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Investigation of Different Emissions Tax Calculation Methods for Kuala Lumpur International Airport

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Abstract

The aviation sector is among the most active industries globally and has been evolving for over a century. Aviation's rapid expansion significantly contributes to emissions. This study aims to propose a methodology for calculating nitrogen oxides (NO_x) emission taxes for Kuala Lumpur International Airport (KLIA) while concurrently analyzing the departure traffic in the vicinity. This study attempts to identify the airline and differentiate the engine type that contributes to NO_x emissions at KLIA. Departure information and aircraft statistics at the specified airport were acquired via FlightRadar 24 and Airfleets.net. The data was collected over a three-month period from September to November 2023. Upon compilation of the collected data, the tax prices are calculated and analyzed using three distinct methodologies. The NO_x emission index is derived from the latest version of the ICAO databank. The peak departure hours at KLIA are 9:00 am and 1:00 pm. AirAsia is the airline with the largest daily departure activity, and CFM engines are likely the primary contributors to NO_x emissions. Finally, the Copenhagen method is recommended for implementation at KLIA due to its fair and efficient NO_x emission tax system, which accurately represents the environmental consequences of its operations and promotes more sustainable behaviors within the aviation sector.

1. Introduction

The aviation industry offers a vast global network of transportation for people, including those in remote areas. In recent years, global aviation has increased annually at a rate of 5% and is anticipated to continue growing [1]. The number of aircraft keeps rising daily, which harms the environment. Like automobiles, aircraft also emit harmful gases and substances, namely carbon dioxide (CO_2), water vapor (H_2O), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur oxides (SO_x), and unburned combusted hydrocarbons, which are also known as volatile organic compounds (VOCs).

This research concentrates on the release of nitrogen oxides (NO_x), which dominate aircraft emissions over carbon monoxide and hydrocarbons. When nitrogen oxides (NO_x) are released in significant amounts over extended periods, they can cause environmental effects, influence local and global health, and directly impact the climate [2]. As a member of ASEAN, Malaysia has experienced one of the world's fastest economic expansions. The aviation industry impacts the environment as a source of pollutant emissions [3]. This can be seen in most first-world countries, which have focused more on green technologies to cater to the upcoming climate change.

The aviation industry is experiencing the fastest growth compared to other transportation industries. Due to the rapid growth, aviation remains the major factor contributing to emissions. Both in and around airports and at altitudes that affect background concentrations, aviation emissions impact local air quality and human health. This study aims to provide enough evidence to suggest a calculation method for tax emissions at Kuala Lumpur International Airport. This research also studies the best tax calculation method for Malaysian airports.

Only 20 airports account for 27% of the global passenger air transport sector's total greenhouse gas emissions, according to an analysis by environmental NGOs and think tanks like the International Council on Clean Transportation (ICCT), ODI, and Transport and Environment (T&E). Every engine portrays different performance parameters as they come from various companies, and their design differs from one another. Different performances would result in different emissions from the engine. Recognize that airlines have been demanding efficient specific fuel consumption from their engines in recent years, which has led the manufacturer to optimize the engine's core temperature during combustion.

It is expected that engine manufacturers will produce engines following ICAO [4] and IATA regulations to avoid fees associated with breaking the law and, in the process, [5], contribute to a greener environment. Few major engine makers currently hold most of the market, including Rolls Royce, CFM, and Pratt and Whitney [6]. The term "emission" refers to the release of a substance or any other substance, primarily from engines [29]. Nitrogen and oxygen in the air combine to form nitrogen oxides (NO_x) when air passes through high-temperature or high-pressure combustion. When cruising at a higher altitude of 2,000 feet, a five-ton heavier aircraft produces 11.2% more NO_x emissions or 2.7% less NO_x intensity, respectively [7]. Nitrogen dioxide reacts with chemicals produced by sunlight to produce nitric acid, a key component of acid rain. Additionally, the reaction of nitrogen dioxide with sunlight results in ozone and smog formation in the air we breathe [8].

The report also notes that, primarily due to the industry's slow recovery from the pandemic, the central traffic forecast for Waypoint 2050 is approximately 16% lower in 2050 than it was in the world before COVID-19. This could indicate that the aviation industry is lagging behind in accomplishing its objective. Governments are attempting to promote a clean energy transition through initiatives such as the use of sustainable aviation fuel (SAF) and the development of new energy industries [9]. This can involve securing additional funding for the expansion of SAF capacity through loan guarantee programs, conducting direct research and development activities for local SAF production pathways, and promoting its use.

The analysis of emission departure charges addressed the difficulties encountered by the ETS. Numerous countries and regions have lately established carbon pricing mechanisms for the aviation industry. In 2012, Switzerland implemented a flying carbon levy, imposing a fee for each substantial CO_2 emission from flights departing Swiss airports. In 2018, Sweden implemented a comparable aviation tax, imposing fees depending upon distance. The implementation and magnitude of departure fees vary by country and region. Some fees apply to all flights, while others are exclusive to domestic flights. Moreover, there exists a range of rates and methodologies for fee calculation, including charges per passenger or assessments based on aircraft weight or emissions. Tax emissions are a solution that benefits multiple stakeholders. The authorities could utilize the enacted tax as an effective instrument for environmental conservation. It has been demonstrated to be advantageous and a measure contributing to the airport's sustainability.

2. Methodology

This research used a “digital” method to gather data. The research focuses on the activities of aircraft departing from KLIA (Kuala Lumpur International Airport). These tracking applications are well-developed and are legal to use for data collection. This research will utilize Flightradar24 and Airfleet.net software. Each software specifically designs different data sets to aid in this research.

First, all data were acquired from FlightRadar 24 as shown in Figure 1. The data collected will be divided into two inputs: $\boldsymbol{A}$, which is the input required to achieve the first objective, and $\boldsymbol{B}$, which is the input required to achieve the second and third objectives. The second step involves subjecting the data to a validation procedure to ensure its inclusion of all necessary components. The data for input $\boldsymbol{A}$ were arranged according to a 1-hour time interval. This enables the completion of a thorough analysis and a more comprehensive understanding of the outcome. Third, the input data for $\boldsymbol{B}$ is sorted in descending order for the airline category and based on the engine manufacturer for the engine. The engine type data was introduced for calculation, and the analysis was conducted on airline data. The ICAO emission databank, which had been previously acquired, was utilized to facilitate the calculation procedure. The engine type is included in the engine data; therefore, the data was compared to the database to obtain the $\boldsymbol{NO_x}$ index. An analysis was conducted to evaluate the calculation results of three emission tax methods.

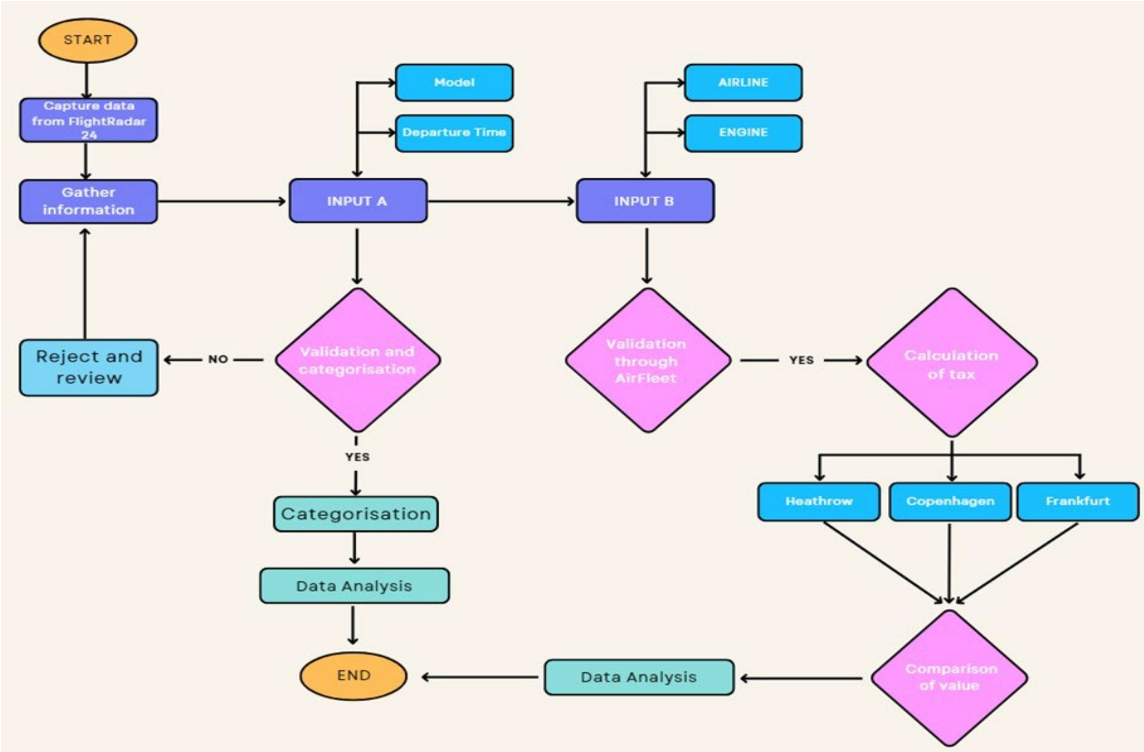

Fig. 1 *Flowchart of data collection process*

2.1 Data Collection

The collected data includes aircraft departure time, aircraft model, airline, and aircraft code. Data collection commenced with daily access to Flightradar24 for 24 hours over a span of seven days. Validation is essential prior to data extraction, serving as a barrier or filter to guarantee the accuracy and completeness of the collected data, as illustrated in Fig. 2. Figure 3 depicts several examples in which we dismiss information owing to airline cancellations, delays, absent flights, and unforeseen events.

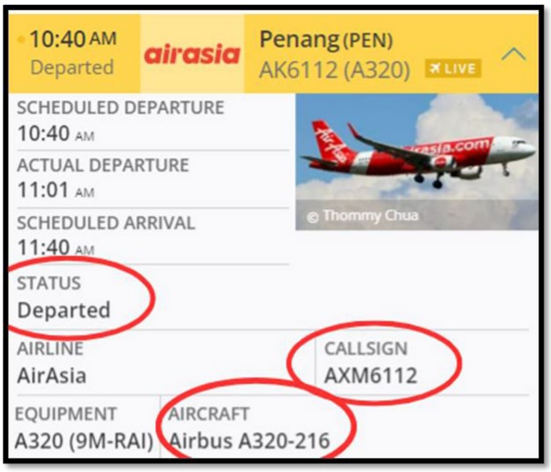

Fig. 2 *Complete dataset*

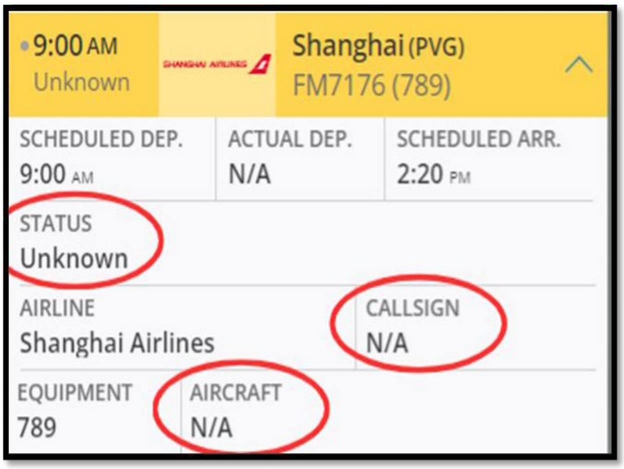

Fig. 3 *Incomplete dataset*

2.2 Engine Identification

Since competition drives technological advancement, there are many engine manufacturers in the aviation industry. There is a wide range of engines available, each with its own design objectives and applications. The software Airfleets.net monitors aircraft and houses a database of each aircraft's engines. Before computing the emission fee, the required callsign was inserted to determine the engine identifications.

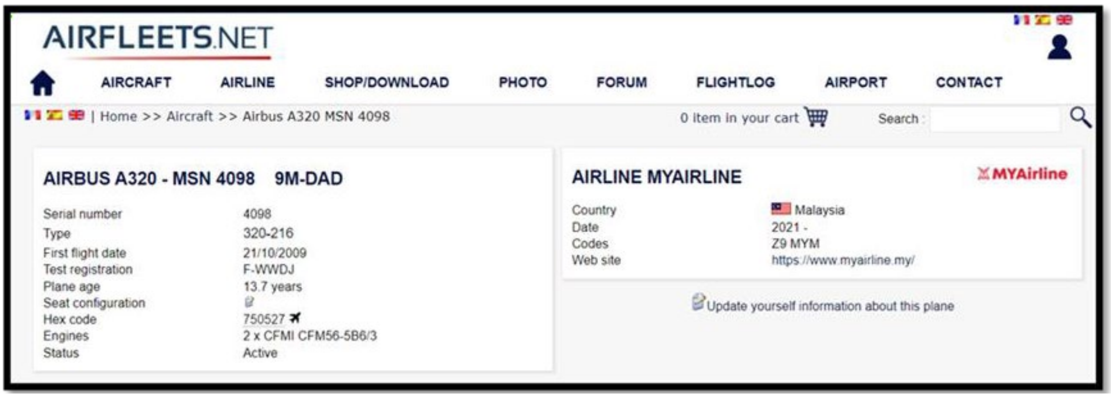

Fig. 4 *Engine identification from Airfleets.net*

2.3 Emission Tax Calculations

This section defines the procedure for calculating the emission tax utilizing all three methodologies. A comparison was conducted following the calculation of the total tax, and a recommendation was provided. This process aimed to fulfill the third objective: to propose a method for calculating the emission tax. The engines' emission index was derived from the ICAO emissions databank. Figure 5 presents a sample of the emissions index for the A320, sourced from the ICAO emissions databank. Table 1 displays a sample of the calculated emissions tax, which was calculated using three distinct methods in this study.

MEASURED DATA

MODE	POWER SETTING (%F_{oo})	TIME (minutes)	FUEL FLOW (kg/s)	EMISSIONS INDICES (g/kg) HC	CO	NO_x	SMOKE NUMBER
TAKE-OFF	100	0.7	0.965	0.02	0.17	17.73	11.3
CLIMB OUT	85	2.2	0.800	0.03	0.17	14.88	8.4
APPROACH	30	4.0	0.279	0.07	4.35	8.29	2.1
IDLE	7	26.0	0.095	2.93	38.39	3.94	2.1
LTO TOTAL FUEL (kg) or EMISSIONS (g)			361	440	5912	3363	-
NUMBER OF ENGINES				3	3	3	3
NUMBER OF TESTS				7	7	7	7
AVERAGE D_p/F_{oo} (g/kN) or AVERAGE SN (MAX)				4.2	57.5	32.8	11.3
SIGMA (D_p/F_{oo} in g/kN, or SN)				0.5	2.7	1.1	2.6
RANGE (D_p/F_{oo} in g/kN, or SN)				3.7-4.61	54.3-59.3	31.8-34	8.3-12.9

Fig. 5 *The emission data of CFM 56-5B6/3*

Table 1 *Calculations of emissions tax*

Method	Calculation
Copenhagen	Takeoff calculation: $Total\ time = 0.7 \times 60 = 42\ s$ $Total\ fuel = fuel\ flow \times total\ time = 0.965 \times 42 = 40.53\ kg$ $NO_x = NO_x\ Index \times total\ fuel = 17.73 \times 40.53 = 718.6$ g Total amount: $Emission\ Value = 2\ engines \times 718.6\ g = 1437.2\ g$ @ $1.4372\ kg$ Price of emission charge per takeoff: 16.50 DKK per kg NO_x.
Heathrow	EASA Emissions Database: NO_x *Total mass = 3.363 kg per engine* Calculation: NO_x × Number *of engines × Unit (£)*
Frankfurt	NO_x*, aircraft [kg] = (No. of engines x ∑ Mode time [s] x fuel consumption [kg/s] x emission factor [g/kg]) / 1000*

$$NO_x \; charge = Emission \times 3.37$$

Fig. 6 above shows samples of a calculator system made in Excel. The calculator was created for every engine for the crosschecking process. This is to ensure the accuracy of the emissions tax calculated. The calculator's results were then used to calculate the accurate amount of tax based on the results gathered.

PW PW4168A		
COPENHAGEN METHOD		MYR
Total time	42	
total fuel flow	119.11	
NOX	5049.16	
total emission	10.10	
total	166.62	**113.30**
FRANKFURT METHOD		
Total	34.03	**172.88**
HEATHROW METHOD		
NOX total mass	19.70	
	337.73	**1975.70**

PW PW1133G		
COPENHAGEN METHOD		MYR
Total time	42	
total fuel flow	42.97	
NOX	1084.03	
total emission	2.17	
total	35.77	**24.33**
FRANKFURT METHOD		
Total	7.31	**37.12**
HEATHROW METHOD		
NOX total mass	4.86	
	83.37	**487.71**

PW PW4056		
COPENHAGEN METHOD		MYR
Total time	42	
total fuel flow	102.86	
NOX	3342.89	
total emission	6.69	
total	110.32	**75.01**
FRANKFURT METHOD		
Total	22.53	**114.46**
HEATHROW METHOD		
NOX total mass	13.04	
	223.56	**1307.81**

PW PW1127G		
COPENHAGEN METHOD		MYR
Total time	42	
total fuel flow	33.60	
NOX	596.74	
total emission	1.19	
total	19.69	**13.39**
FRANKFURT METHOD		
Total	4.02	**20.43**
HEATHROW METHOD		
NOX total mass	3.24	
	55.60	**325.27**

Fig. 6 *Calculator in Excel for Pratt & Whitney engines*

3. Results

The main focus of this study is the research result, based on data collected during the three months of September, October, and November 2023. In this section, we will discuss the data collected from the engine aspect: the number of departures, the airlines, and the time. Each component signifies the achievement of the stated objectives.

3.1 Engine

Determining which engine contributes to the NO_x emissions is essential, as implementing the emissions tax should be based on the airline's engine type. As shown in Fig. 7, CFM International dominates in all three months, with more than 10,000 aircraft departing. Pratt & Whitney came in second with an average of 836 aircraft, Rolls Royce in third, and General Electric and International Aero Engine in last place with 784, 757, and 413, respectively. It can be observed that CFM dominates the category with a huge gap. This is due to the engine's characteristics, which lead airlines to choose that particular aircraft variant. CFM engines in this region have commonalities and interchangeability. Having more than one aircraft of the same engine type can benefit the airlines in terms of maintenance, training, and spare parts inventory. Hence, it would lead to cost savings and operational efficiencies. Moreover, the CFM engine, particularly the CFM56 seen in the A320, A321, and Boeing 737, has a long history of reliability and performance. It has a favorable track record for safety and efficiency, making it a trustworthy and outstanding choice for airlines.

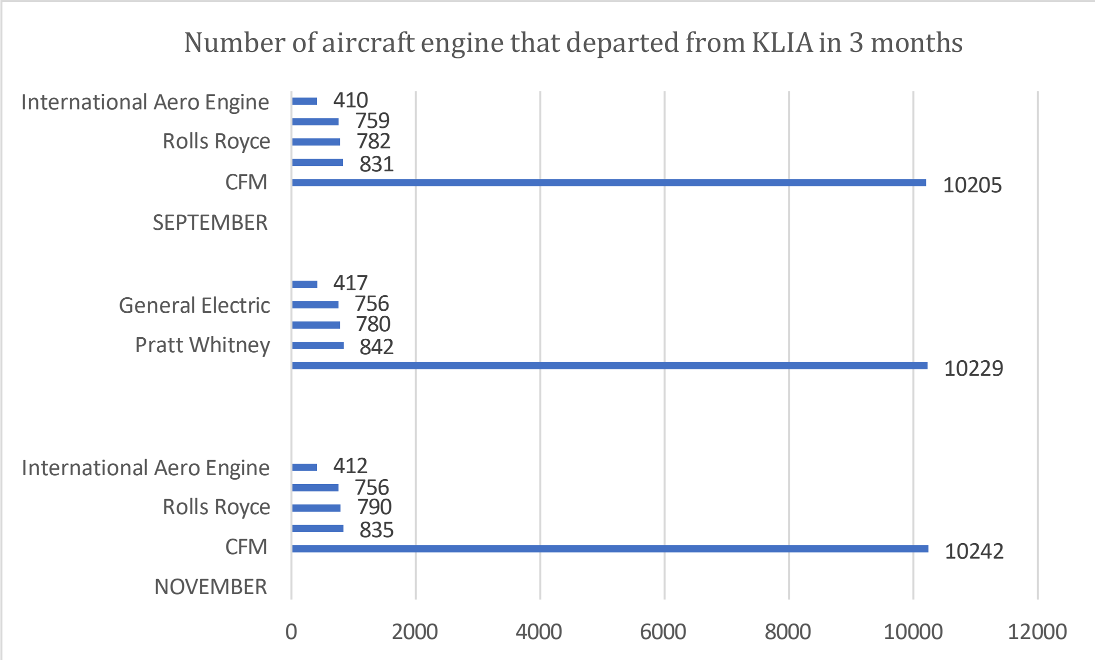

Fig. 7 *Number of aircraft engines departed from KLIA in 3 months.*

3.2 Airline

Airlines are the main clients of any airport in the world. An airport can establish an operating policy where they see fit. The airport provides complete pre-flight, during-flight, and post-flight services for any airline that either departs or arrives in its authorized area; hence, it is legal for them to enforce taxes on the airlines. Referring to Fig. 8, AirAsia has the highest figure, with more than 5,000 monthly departures. MAB does not fall far behind, with more than 3,500 departures monthly. AirAsia boasts a fleet of 100% A320 series aircraft, along with the A321. Fig. 8 shows that MAB and Batik Air dominate the Boeing 737 Max/NG fleet at 58.7% and 76.5%, respectively. All dominant aircraft types operate with engines from CFM, which primarily influences the daily emissions collected.

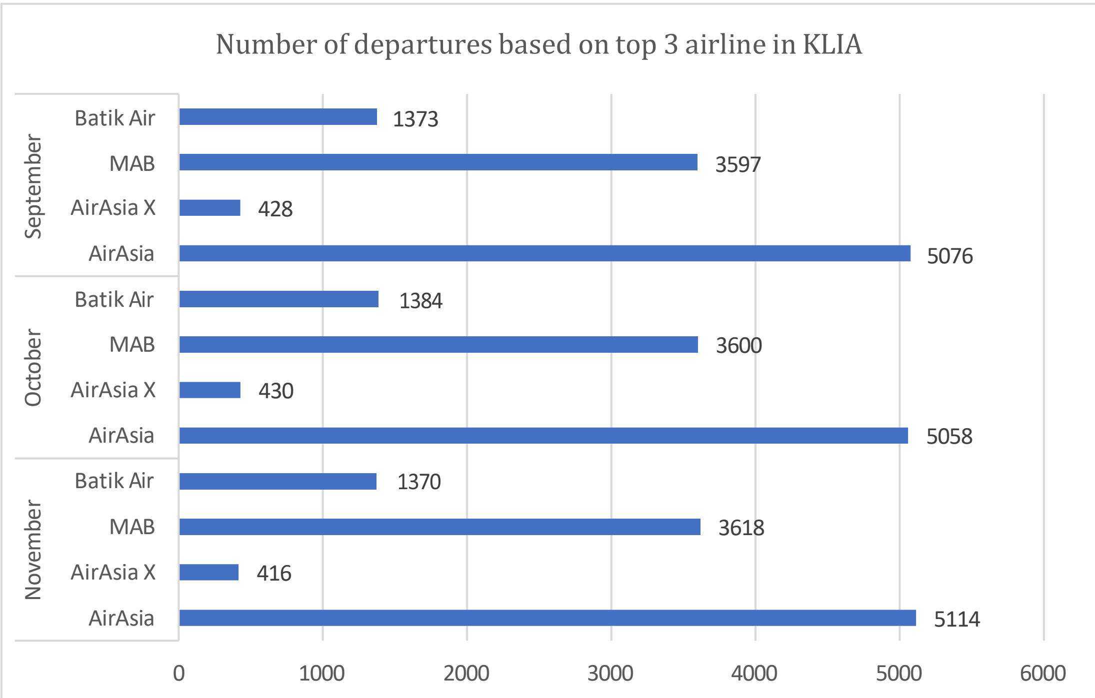

Fig. 8 *Number of departures based on the top 3 airlines in KLIA*

3.3 Time

Time is an essential factor in this study as it helps determine the active period in KLIA. The study collected data on the daily activity from 12:00 am to 11:59 pm. This was done to accurately estimate the activity of the aircraft. We can use this data to plan a strategy to control NO_x emissions and collect taxes from the airlines that pollute the air the most. As depicted in Fig. 9, there is an increasing trend in the early morning. The graph indicates that the highest number of aircraft departures occurs daily between 9:00 am and 10:00 am. Due to time zone differences, KLIA often experiences increased activity in the morning as travelers embark on early flights for business or leisure purposes. Another factor contributing to these results is that KLIA is a major hub for connecting flights in this region. Therefore, there may be a steady daily traffic flow as passengers connect to various destinations. This would significantly impact the NO_x index in the vicinity of KLIA.

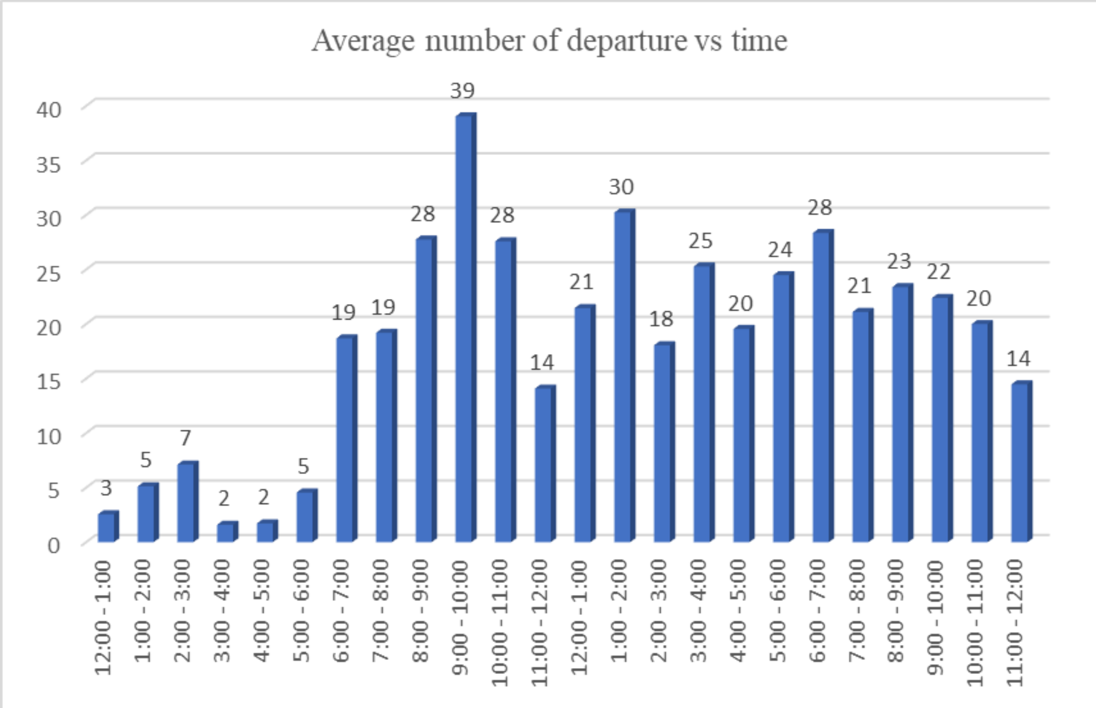

Fig. 9 *Graph of particulate matter (PM_{10}) against time*

3.4 Emission Tax

An emissions tax is a novel and innovative concept that aligns with the principle of achieving multiple objectives simultaneously. An airport tax emission charge is a fee that the airline must pay to the government or any agency responsible for environmental care due to the impact of flights. The charge aims to mitigate the environmental harm that airplanes emitting nitrogen oxide (NO_x) and other pollutants inflict. The charges are usually based on the emissions a flight produces. The bigger the airplanes, which burn more fuel, typically have higher charges. Environmental projects, such as planting trees or developing cleaner technologies, often use the collected tax to offset the pollution from flights. In summary, the airport tax emission charge aims to enhance the environmental friendliness of air travel by indirectly holding airlines and passengers responsible for their carbon footprint. This results in an impact that benefits not only one but at least two industries or parties, such as generating revenue for the airport and reducing pollutants. Table 2 shows that KLIA collected the highest number of NO_x emissions in November, totaling 214,007.01 kg. The number of departures mainly influences an increasing trend.

Table 2 *Amount of NO_x emissions released (kg) in KLIA in 3 months.*

Months	NO_x Emission (kg)
September	188,876
October	190,765
November	214,007.01
Total	593,684.01

Based on Fig. 10 and the Heathrow calculation method, KLIA has the highest potential tax revenue from airlines. KLIA can earn an average of RM 8,737,148.94 for three months. Using the Copenhagen method will result in the lowest earnings for KLIA, with an average of only RM 501,129.92.

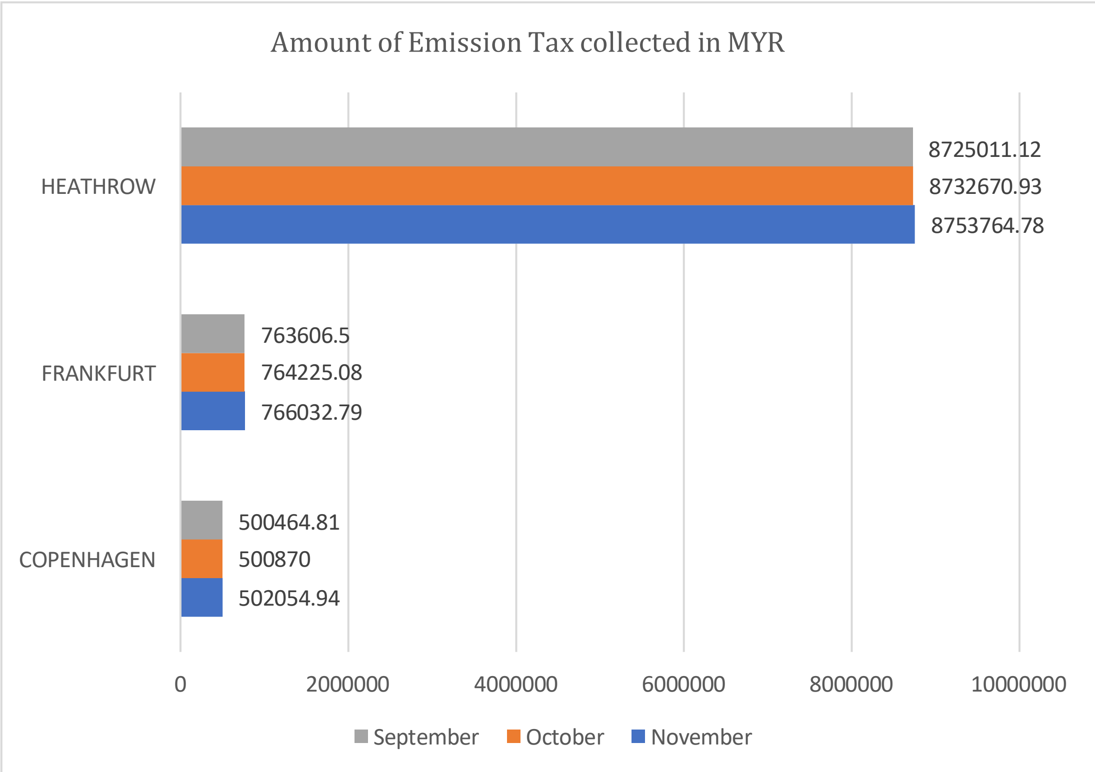

Fig. 10 *Amount of emission tax collected in MYR*

Based on Table 3, the Heathrow method provides the highest total tax compared to Copenhagen, which is the lowest, and Frankfurt, which is in the middle. The Heathrow method yields a significantly higher profit margin than both Frankfurt and Copenhagen due to its simpler calculation method, which eliminates the need for a complex process to calculate the tax.

Table 3 *Total tax earned in 3 months.*

METHOD	TOTAL TAX EARNED (RM)
Copenhagen	1,503,389.75
Frankfurt	2,293,864.37
Heathrow	26,211,446.83

4. Conclusion

In conclusion, various factors influence the traffic at KLIA. The factors influencing the outcomes include peak hours, off-peak hours, connecting flights, and seasonal flights. The data indicates that KLIA experiences peak traffic at 9:00 am, averaging over 30 flights daily, and at 1:00 pm, over 30 flights daily. During off-peak hours, air traffic is minimal in the early morning, specifically from 1:00 am to 5:00 am, with fewer than ten flights per day, consistently limited to seven flights daily across the three-month period. The study's findings indicate that KLIA might potentially benefit from its daily traffic by instituting an emission charge.

Domestic airlines prevail in daily statistics owing to increased demand for local products and typically possess a more comprehensive domestic route network, linking numerous towns and regions inside the nation. Figure 8 illustrates this, with AirAsia, a successful regional airline, recording 15,248 total departures, MAB reporting 10,815, and Batik Air documenting 4,127 over a three-month span. Local airlines possess the advantage of comprehending regional economic situations, enabling them to modify their operations accordingly. According to the figures depicted in Fig. 7, CFM engines are the predominant and most utilized engine type for departures from KLIA, accounting for a share of 30,676. Pratt & Whitney, Rolls Royce, General Electric, and IAE follow, with respective shares of 2,508, 2,352, 2,271, and 1,239 over a three-month duration. This results from the competitive pricing and efficiency of CFM engines, which assist airlines in minimizing their overall operating expenses.

The previously acquired data enables the calculation of the tax amount. According to the calculations for each monthly assessment technique, Table 3 indicates that the Copenhagen approach results in the lowest tax amount, whilst the Heathrow method results in the highest. We recommend implementing the Copenhagen technique at KLIA because of its equitable computation and its minimal tax rate of about 16.5 DKK. This yields an income of RM 1,503,389.75 over a period of three months. The Copenhagen technique employs an emission index determined by engine type, as each engine produces a distinct index, and its rate is suitable for KLIA.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Alif Izzuddin Azrin, Mohammad Fahmi Abdul Ghafir;* ***data collection:*** *Alif Izzuddin Azrin, Mohammad Fahmi Abdul Ghafir;* ***analysis and interpretation of results:*** *Alif Izzuddin Azrin, Mohammad Fahmi Abdul Ghafir;* ***draft manuscript preparation:*** *Alif Izzuddin Azrin, Mohammad Fahmi Abdul Ghafir. All authors reviewed the results and approved the final version of the manuscript.*

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