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ANALYSIS OF FUEL CONSUMPTION AND EMISSIONS PRODUCED BY AIRCRAFT AT INDONESIAN AIRPORTS

Garis Chikagraha Pitanova[1]*, Ervina Ahyudanari[2], Freddy Chilongola[3]
[1]Department of Civil Engineering, Faculty of Civil Planning and Geo Engineering, Institut Teknologi Sepuluh Nopember, Keputih, 60111, Surabaya, Indonesia
[2]Department of Civil Engineering, Faculty of Civil Planning and Geo Engineering, Institut Teknologi Sepuluh Nopember, Keputih, 60111, Surabaya, Indonesia
[3]Department of Aeronautical Information Management, Tanzania Civil Aviation Authority, Kilimanjaro, 30, Tanzania
*garischikagrahap@gmail.com

ABSTRACT
Indonesia marked a significant milestone in December 2022 by becoming Southeast Asia's largest aviation market, boasting 9.6 million available seats. This impressive figure reflects a remarkable 69% growth compared to pre-pandemic levels in 2019, primarily fueled by an uptick in domestic routes across the region's top 10 busiest airports. However, this surge in flight demand has sparked operational challenges for airlines. Notably, increased flights mean higher operational costs, compounded by the environmental impact of fuel consumption and subsequent carbon emissions. Consequently, airlines are now required to offset these environmental costs through carbon fees (CO2). This study aims to delve into the correlation between flight duration, fuel consumption, and resulting emissions at Indonesian airports. The methodology involves calculating fuel usage based on flight time and employing the "Carbon Emissions Calculator Methodology" for emission assessments. Sultan Hasanuddin Airport emerges as a standout, showcasing the most substantial variance in both fuel consumption and emissions compared to other airports. This emphasizes the pivotal role of actual flight duration in influencing emissions—a crucial indicator of airline fuel efficiency. The study's outcomes hold promise as a guiding reference for stakeholders, offering insights to develop more efficient fuel utilization methods. Ultimately, this could mitigate aviation fuel costs while simultaneously reducing environmental impacts.

Keywords: aircraft, airport, emissions, fuel, air transportation

INTRODUCTION
Air travel is favored for its speed, convenience, and exceptional time efficiency, especially for long-distance and international journeys. However, recent statistics from Official Airlines Guide (OAG.com) reveal Indonesia's aviation market as the largest in Southeast Asia in December 2022, boasting 9.6 million available seats. This remarkable surge reflects a staggering 69% growth compared to pre-pandemic figures in 2019. This growth surge has been predominantly fueled by an expansion in domestic routes within the top 10 busiest airports in Southeast Asia, managed by PT Angkasa Pura I. Notable airports in this network include I Gusti Ngurah Rai Airport, Juanda Airport, and Sultan Hasanuddin Airport. Among these, five airports serve as vibrant hubs: I Gusti Ngurah Rai Airport, Juanda Airport, Sultan Hasanuddin Airport, Sultan Aji Muhammad Sulaiman Airport (SAMS) Sepinggan, and Yogyakarta International Airport (Yuliawati, 2018). Moreover, these airports exhibit high connectivity, evident from an index (γ) surpassing 0.8 (Salma & Ahyudanari, 2021).

The rising demand for flights brings about operational expenses for airlines, compounded by the environmental impact of emitted fuel byproducts. Consequently, airlines are required to offset these environmental costs through a carbon fee (CO2) (Airports Commission Consultation, 2014). Over recent years, environmental emissions from aircraft have gained significant attention within the aviation industry, drawing involvement from both international and local regulators. Emissions from combustion gases, especially at higher altitudes, stand as a crucial concern in civil and commercial aviation. Among these emissions, CO2 remains particularly noteworthy due to its long-lasting impact, persisting in the atmosphere for up to a century. The major culprit behind CO2 emissions lies in the reliance on fossil fuels within the air transportation sector. For instance, an average calculator estimates approximately 330 kg of CO2 per passenger for every 1000 nautical mile trip, equating to 660 kg per passenger for a 2000-mile journey (Filippone, 2008).

The 41st ICAO Assembly in 2022 saw the adoption of a resolution aiming to achieve "net zero by 2050" for CO2 emissions in the international aviation sector. This resolution involves active collaboration between the ICAO Council, member states, and notably includes Indonesia (Ministry of Foreign Affairs Republic of Indonesia, 2022). A study conducted by Chilongola & Ahyudanari (2019) revealed specific fuel consumption estimations during peak hours at Juanda International Airport. The breakdown includes approximately 7307 kg for idle/taxi, 3338 kg for approach, 5482 kg for climb out, and 2135 kg for take-off. Notably, the analysis highlights the Boeing 737-800 (B738) aircraft as the most prevalent contributor, accounting for 33% of total aircraft movements. Following closely is the Airbus 320-214 (A320) with a 24% share of all movements. This prevalence of B738 operations during peak hours significantly influences the airport's overall fuel consumption during these periods. Considering the evident contribution of aviation activities to emissions, the escalating aircraft movements across the five airports, coupled with amplified fuel demands, necessitate efforts to mitigate environmental impact. Thus, this study aims to assess the fuel consumption and emissions generated through arrival and departure routes at these airports.

METHOD

Data Processing

In this study, we gathered data on all domestic and international flight operations accessible through flightradar24.com, as outlined in Table 1. This dataset encompasses various details such as landing and take-off times, origin and destination cities, airport specifics, aircraft information, and other pertinent elements. Our research honed in on a specific day carefully selected to represent the peak service of the route within that week, denoted as the 'peak day.

Table 1.
Research Data Information

Airport	Day	Date	Total Movements	
			Departure	Arrival
Juanda Airport	Monday	07/08/2023	121	123
I Gusti Ngurah Rai Airport	Friday	11/08/2023	193	192
Sultan Hasanuddin Airport	Wednesday	09/08/2023	104	94
Yogyakarta International Airport	Monday	07/08/2023	40	40
Sultan Aji Muhammad Sulaiman Sepinggan Airport	Friday	11/08/2023	54	47

Aircraft Fuel Consumption Analysis

This analysis comprises several steps aimed at assessing the variance between scheduled and actual flight times of aircraft in relation to fuel consumption. Through this examination, we aim to uncover the impact of flight duration on overall fuel usage. The forthcoming calculations will determine aircraft fuel consumption based on the methodology outlined in Horonjeff et al. (2010):

Fuel consumption = $\frac{flight\ time\ (minute)}{60} x fuel\ comsumption\ (\frac{lb}{hour})$ (Equation 1)

Where:

Flight time = the time required by the aircraft to perform the flight.

Fuel comsumption = the amount of fuel consumed by the aircraft during the flight.

Table 2.
Average Fuel Consumption of a typical Airplane

Airplane	*Fuel Consumption* (lb/h)
EMB-145	2253
A320-200	4054
A319-100	6966
B737-500	7879
B737-200	8829
B757-200	11109
B767-300	11893
A340-300	16093
B747-200	28638

Analysis of Emissions Generated on Aircraft

The estimation of CO2 emissions per passenger is determined by considering various variables, including travel distance, aircraft fuel consumption, passenger load per seat, passenger load per item, and seat capacity. Utilizing these factors, the calculation for CO2 emissions per passenger is performed according to the methodology outlined by ICAO (2017):

$$CO_2 \textit{ per pax} = 3.16\ x\ \frac{(total\ fuel\ x\ pax-to-freight\ factor)}{(number\ of\ y-seats\ x\ pax\ load\ factor)} \quad \text{(Equation 2)}$$

Where:

Total fuel = the weighted average of the fuel used by all flights departing from the origin airport to reach the destination airport.

Pax-to-freight factor = a ratio calculated from the ICAO statistical database based on the number of passengers and tonnage of goods and cargo, transported in a given route group.

Number of Y-seats = the total number of economy equivalent seats available on all flights serving a particular city pair.

Pax load factor = a ratio calculated from the ICAO statistical database based on the number of passengers carried and the number of seats available in a given route group.

3.16 = a constant representing the number of tons of CO2 produced from burning one ton of aviation fuel.

RESULTS AND DISCUSSION

Actual and Scheduled Time Differences for Arrival and Departure Fuel Amounts at 5 Airports

The following is an illustrative calculation with a flight case from Sultan Aji Muhammad Sulaiman Sepinggan Airport to Juanda Airport using a Boeing B737-900 aircraft. With the following data:

Table 3.
Sultan Aji Muhammad Sulaiman Sepinggan Airport Data - Juanda Airport

Flight Time		*Average Fule Comsuption*	= 7879 lb/hr
Actual	= 68 min		= 3573,85 kg/hr
Schedule	= 73 min		

$$Actual = \frac{68(minute)}{60}\ x\ (3573{,}85\,\frac{kg}{hour})$$

$$= 4050{,}36\ \text{kg}$$

$$Schedule = \frac{73\ (minute)}{60} x\ 3573{,}85\ (\frac{kg}{hour})$$
$$= 4348{,}19\ \text{kg}$$

Differences in Actual and Scheduled Times of Total Arrival and Departure Emissions at 5 Airports

After obtaining the amount of fuel that fits into the aircraft. Then perform the emission calculation process. Assume the following data:

Table 4.
Load Factors by Route Group

	Route Group	*Passenger Load Factor*	*Passenger to Freight Factor*
63	Intra Pacific South East Asia	77,57%	79,99%

Table 5.
Number of Y-Seats

:	Seat		
	Economy	Business	Total
A320	174	0	174

$$Actual = 3{,}16\ X\ \frac{(4050{,}36\ x\ 79{,}99\%)}{(174\ x\ 77{,}57\%)}$$
$$= 75{,}85\ \text{kg/pax}$$
$$Schedule = 3{,}16\ X\ \frac{(4348{,}19\ x\ 79{,}99\%)}{(174\ x\ 77{,}57\%)}$$
$$= 81{,}43\ \text{kg/pax}$$

Figure 1 illustrates a notable trend: the total fuel consumption and emissions from actual arrival flights at each airport surpass those from scheduled arrival flight times. Contrarily, Figure 2 presents a distinct scenario. Here, the total actual arrival flight times at Juanda Airport and I Gusti Ngurah Rai Airport depict lower fuel consumption and emissions compared to their scheduled arrival flight times. This discrepancy potentially signifies operational efficiency disparities among these airports.

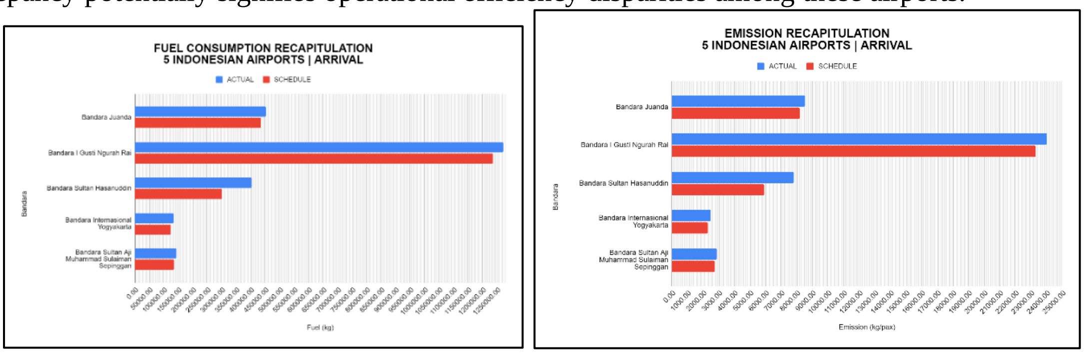

Figure 1. Fuel Consumption and Emission Recapitulation 5 Indonesian Airports | Arrival

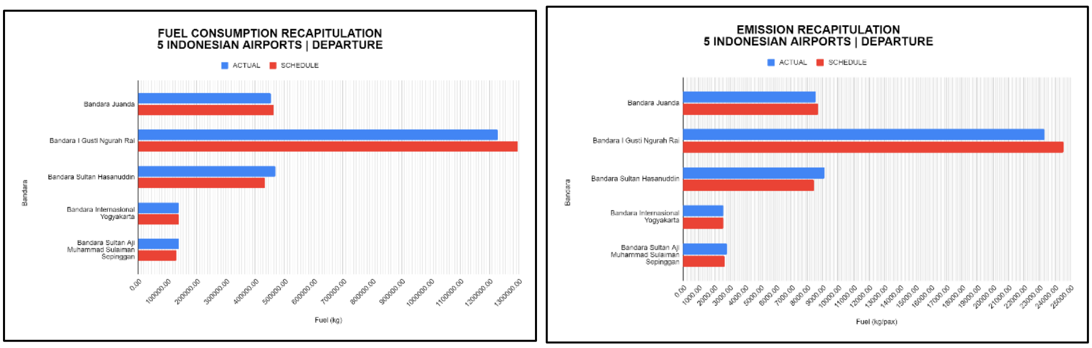

Figure 2. Fuel Consumption and Emission Recapitulation 5 Indonesian Airports | Departure

Based on the preceding explanation, it can be inferred that flight duration indirectly influences fuel consumption and emissions. This observation aligns with Carlier et al.'s prior research (2007), which suggests that surpassing pre-planned flight durations tends to elevate both fuel consumption and emissions. Consequently, prolonged flight times emerge as a factor meriting consideration in mitigating aviation's environmental footprint.

However, this study's scope is confined to analyzing flight duration and mixed traffic on peak days at each airport under study. Thus, further research with more extensive analyses becomes imperative, particularly in delving into the potential environmental repercussions stemming from specific facets of aviation operations. Enhanced investigations could encompass detailed assessments of emissions contributions, air traffic patterns, and other environmental factors, providing a more holistic perspective on the cumulative impact of aviation activities at these airports.

CONCLUSIONS

Despite I Gusti Ngurah Rai Airport's high flight volume, it doesn't necessarily translate to the highest emissions. The study reveals that the timing of arrival flights significantly influences emissions. Notably, Sultan Hasanuddin Airport displays the largest emission variance between actual and scheduled flight times. The research effectively quantified fuel consumption and emissions for each airport. Interestingly, the environmental impact and deviations in scheduled flight times seem more impactful than initially estimated in this study. These findings significantly contribute to understanding the fuel consumption and emissions associated with flight operations across diverse airports. The significance of actual flight duration in elevating emissions serves as a gauge for assessing airline fuel efficiency. Furthermore, the findings of this study offer valuable insights for stakeholders to devise more efficient approaches in fuel utilization, thereby mitigating aviation fuel expenses. Future research could extend this investigation to evaluate emission levels across distinct airport components, including taxiways, aprons, and ground handling, contributing to a more comprehensive understanding of environmental impacts within airport operations.

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REFERENCES

Airports Commission Consultation. (2014). *Economy: Delay Impacts Assessment*. Government London. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/372619/AC08_tagged.pdf

Carlier, S., Lépinay, I. de, Hustache, J.-C., & Jelinek, F. (2007). Enveromental Impact of Air Traffic Flow Management Delays. *Enviromental and Economics Research for Transportation*, *5*, 1–13.

Chilongola, F. D., & Ahyudanari, E. (2019). Aviation and Aircraft Engine Emissions at Juanda International Airport. *The International Conference on Aerospace and Aviation*, *645*(012022). https://doi.org/10.1088/1757-899X/645/1/012022

Filippone, A. (2008). Analysis of Carbon-Dioxide Emissions from Transport Aircraft. *Journal of Aircraft*, *45*(1), 185–197. https://doi.org/10.2514/1.31422

Horonjeff, R., Mckelvey, F. X., Sproule, W. J., & Young, S. B. (2010). *Planning and Design* *of Airports* (Fifth).

ICAO. (2017). *ICAO Carbon Emissions Calculator Methodology*. *June*. https://www.legislation.gov.au/Details/F2021C01312

Indonesian in International Civil Aviation Organization (ICAO) | G20 Aviation Dialogue: Financial Measures for the Aviation Recovery. (2022). Ministry of Foreign Affairs Republic of Indonesia; International Civil Aviation Organization (ICAO). https://kemlu.go.id/portal/en/read/4255/halaman_list_lainnya/international-civil-aviation-organization-icao

OAG. (2023). *South East Asia Aviation Market*. https://www.oag.com/south-east-asia-aviation-flight-data

Salma, U., & Ahyudanari, E. (2021). Analisis Konektivitas Transportasi Udara Antar Ibukota Provinsi di Indonesia Akibat Pandemi Covid-19. *Jurnal Teknik ITS*, *10*(2). https://ejurnal.its.ac.id/index.php/teknik/article/view/69241/6870

Yuliawati, E. (2018). Determination of the International Hub Airport to Support the Flight Network Efficiency of ASEAN Region Countries (Case Study of the Indonesian Airport System). *Aviation and Its Management*, 1–13. https://doi.org/10.5772/intechopen.81305