustainable airport development techniques.

The study examines how the existing airport facilities match sustainable standards by assessing their environmental impact and their social and economic effects on the land. The study will determine sustainable development solutions through infrastructure quality enhancements and community well-being promotion. The development assessment requires the evaluation of multiple options by confirming their suitability for economic and environmental sustainability in addition to social welfare standards. The research starting point focuses on determining flight safety challenges of the airport runway's current status while examining difficulties that impact runway development. Research findings will emerge from in-depth interviews that involve stakeholders who utilize the airport facilities. The research results will contribute to forming the last research query, which explores procedures to enhance airport wellness and development alongside sustainable frameworks. The planned method creates a complete understanding to guide Rendani Airport development efforts focused on safety enhancement and sustainability.

4. Results and Discussion

4.1. Overview of Rendani Airport

The study examines how the existing airport facilities match sustainable standards by assessing their environmental impact and their social and economic effects on the land. The study will determine sustainable development solutions through infrastructure quality enhancements and community well-being promotion. The development assessment requires the evaluation of multiple options by confirming their suitability for economic and environmental sustainability in addition to social welfare standards. The research starting point focuses on determining flight safety challenges of the airport runway's current status while examining difficulties that impact runway development. Research findings will emerge from in-depth interviews that involve stakeholders who utilize the airport facilities. The research results will contribute to forming the last research query, which explores procedures to enhance airport wellness and development alongside sustainable frameworks. The planned method creates a complete understanding to guide Rendani Airport development efforts focused on safety enhancement and sustainability.

Table 1. Air side facilities of rendani airport

Num	Airside Facilities	Dimension	Bearing Strength
1	Runway	2.300 m x 45 m	PCR 450 F/C/X/T
2	Runway Strip	2420 m x 140 m	
3	Taxiway Alfa	87 m x 15 m	PCR 270 F/C/X/T
4	Taxiway Bravo	87 m x 15 m	PCR 270 F/C/X/T
5	Taxiway Charlie	99 m x 23 m	PCR 450 F/C/X/T
6	Taxiway Delta	99 m x 23 m	PCR 450 F/C/X/T
7	Apron Alpha	181 m x 68 m	PCR 300 F/C/X/T
8	Apron Bravo	323 m x 85 m (6 Parking Stand)	PCR 450 F/C/X/T
9	Take Off Run Available (TORA)		
	a Threshold/TH 17	2300 m	
	b Threshold/TH 35	2300 m	
10	Take Off Distance Available (TODA)		
	a Threshold/TH 17	2300 m	
	b Threshold/TH 35	2300 m	
11	Accelerate Stop Distance Available (ASDA)		
	a Threshold/TH 17	2300 m	
	b Threshold/TH 35	2300 m	
12	Landing Distance Available (LDA)		
	a Threshold/TH 17	2000 m	
	b Threshold/TH 35	2300 m	

Table 2. Land side facilities of rendani airport

No	Description		Dimension
1.	Passenger Terminal		4.359 m2 ; 2F
2.	VIP Terminal		120 m2
3.	Cargo		600 m2
4.	Parking		250 m2
5.	Aircraft accident rescue and fire fighting		
	a.	Dimension	485 m2
	b.	Category	6
6.	AIR Traffic Control		66 m2
7.	Workshop		300 m2
8.	Airport Administration Office		453 m2
9.	Airport Authority Office		1986 m2
10.	Main Power Station		108 m2
11.	CCR		450 m2
12.	Concession		300 m2
13.	Aircraft Fuel Depot		2025 m2
14.	Government Services		300 m2
15.	BMKG Office		54 m2
16.	Housing		
	a.	Type 70	9 Unit
	b.	Type 36	54 Unit

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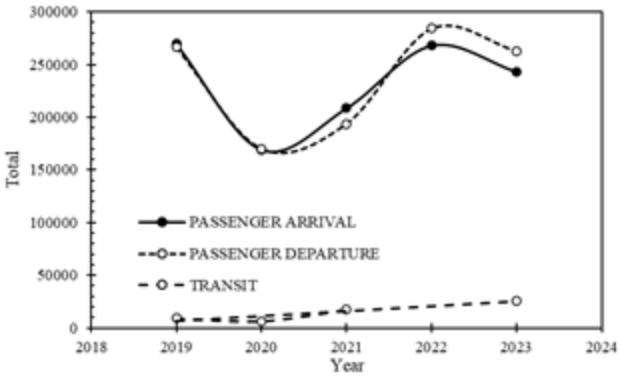

Fig. 2 Passenger traffic at rendani airport, 2019-2023

Yet, by 2020, there were significant increases in cargo shipments despite all mobility restrictions. Gradually, over the years, the volume of cargo into the country increased in terms of marine products like fish, crab, and shrimp. The shipment charts below show the primary commodities that come from Manokwari and surrounding areas.

Based on analysis of data of aircraft movements in the period between 2019 and 2023, the types of most frequently used aircraft include Boeing 737-800, Airbus A320, and Boeing 737-900ER. These Jacobian aircraft are majorly flown by Lion Group. According to this, the biggest of the Boeing models is the 737-900ER. The aircraft type directly relates to the minimum runway length requirement for safe take-off and landing. Example: A Boeing 737-900ER has a required runway of about 2,470 meters, which is inferred from its Aeroplane Reference Field Length (ARFL), making it more urgent in runway extension arrangements at Rendani Airport to accommodate larger aircraft within flight safety parameters. Currently, an existing runway length limits the load capacity of aircraft operating at the airport based on safety.

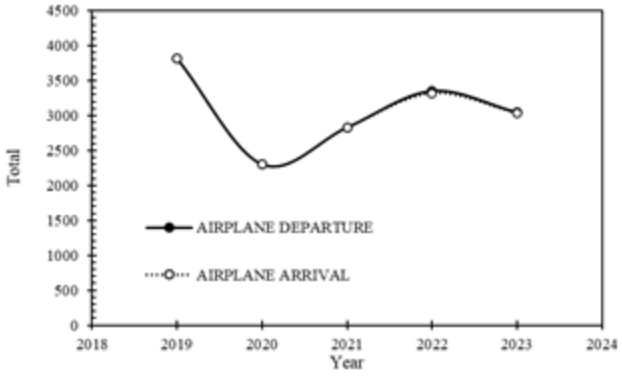

Fig. 3 Airplane traffic at rendani airport, 2019-2023

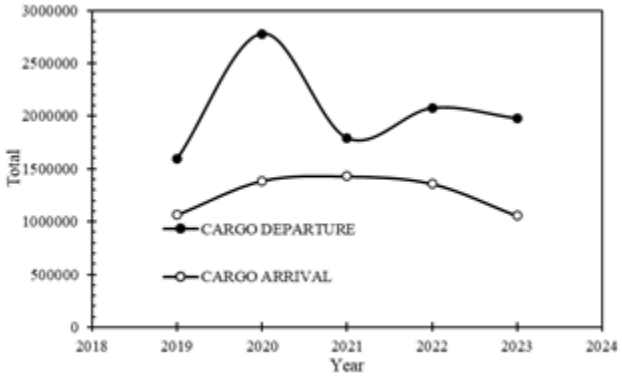

Fig. 4 Cargo traffic at rendani airport, 2019-2023

Table 3. Aircraft movements by type, 2019-2023

Year	Aircraft Type						
	Boeing 737-900 & 737-900ER	Boeing 737- 800	Airbus A320-200	Boeing 737-500	Boeing 737-400	Boeing 737-300	Total Flight
2019	36	375	2.128	868	3	503	3.913
2020	318	1.057	1.101	10	2	34	2.522
2021	529	1.353	778	16	-	2	2.678
2022	1.282	1715	888	-	-	3	3.888
2023	613	1702	786	-	-	-	3.101

4.2. Landing Failures at Rendani Airport

Aerodromes and their functioning tend to experience incidents during flights. The scenarios in which an aircraft fails to land range from weather conditions being adverse to wind direction even to rain conditions affecting visibility. When pilots feel they cannot land due to the conditions they witness, common actions include using a Go Around, Returning To Base (RTB), or diverting to another airport location. The study found that from Airnav Manokwari Branch, which was from 2019 to 2023, aircraft that made them most often fail to land were large aircraft, but the major causes were the weather conditions such as speed and direction of the wind.

Table 4. Landing failures, 2019-2023

Year	Go Around	RTB (Return to Base)	Divert	Total
2019	3 Flight	-	-	3 Flight
2020	15 Flight	-	1 Flight	16 Flight
2021	31 Flight	2 Flight	4 Flight	37 Flight
2022	21 Flight	-	3 Flight	24 Flight
2023	37 Flight	2 Flight	4 Flight	43 Flight

Wind affects aviation operations, particularly concerning the direction of takeoff or landing and establishing runway orientations. These matters play a significant role in flight safety. The table of failed landing incidents presumably delineated incidents within the domain between 2019 and 2023, with a noticeable uptick in occurrences in 2020 and another noticeable uptick in 2023. This wind was strong and added on at high speeds. The evidence stems from data that often have average wind speeds exceeding 10 knots, especially in attempts for landing. In addition to all those incidents, Rendani Airport has hosted spectacular happenings, such as a Merpati Air Boeing 737-300 overrun in April 2010 and a Sriwijaya Air Boeing 737-300 overrun in May 2017. The required runway length for those aircraft" is, according to their Aeroplane Reference Field Length (ARFL), 2,170 meters, but the runway at Rendani was only 2,000 meters long at the time of these incidents.

Per discussions with the Lion Air Group Airport Manager for Rendani Airport, there are standing SOPs for Lion Air and Batik Air aircraft that no more than 10 knots should be used as the maximum wind speed for safe landing conditions. This is especially critical for the Boeing 737-900ER, the largest aircraft operated by Lion Air, as most often, it would find it difficult to land with winds greater than this value. To ensure that risks are minimized, Lion Air has further limited the weight load of Boeing 737-900ER and Boeing 737-800NG aircraft landing at Rendani in perspective to runway length limitations and high wind speeds.

The Maximum Take Off Weight (MTOW) for the Boeing 737-900ER is 85,360 kg, while the Regulated Take Off Weight (RTOW) stands at 70,928 kg, leaving a deficit of 14,432 kg. The Maximum Take Off Weight (MTOW) is set at 79,240 kg for Boeing 737-800 airplanes, whereas the regulated take off weight is 72,487 kg, resulting in a difference of 6,753 kg between the two. These values indicate the limitations of the airport runways and environmental conditions concerning a flight operation.

Wind patterns at Rendani Airport are dominated by southeast and eastward winds, which are basically associated with the influence of the nearby ocean. The western approach, however, is hindered by hilly terrain, capable of generating hazardous crosswinds during landing. Interviews with the Rendani Meteorological Station revealed that weather data such as wind direction and speed, temperature, visibility, and air pressure is updated and sent to the Air Traffic Control (ATC) tower once every hourly interval in real-time. Their recommendations further included enhancing the number of Automatic Weather Observing System (AWOS) stations to better improve pilots' weather data reports.

From 2019 to 2023, it has been discovered that wind speed and risk landings have a correlative reason. For instance, on average, the wind speeds in 2019 were 2.2 knots, with gusts recorded up to 15 knots, and only three incidents of flight operation were reported. However, in 2020, ranging from 2.6 to 28 knots, the winds caused numerous risked landings, particularly because of lower flight frequencies during the COVID-19 pandemic. In the following years, higher wind speed continued to affect the success of landing attempts, especially on the Boeing 737-900ER, which finds it difficult to land under higher crosswind conditions approaching runway 17. Therefore, it can be concluded that high wind speeds make aircraft landing problematic at Rendani Airport and especially affect heavier aircraft types, such as the Boeing 737-900ER. The Airbus A320-200 could still land safely on runway 17. At the same time, the Boeing 737 series has faced difficulties in the presence of obstacles in the area of approach, indicating the necessity of further runway and infrastructure improvements in support of safer operations of these aircraft types.

4.3. Development Plans and Problems

Rendezvous was initiated to develop an airport that would connect travelers and regions more effectively and improve services with aviation safety and security as the underlying themes. This is why airport development must be in accordance with the master plan because every airport development project should be done in a targeted and efficient manner. The master plan for an airport is operational for the next 20 years but updated every five years.

A schematic development plan for Rendani Airport has been laid out in KM 81 of 2022 concerning the Master Plan for Rendani Airport in Manokwari, Province West Papua. This airport is expected to be developed within an area of execution space of around 151.13 hectares. Out of this area, 135.5 hectares have been certified, but some land for that area remains occupied by the community. An additional land acquisition of 15.63 hectares is required as per the master plan. However, what is apparent here is that decisions concerning the development will still be based on the master plan but will consider other parameters such as priority infrastructure requirements, availability of land, and financial constraints.

This fund participates in expanding the airport, supported by the Central government, West Papua, and the Manokwari Regency government. Development takes place in phases, focusing most on the airside aspect and allowing budget and space considerations along the master plan. Notable developments include building runways, taxiways, and aprons, part of which comes from the national budget (APBN) and part from the local budget (APBD). This integrated program will improve safety and security in aviation services, especially the runway's quality and capacity.

Despite progress, there are issues in land acquisition and relocation. The certified area of the airport has several residential structures, official accommodation for airport workers, and accommodation for other government employees and the general public. The government is attending to resolving these land issues according to the regulations on compensation of affected communities. Based on Presidential Regulation No. 62 of 2018, compensation is computed based on an independent appraisal considering clearing costs, relocation, and loss of income due to land use. Interview with local residents shows their support for the airport expansion but expect decent compensation.

Several steps have to be taken in the acquisition of land for the airport expansion, especially in the case of legally owned land. The local authority engages independent appraisal teams to assess land values accurately. Such appraisals consider historical value, physical condition, and any visible vegetation on the land to evaluate the worth of the land, thus making their compensation values higher than in other areas outside Papua. With regard to the access road to Rendani Airport, this temporary status must be aligned with the master plan once the runway strip is widened. The road is under the auspices of the Public Works Department (PUPR) of West Papua Province, making way for its elevation to a National Road. This road will follow the coastline and be complemented by a bridge; it will become a regional key feature. But it also has to solve all lands before construction. Some other utility networks need relocation, like water pipes from local PDAM that run under the runway, which is risky since the leakage would corrode the integrity of the runway. Similarly, cabling for electrical and telecommunication networks would be rerouted to avoid hindrance to airport operations. Another aspect for consideration is compliance with Airport Safety Zone (KKOP) regulations. Tall buildings and trees established in the areas free from obstacles may threaten aviation operations. The cooperation of the Airport Authority, Airnav, and local governments is essential to enforce those safety zones and guarantee operational safety for the airport.

In conclusion, the various development efforts directed towards Rendani Airport are ongoing and present several challenges, including land acquisition, upgrading of infrastructures, and compliance with regulations. The successful addressing of these challenges to achieve the objectives of the airport, which include improving regional connectivity, supporting local economies, and enhancing aviation safety and security, will require collective interest from all levels of government and adherence to the master plan.

4.4. SWOT Analysis

Several internal and external strategic factors regarding the runway development at Rendani Airport have been identified through data collection and observation. Internal factors involve the strengths and weaknesses of this airport, while external ones focus on opportunities and threats. Some of the strategic SWOT elements for runway development are as follows:

Strength-the airport is the strongest as being the largest in the province of Papua Barat and situated in the province's capital city. In addition, the airport offers services for goods, which already contribute a lot to the regional economy. All of these things positively impact the potential development of this airport, indicated by the strength score in total, which is 2.00, but weaknesses such as limited runway facilities, land ownership issues for local communities, and proximity to the sea, which cause crosswinds, contribute to hindrances to growth. The score assigned to such weaknesses is 0.79.

Several opportunities exist in the external operating environment of the Rendani Airport. The potential for business and tourism development in the area provides an excellent opportunity for further growth. In addition, a chance to increase cargo service, especially for marine products, will help boost the regional economy. The support extended to the airport's development by both central and regional governments adds another opportunity, making it a score of 2.00. However, community demands regarding land for the airport are among the threats, along with high capitalization and maintenance costs for the runway and public ignorance of aviation safety. These threats come to a score of 0.58.

Table 5. Internal strategic factors analysis summary (IFAS)

Element			Bobot (a)	Rating (b)	Nilai (a*b)
Strengths	1.	Rendani Airport is located in the capital city of West Papua Province	0.2	4	0.71
	2.	The largest airport in West Papua Province	0.2	5	0.88
	3.	Airports with Cargo Services in West Papua Province	0.1	3.5	0.41
	Sub Total A.		**0.5**		**2.00**
Element			Bobot (a)	Rating (b)	Nilai (a*b)
Weaknesses	1.	Limited runway facilities	0.18	1.5	0.26
	2.	Much of the airport land is controlled by the community	0.18	2	0.35
	3.	The runway's position is close to the sea, so crosswinds often occur.	0.18	1	0.18
	Sub Total B.		**0.5**		**0.79**
	Total = Sub Total A + SUB Total B		**1.0**		

In making the internal and external factor comparison, the merger of the strengths and weaknesses brings a score of 2.00 – 0.79= 1.21 on the x-axis, while opportunities and threats = 2.00 – 0.58 = 1.42 on the y-axis. Therefore, based on the combination of these coordinates, the runway development lies in Quadrant I of the SWOT diagram, indicating that the best strategy is to apply the identified strengths toward the identified opportunities.

Table 6. External strategic factors analysis summary (IFAS)

Element			Bobot (a)	Rating (b)	Nilai (a*b)
Opportunities	1.	Potential for Business and Tourism Development	0.17	4	0.67
	2.	Potential for Cargo Transportation in the form of marine products	0.17	4	0.67
	3.	Support from the Central Government and Regional Government regarding Airport Development	0.17	4	0.67
	Sub Total C.		**0.50**		**2.00**
Threats	1.	Community demands/claims on airport land	0.17	1.5	0.25
	2.	High investment, operational and maintenance costs of runways	0.17	1	0.17
	3.	Lack of public awareness and concern for aviation safety and security	0.17	1	0.17
	Sub Total D.		**0.50**		**0.58**
	Total = Sub Total A + Sub Total B		**1.0**		

From the standpoint of strategy, those classified as Strength-Opportunity (SO) strategies develop Airport services to help improve tourism and cargo, create cargo services for adjacent areas, and foster relations with government offices in charge of airport development; Weakness-Opportunity (WO) strategies will focus on improving airport infrastructure for safety and operational standards, partnering more actively with local governments to solve land problems, and establishing advanced weather-monitoring systems to enhance operational decision-making. Working with the local governments and law enforcement to address land disputes, seeking external funding to ease financial constraints, and raising stakeholder awareness about aviation safety constitute Strength-Threat (ST) strategies. Weakness-Threat (WT) strategies emphasize working within better collaboration with stakeholders to avert legal issues, conducting regular assessments of development plans, and enforcing stringent aviation safety and security regulations. In a nutshell, these strategic actions are essential for the future growth and development of Rendani Airport, which would ultimately benefit the local community and region.

Table 7. SWOT strategies matrix

SO Strategies		**WO Strategies**
Improving the quality of airport services	1.	Fulfillment of the standards of facilities and infrastructure at Rendani Airport
Developing Air Cargo services to support Manokwari's buffer areas	2.	Improving cooperation with Regional Government Level I and Level II regarding land issues with the community
Increasing cooperation in the construction and development of Rendani Airport with the Regional Government Level I and Level II	3.	Improve weather monitoring facilities and infrastructure so that weather information is more accurate.
ST Strategies		**WT Strategies**
Improve coordination with Level I and Level II Governments, accompanied by Law Enforcement Officers.	1.	Strengthening MoU/Cooperation with related stakeholders
Intensive efforts to build financing cooperation outside the State Budget and Regional Budget	2.	Periodic evaluation of airport development and expansion plans
Collaboration between stakeholders to conduct socialization of aviation security and safety	3.	Action against unlawful behavior that threatens aviation safety and security to provide a deterrent effect

Located in a place of highly beautiful natural features, through a coastline and a quite serene lake within the land development zone, Rendani Airport is located. There is hardly an airport with such attractive nature points all around, and the uniqueness has great potential if managed and developed properly. Particularly, the area with a lake has the potential to become a fresh tourism icon for the Manokwari people, adding an impetus to the local economy, especially around the airport. This airport could thus be transformed from being a transportation hub into a potential eco-tourism destination and a place for recreation. It would attract people traveling through the air and, at the same time, enjoying the natural environment surrounding them. One of the fundamental initiatives after the entire relocation process of local communities will be restoring the airport's coastal area to greener and lusher conditions. This involves planting trees, especially mangrove species, along the coastline and planning other ground facilities so that environmental reestablishment is prioritized. The development should strike the appropriate balance between providing new infrastructures and preserving the natural landscape. In the airport's master plan, the area around Rendani Lake is envisioned as open green space. This vision directly contradicts the plan to site residential buildings for airport staff within this area and is, therefore, likely to disturb the lake's natural environment. The placement of these structures must, therefore, be rethought to ensure judicious use of land while emphasizing environmental conservation. The plan to make Rendani Airport more environmentally friendly while still fulfilling its primary purpose of supporting air travel operations has received backing from the local government of Manokwari.

The Regent of Manokwari has even said this during the launch event. He said that "the airside area of the airport, which is currently mostly occupied by residents, will relocate in accordance with airport land certificate boundaries." This land acquisition would also reach the new road area (Jl. Drs. Esau Sesa), some of which will also become green open space, except for the runway strip, as indicated in the master plan (140 meters from the runway centerline). This effort will strongly support the creation of a harmonious balance between the development of infrastructures and environmental sustainability in Rendani Airport.

5. Conclusion

The development of and prospects for the expansion of Rendani Airport face a list of factors, some of which are challenges and others opportunities. In its present state, the airport's runway is 2300 meters long and 45 meters wide and extending it to 2500 meters by 45 meters may be necessary to accommodate larger aircraft, particularly the Boeing 737-900ER. The existing runway limits the maximum load capacity, meaning aircraft have to fly into the wind with limited loads to compensate for restricted runway length and strength. The airport itself is surrounded by water to the east and hills to the west, and its geographical location frequently leads to crosswinds usually exceeding 10 knots, therefore impairing operations through go-arounds and diversions.

Furthermore, the land occupied by Rendani Airport, including the projected expansion area, is being occupied by local citizens, thus generating huge financial obligations regarding land acquisition and relocation. While approved by the central government and local authorities for further development, the runway alignment will require major changes to infrastructure such as access roads, electricity poles, telecommunication infrastructure, and water pipelines in order to satisfy the common master plan. Presently, the environmental management of Rendani Airport is poorly attended to owing to limited facilities and the lack of timely statutory regulations on environmental airport practices for

secondary service-level airports. By the same token, the construction of the operational safety zone (KKOP) has not been fully operational due to obstructions and structures that may endanger air traffic safety.

The coastal area around Rendani Airport has changed from its natural state to accommodate residential developments, but the vast potential still exists. Particularly, the area around the lake has the potential to become a local tourist attraction, adding extra value to the airport's role in the community; however, the potential has not yet been tapped. Several recommendations have been developed to remedy such problems and foster further opportunities for the airport. Foremost, it is recommended that the planning and execution of the runway extension take into consideration phased implementation according to the master plan with the utmost regard for aviation safety.

Upgrading weather detection equipment to include Automated Weather Observing Systems (AWOS) would enhance the accuracy of weather reporting for more reliable flight operations. Also, communication and socialization with local communities, which affect the airport's land, have to be made with respect to the relocation process for runway expansion. Clear authority boundaries need to be established between the central government, Papua Barat provincial government, and the government of Manokwari district so that smooth coordination is ensured, alongside efficient airport development.

The participation of various stakeholders would, thus, assure the relocation of public utilities-such as power lines, telecommunication poles, and water pipes-to dovetail within the airport master plan. Environmental management infrastructure should be featured further in the master plan provision according to green airport design principles, ensuring that environmental sustainability is applied to the functional needs of airports. It has to be coordinated to remove or eliminate obstructions in the operational safety zone that can impede safety in the flight. Finally, since the natural areas around it have some potential, it would be advisable to make a long-term plan that some areas of that land be earmarked for green open spaces or conservation areas so that Rendani Airport is also a center for transport as well as a base for environment preservation and community welfare.

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