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Research Article

Using Advanced Modelling Tools to Analyse Emission Impacts of Different Aircraft Models on Domestic Flights

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Abstract

The aviation sector attains environmental sustainability objectives through precise measurement and assessment of gas and particulate matter emissions generated during flight operations. The research investigates the operational and environmental effects by performing different flight scenarios between Istanbul Sabiha Gökçen Airport (LTFJ) and Antalya Airport (LTAI) and using aircraft with wide-body and narrow-body types that meet identical passenger demands. The analysis is carried out using tools such as EUROCONTROL's IMPACT web-based platform and the BADA database that supplies the necessary information for analysis. Analysis of results shows that, on its flights on LTAI-LTFJ and LTFJ-LTAI, the wide-body aircraft releases an average of 17796 kg of CO_2 emissions. In comparison, reaching an equivalent passenger capacity using two narrow-body aircraft on corresponding routes results in a total of 12597 kg of CO_2 emissions. This is an illustration of aircraft type playing a major role in total levels of emissions, highlighting narrow-body aircraft in reducing carbon output for short-haul flights. The result of this study underlines aircraft selection in reaching operational and environmental sustainability, adding that an airline willing to lower fuel consumption and emissions can make its fleet planning strategies more effective by utilizing web-based advanced modeling tool.

Keywords: fuel consumption, emission, IMPACT, environmental sustainability

Yurtiçi Uçuşlarda Farklı Uçak Modellerinin Emisyon Etkilerinin Analizi İçin Gelişmiş Modelleme Araçlarının Kullanılması

Öz

Havacılık sektörü, uçuş operasyonları sırasında oluşan gaz ve partikül madde emisyonlarının hassas bir şekilde ölçülmesi ve değerlendirilmesi yoluyla çevresel sürdürülebilirlik hedeflerine ulaşabilir. Araştırmada, aynı sayıda yolcu talebini karşılayacak geniş ve dar gövdeli uçaklar kullanarak İstanbul Sabiha Gökçen Havalimanı (LTFJ) ile Antalya Havalimanı (LTAI) arasında gerçekleştirilen farklı senaryolar üzerinden operasyonel ve çevresel etkileri analiz edilmektedir. Çalışma, EUROCONTROL'ün IMPACT web tabanlı platformu ve analiz için gerekli bilgileri sağlayan BADA veritabanı gibi araçlar kullanılarak gerçekleştirilmektedir. Çalışma kapsamında elde edilen sonuçlar, geniş gövdeli uçağın LTAI-LTFJ ve LTFJ-LTAI uçuşlarında ortalama 17796 kg CO_2 emisyona neden olduğunu göstermektedir. Buna karşılık, ilgili rotalarda iki dar gövdeli uçak kullanılarak aynı sayıda yolcu taşındığında ise toplam 12597 kg CO_2 emisyonu oluşmaktadır. Bu sonuçlar, uçak tipinin toplam emisyon seviyelerinde önemli bir rol oynadığının bir örneğidir ve dar gövdeli uçakların kısa mesafeli uçuşlarda karbon salınımını azalttığını vurgulamaktadır. Bu çalışma, operasyonel ve çevresel sürdürülebilirliğe ulaşmada uçak seçiminin öneminin altını çizerek, yakıt tüketimini ve emisyonları düşürmeyi planlayan bir havayolunun, web tabanlı modelleme teknolojisini kullanarak filo planlama stratejilerini daha etkili hale getirebileceğini göstermektedir.

Anahtar Kelimeler: yakıt tüketimi, emisyon, IMPACT, çevresel sürdürülebilirlik.

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1. Introduction

The aviation sector provides an important advantage by combining speed and safety in the transportation of passengers and cargo when compared to other transport sectors. However, the aviation sector has a significant share in increasing air pollution due to its activities based on fossil fuel consumption, which also contributes significantly to the acceleration of climate change. In addition to contaminating the atmosphere and contributing to climate change through greenhouse gases, aircraft emissions also have a detrimental effect on human health. [1-3]. Under the European Green Deal, the European Union has also established a 90% reduction of transport emissions by 2050 compared with 1990 levels. Corresponding with this ambition, the ReFuelEU Aviation has been adopted specifically with regard to the aviation sector. The initiative includes the provision of sustainable aviation fuels at the airports from 2025 and has estimated that this will be 70% of the total by 2050 [4]. In addition to this, The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), developed by the International Civil Aviation Organization (ICAO), is a global market-based mechanism aimed at stabilizing CO_2 emissions from international aviation [5]. These organizations sustainable aviation, which aims to reduce environmental impacts and carbon footprints, a strategic priority for governments, airlines, and all stakeholders in the sector. The sector's ability to achieve its sustainability goals is not limited to measures taken to minimize the environmental impacts caused by aircraft; it also requires the research of innovative and holistic strategies in terms of economic and operational sustainability. The aircraft models used in air transportation and the performance of the engines of these aircraft are the main elements that directly affect fuel consumption and emission values. Therefore, in order to achieve the sustainability goals aimed in aviation, comprehensive examination and comparison of fuel and emission performances of different aircraft models by ensuring that they fly on similar routes makes great contributions to aviation for economic and environmental sustainability as an alternative method. During flights, the combustion process in the engines and the reaction activity following this combustion process cause approximately 30% of the emissions to be water vapor (H_2O), 70% to be carbon dioxide (CO_2), and the remaining approximately 1% to be carbon monoxide (CO), nitrogen oxides (NO_X), hydrocarbons (HC), sulphur oxides (SO_X), and particulate matter (PM). Exploring the harmful effects of emissions on the environment and, by extension, human health, it is found that CO_2 is one of the most important gases contributing to global warming. The other greenhouse gas, defined as H_2O, is formed because of the reaction between the hydrogen and oxygen gases formed after the combustion process is completed. While the HC and CO gases formed are produced after the incomplete combustion of the aviation fuel, the sulphur in the SO_X molecule is formed by reacting with oxygen during combustion [6-8]. Studies in the literature show that by optimizing flight routes, fuel consumption, and the resulting emissions can be significantly reduced in aircraft [9-12]. Khardi [13] study reveals that by optimizing flight routes, fuel consumption can be reduced by 3% and 27% in the take-off and landing phases, respectively. This study demonstrates that improvements made in the take-off and landing flight phases not only provide positive contributions to the environmental impacts but also significantly reduce the costs of airline companies. Well et al. [14] examine flights between New York and London in their study. It is shown that taking into account wind fields while optimizing flight routes can shorten flight range by 0.7% to 16.4% and thus significantly reduce fuel consumption and emission values in aircraft. Murrieta-Mendoza and Botez [15] use metaheuristic optimization methods to reduce costs by reducing the amount of fuel consumed during the cruise flight phase. These metaheuristic methods show that fuel consumption, emission values, and costs can be reduced by allowing flight routes to be optimized. These studies in the literature clearly show that optimization studies carried out to minimize fuel consumption and environmental impacts of flight operations are of critical importance in achieving sustainability goals in aviation. In academic studies conducted especially in the last few years, the Integrated Aircraft Noise and Emission Modelling Platform (IMPACT) developed by EUROCONTROL has been used to analyse in detail the types and amounts of fuel consumption and emissions caused by aircraft. Kılıç [16] analyses the fuel consumption and emission measurements of narrow-body and regional jet aircraft using the IMPACT web-based platform. This analysis shows that regional jet aircraft are a more suitable choice for environmental sustainability, especially on domestic routes where passenger demand is low, compared to narrow-body aircraft. Ekici et al. [17] conduct a comparative analysis of fuel consumption and emission values for all flight phases between Ankara Esenboğa Airport (LTAC) and Heathrow Airport (EGLL). This study evaluates the effects of different aircraft-engine combinations on fuel consumption and emission amounts between certain routes and analyses in detail how they perform in terms of environmental sustainability. In addition, it is seen that modelling tools along with comprehensive aircraft-engine databases developed by EUROCONTROL are used in the examination of four different flight scenarios in the study. Kılıç [18] examines the environmental impacts of turboprop and turbofan engine aircraft with the same seat capacity flying between Istanbul Sabiha Gökçen Airport (LTFJ) and Wien Schwechat Airport (LOWW) and Sabiha Gökçen Airport (LTFJ) and Izmir Adnan Menderes Airport (LTBJ) via the web-based IMPACT platform. When the aircraft are examined for these two flight scenarios, it is emphasized that turboprop engine aircraft have lower fuel consumption and emission values compared to turbofan engine aircraft in short-range flights. Ekici et al. [19] analyse fuel consumption and emission values at different flight stages thanks to different turbofan engines that can be used on the same aircraft model. In other words, this study reveals the effects of design and performance differences of different turbofan engines on environmental sustainability. The IMPACT platform developed by EUROCONTROL is preferred for calculating the emission values caused by different flight stages and different turbofan engines. Ekici et al. [20] examine how fuel consumption and emission values change depending on the change in the cruising altitude of aircraft. In this context, five different aircraft models flying at flight levels ranging from FL300 to FL385 are analysed comprehensively. The data set used in this study is obtained from the IMPACT platform developed by EUROCONTROL with BADA 4, ANP, and AEM. In addition, especially in the aviation sector, calculation methods developed by the ICAO are widely used in calculating emission values [21].

In the study, operational and environmental impacts are examined in detail through different scenarios that meet the same number of passengers' demands using different aircraft models. In addition, this study is to provide a scientific basis for minimizing the effects of aviation operations (gas emissions and particulate matter release) by modelling the effects of different flight scenarios with different aircraft types on environmental sustainability. Compared to the literature, the most important contributions and originality of this study are;

- The study provides more accurate and realistic models compared to simplified fuel and emission calculation methods frequently utilised in the literature, using the IMPACT analysis tool developed by EUROCONTROL with different aircraft types and different scenarios created with these aircraft.
- The literature generally discusses the fuel consumption and emission values of different aircraft models individually. In this study, the operational and environmental effects of wide-body and narrow-body jet aircraft are examined in detail to meet the same number of passenger demands. This approach provides a new perspective for fleet management and environmental sustainability processes for companies providing services in air transportation.
- The study presents a regional scale analysis by considering the LTFJ-LTAI and LTAI-LTFJ routes, which have some of the busiest domestic passenger traffic. Considering the lack of previous studies on these routes, this analysis makes a significant contribution to the literature.

2. Material and Methods

The research includes the comparison of different aircraft models in terms of emission values in flights between LTFJ and LTAI routes. The study focuses on two different types of aircraft: the AE-1, which is a wide-body aircraft, and the AE-2, which is a narrow-body aircraft. In the established scenarios, wide-body aircraft can accommodate passenger demand on designated domestic routes in a single flight, whereas narrow-body aircraft require two flights to fulfil the same demand. The study analyses each of these scenarios concerning emission values in detail and provides important inferences, particularly for flight planning. Fig. 1. represents the scenario involving the use of the AE-2 aircraft, while Fig. 2. shows the scenario involving the use of the AE-1.

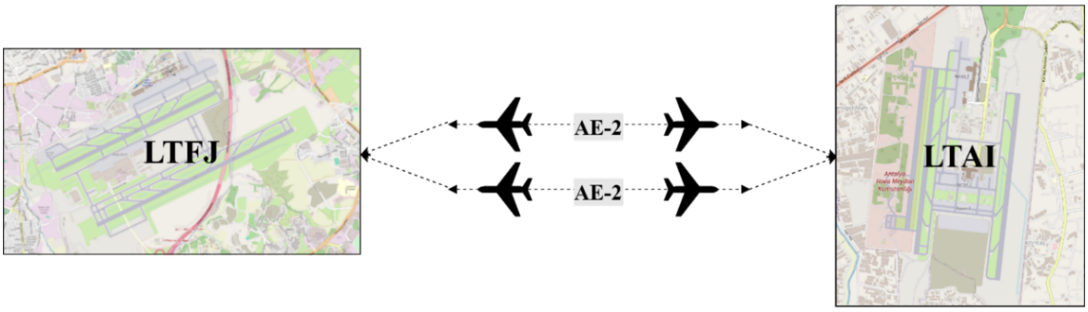

Figure 1. Demonstration of flights of narrow body (AE-2) aircraft between LTFJ-LTAI

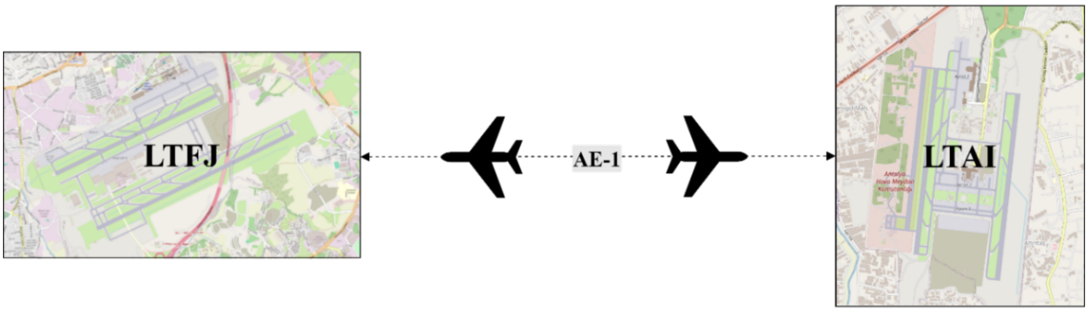

Figure 2. Demonstration of flights of narrow body (AE-1) aircraft between LTFJ-LTAI

2.1.Determination of Airports

The study considers two basic criteria when selecting the airports. Initially, the chosen airports are required to be among the busiest in domestic passenger traffic within Turkish airspace; thereafter, these airports require infrastructure enough for the landing and take-off operations of wide-body aircraft. These criteria are the basic guiding elements in determining the suitable airports for the study. In case of an increase in passenger demand, passenger transportation service is provided between Istanbul Airport (ICAO code: LTFM, IATA code: IST) and Antalya Airport (ICAO code: LTAI, IATA code: AYT) with wide-body aircraft. In this study, Sabiha Gökçen Airport (ICAO code: LTFJ, IATA code: SAW) is preferred as an alternative approach and the flights between LTFJ and LTAI with different aircraft types are examined by dividing into phases. The emission values of the aircraft used between these two airports are analysed to be evaluated from a sustainability perspective. Within the scope of the study, the cruise altitude is selected as FL320 (32000 feet) in order to compare the fuel consumption and emission analyses of the aircraft more accurately and precisely. In addition to this flight information, headwind values are taken as zero and relative humidity rates are taken as 70% at the airports where the flights are carried out. Table 1 provides detailed information about the LTFJ and LTAI airports.

Table 1. Sabiha Gökçen Airport -LTFJ and Antalya Airport -LTAI

Airport	IATA Code	ICAO Code	Elevation (feet)	Coordinate	Ref.
Antalya Airport	AYT	LTAI	177	36°54′01″K 30°47′34″D	[22]
Sabiha Gökçen Airport	SAW	LTFJ	312	40°53′54″K 29°18′33″D	[23]

2.2.Integrated Method for the Prediction and Assessment of Civil Aviation Environmental Impacts (IMPACT)

IMPACT (Integrated Method for the Prediction and Assessment of Civil Aviation Environmental Impacts) is a web-based application developed for the purpose of calculating the emission and noise values caused by aircraft. The program offers detailed modelling and evaluation of the environmental impacts of aviation activities, especially by analysing noise, gas emissions (e.g., carbon dioxide (CO_2), nitrogen oxides (NO_x)), and particulate matter (PM) emissions. IMPACT also performs modelling of noise and emissions occurring at different stages of civil aviation (take-off, cruise, landing, etc.). The program provides detailed analysis using operational data and routes of aircraft. Offering easy access thanks to its web-based structure, IMPACT allows users to enter flight data and create special scenarios. This user-friendly and modular structure provides flexibility according to specific needs, allowing scenario-based analysis to be performed for different aircraft types, engine technologies, and operational strategies. In this way, while a comparative assessment of environmental impacts is made, the effects of technological innovations and alternative fuels can also be tested. The program produces reliable and scientifically accurate analyses using standard data published by regulatory bodies such as the ICAO. It also has a data-based infrastructure that allows users to make customized assessments with local data. IMPACT plays an important role in environmental assessments such as noise pollution and air quality analyses around airports and in policy development processes by testing the feasibility of flight route optimization and emission reduction strategies. In addition, it contributes to future projections such as evaluating the environmental impacts of new aircraft and engine designs and strategic planning for sustainability goals by estimating long-term environmental impacts. The user workspace enables the basic steps of the study to be carried out via a web portal. In addition, data on the performance and emission factors of aircraft engines are provided through the ICAO Engine Emissions Database. This structure facilitates more verifiable assessments regarding aircraft types and operational efficiency. The calculation procedure is carried out through two main modules: Emission Calculation Module and Noise Calculation Module. The platform employs three methodologies for its emissions calculations: The IMPACT Fuel Flow Method, Boeing Fuel Flow Method, and First Order Approximation Version (FOA). Utilising the data from the input files, IMPACT builds a 4D trajectory for every route in alignment with the specified restrictions. The IMPACT Database employs reference data from the ANP and BADA. In the concluding phase, the IMPACT platform produces the emission quantities for each section of every aircraft trajectory using the Emissions Calculation Module. This workflow aims to analyse the environmental effects of flight operations by providing an integrated process including data validation, modelling, calculation, and result reporting steps. In this context, the system contributes to the presentation of the most appropriate solution proposals in terms of sustainability by comparing the operational and environmental performance of different aircraft types [24-27].

3. Results

In this section, the emission values of all aircraft models (AE-1, AE-2) are calculated separately for all flight phases (take-off, climb-out, climb, cruise, descent, approach, and landing) of the LTAI-LTFJ and LTFJ-LTAI routes.

Figs. 7-8 include the emission values of the AE-1 and AE-2 aircraft during take-off for two different routes (LTFJ-LTAI and LTAI-LTFJ). The AE-1 aircraft causes 11.82 kg of NO_X emissions when taking off from LTFJ Airport and 11.40 kg when taking off from the other airport, LTAI. The aircraft releases 813.48 kg of CO_2 on the LTFJ-LTAI route and 786.45 kg on the LTAI-LTFJ route. When the take-off flight phase of the AE-2 aircraft is examined, it is seen that especially NO_X emissions have proportionally very low values compared to the AE-1 aircraft. The AE-2 aircraft causes an average of 263 kg CO_2, 103 kg H_2O, 0.04 kg CO, and 0.07 kg SO_X emissions, respectively. CO_2 emissions are the greenhouse gas produced in the highest amount compared to other gases. For each aircraft type and both routes, SO_X and CO emission amounts are at very low levels. NO_X emissions also have a similar trend. Upon examining all aircraft independently, the emission values for the two routes reveal similar results for all greenhouse gases.

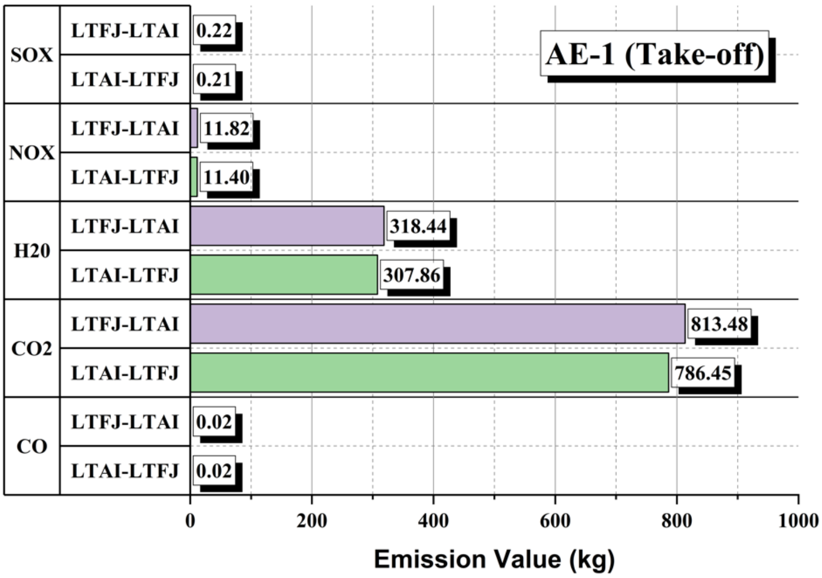

Figure 7. Take-off phase emission values for wide-body aircraft (AE-1)

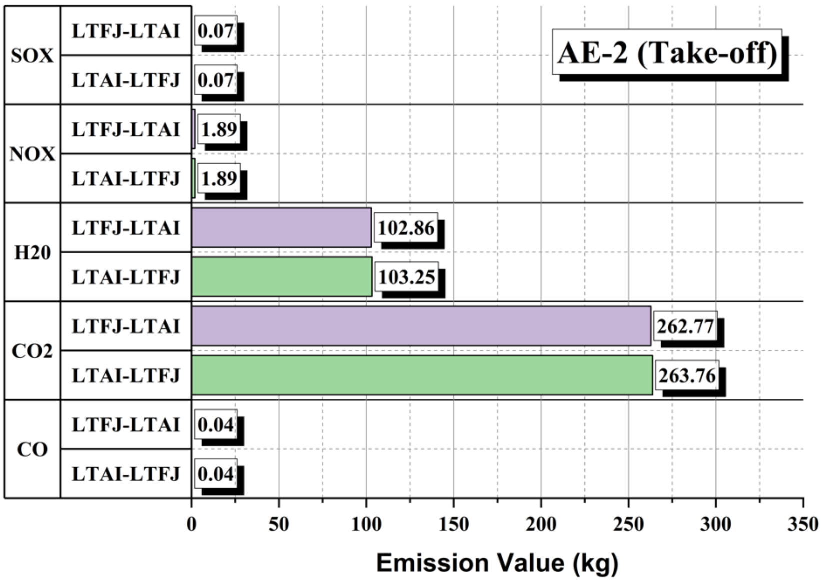

Figure 8. Take-off phase emission values for narrow-body aircraft (AE-2)

Figs. 9-10 compare the emission values of the AE-1 and AE-2 aircraft during climb-out phase for two different routes (LTFJ-LTAI and LTAI-LTFJ). Although the climb-out phase is a short flight phase, it causes the release of significant amounts of greenhouse gases. When the climb and climb-out phases are compared, a ratio of approximately half is observed in the emission values of these phases. While the average climb phase CO_2 value of the two routes for the AE-1 aircraft is calculated as 2315 kg, this value is calculated as 1140 kg on average for the climb-out phase. Figs. 11-12 show the emission values of the AE-1 and the AE-2 aircraft during the climb phase for two different routes (LTFJ-LTAI and LTAI-LTFJ). In the figure showing the emission amounts for the climb phase of the AE-1 aircraft, CO_2 and H_2O emissions have the highest values. Values of 2302.48 kg (LTFJ-LTAI) and 2330.90 kg (LTAI-LTFJ), mostly for CO2, show that there is a lot of carbon in the combustion processes during this phase. H_2O emissions show a similar change with CO_2 as 901.32 kg and 912.44 kg. SO_x and CO values have low values of 0.61 kg and 0.06 kg, respectively. The emissions for the AE-2 aircraft during the climb phase are naturally significantly lower compared to the AE-1. CO_2 emissions are also the highest in this aircraft with 845.80 kg and 846.67 kg. H_2O emissions also vary between 331.09 kg and 331.43 kg in a parallel manner. However, it is observed that these values are reduced by approximately one-third compared to the AE-1. While NO_x emissions are at the levels of 6.16 kg and 6.17 kg in the AE-2 aircraft, SO_x, and CO emissions are again at very low levels, around 0.22 kg and 0.15 kg, respectively. The reason for the high emission values in the climb phase is that the aircraft engines need a lot of thrust in this phase, as in the climb-out phase.

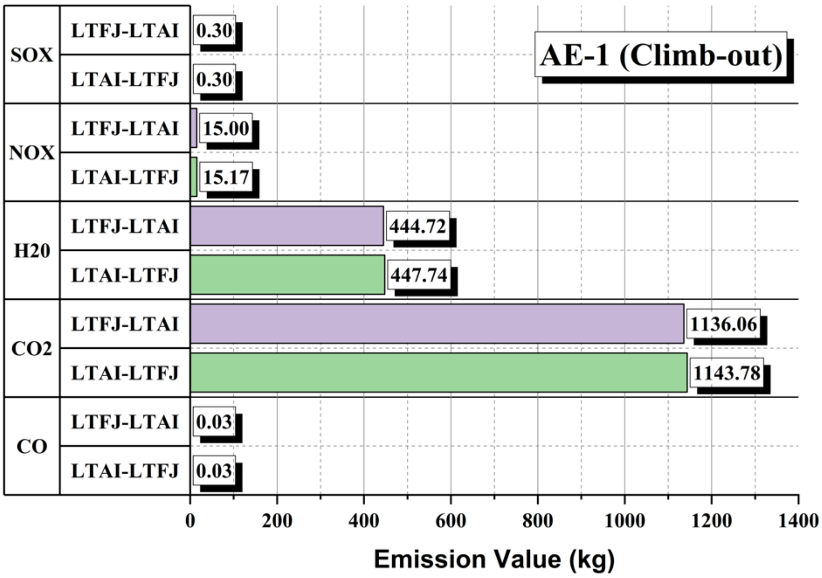

Figure 9. Climb-out phase emission values for wide-body aircraft (AE-1)

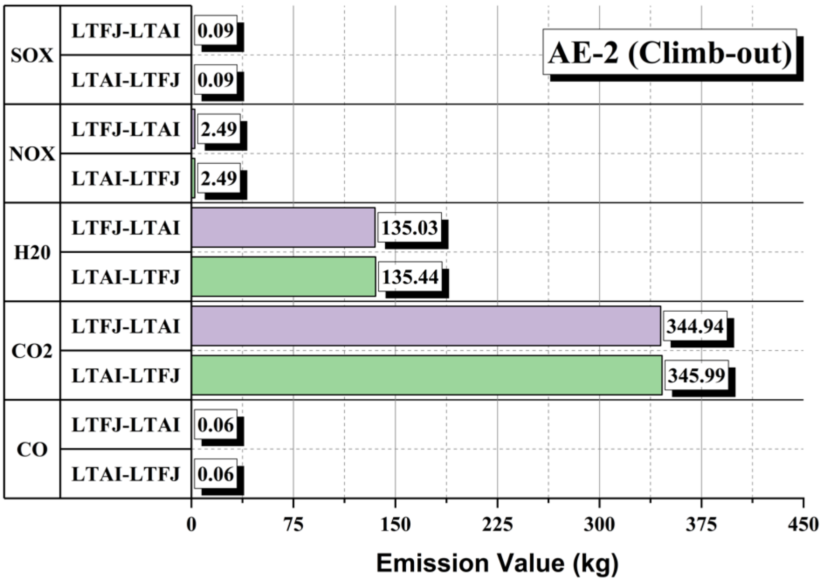

Figure 10. Climb-out phase emission values for narrow-body aircraft (AE-2)

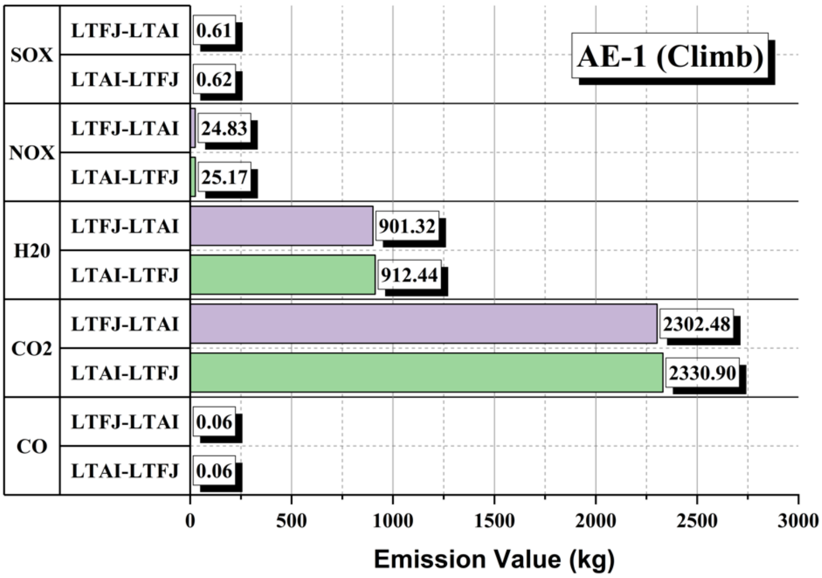

Figure 11. Climb phase emission values for wide-body aircraft (AE-1)

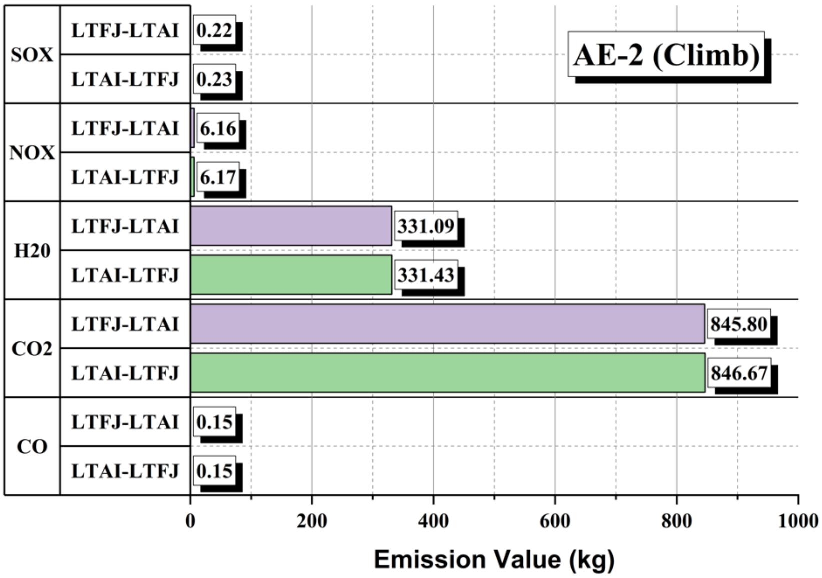

Figure 12. Climb phase emission values for narrow-body aircraft (AE-2)

Figs. 13-14 demonstrate the emission values of the AE-1 and AE-2 aircraft during the cruise flight phase for two different routes (LTFJ-LTAI and LTAI-LTFJ). The AE-1 aircraft has approximately 11600 kg CO_2 emission value during the cruise phase of LTFJ-LTAI route. H_2O emission amount shows a similar trend with CO_2 emission and has a high value of approximately 4542 kg. Other emission causing gases (SO_X, NO_X, and CO) are also significantly higher compared to other aircraft type. Comparing the emission values from other flight phases on the same route for the AE-1, it is seen that the emission difference during the cruise phase is significantly higher. The average amount of CO_2 that the AE-2 plane gives off during the cruise phase is 4244 kg for both routes, while the average amount of H_2O it emits is 1661 kg. When the emissions from the AE-1 and the AE-2 aircraft during the cruise phase are compared, it is understood that the AE-1 aircraft causes more than twice as much emissions as the AE-2 aircraft.

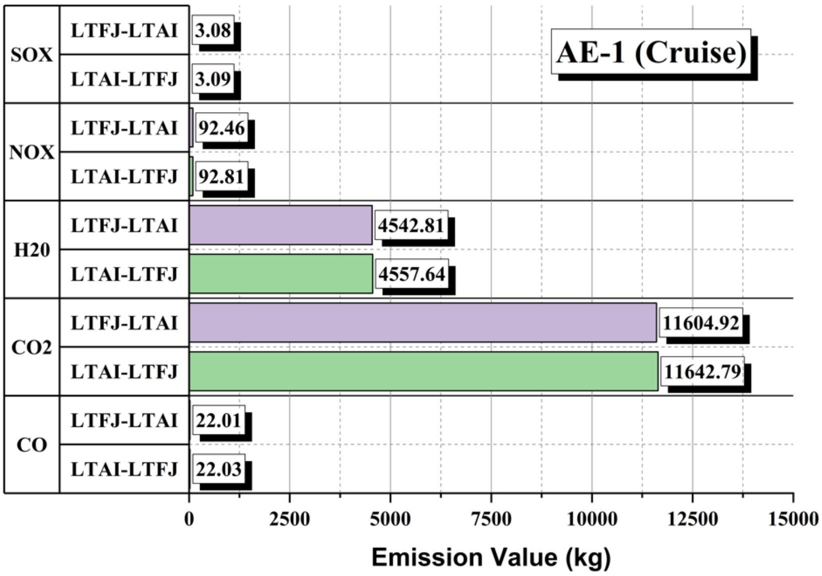

Figure 13. Cruise phase emission values for wide-body aircraft (AE-1)

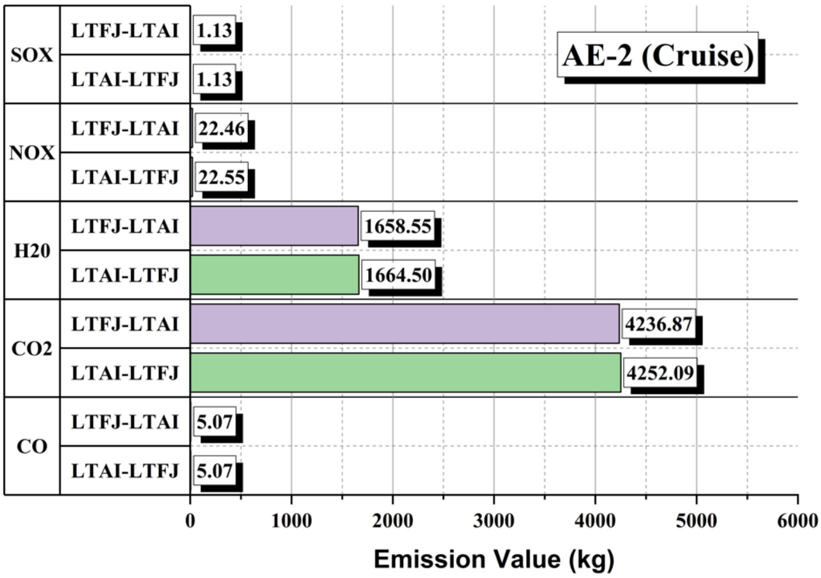

Figure 14. Cruise phase emission values for narrow-body aircraft (AE-2)

Figures 15-16 compare the emission values of the AE-1 and AE-2 aircraft during the descent and approach flight phases for two different routes (LTFJ-LTAI and LTAI-LTFJ). The primary rationale for considering the descent and approach flight phases collectively in these figures is that fuel consumption during the descent phase is at very low levels across all aircraft types, resulting in correspondingly low emission values. When the figures are examined in detail, the average CO_2 emission amount caused by the AE-1 aircraft during the descent and approach phases of both routes is 1815 kg, while the H_2O emission amount is 711 kg. Analysis of the emission values of the AE-2 aircraft during same phases reveals that its emissions are less than one-third of those produced by the AE-1 aircraft. In light of the above information, when the approach phases of the AE-1 and AE-2 aircraft on the LTFJ-LTAI and LTAI-LTFJ routes are compared, it is seen that there are differences between the fuel consumption and emission values of each aircraft. The main reason for this is that the altitude values of both airports are different. These figures also provide a clear understanding of the impact of the airports' altitude values on approach emissions.

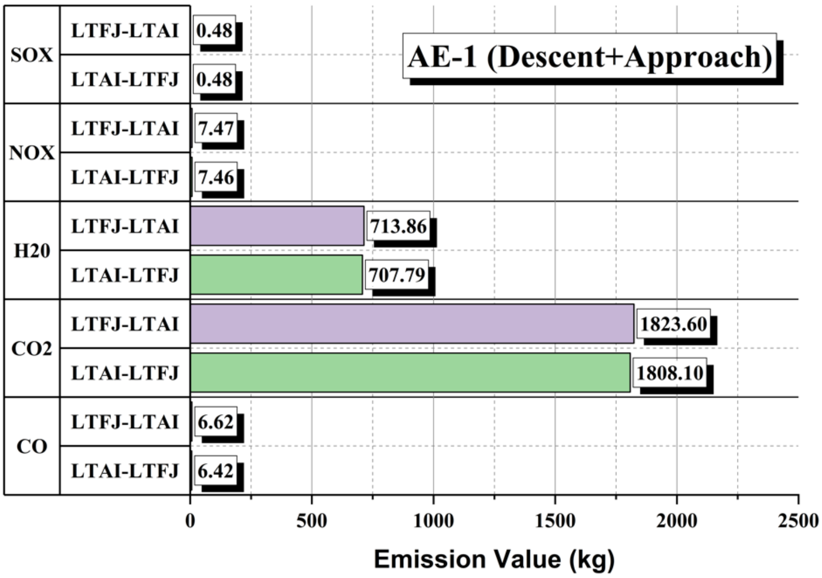

Figure 15. Descent and approach phase emission values for wide-body aircraft (AE-1)

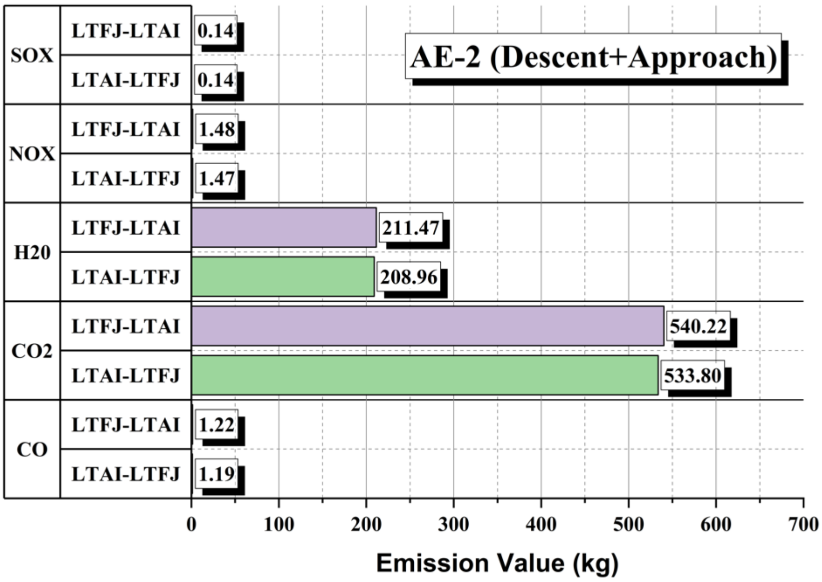

Figure 16. Descent and approach phase emission values for narrow-body aircraft (AE-2)

Figs. 17-18 depict the emission values of the AE-1 and AE-2 aircraft during the landing flight phase for two different routes (LTFJ-LTAI and LTAI-LTFJ). According to the CO_2 emission values for the landing flight phase on the two routes, the AE-1 aircraft put out 100.39 kg of CO_2 on the LTFJ-LTAI route and 98.23 kg on the LTAI-LTFJ route. When comparing their CO_2 emission values, the AE-2 aircraft emit 40% less CO_2 than the AE-1 aircraft. Examining aircraft H_2O emission values during landing shows that H_2O changes with fuel consumption. The AE-1 aircraft has an average H_2O emission value of approximately 38.8 kg on the LTFJ-LTAI and LTAI-LTFJ routes. The H_2O emission values of the AE-2 aircraft during the landing phase for these two routes are 23.70 and 24.72 kg, respectively. When aircraft types are examined in terms of NO_x emissions, the AE-1 and AE-2 aircraft have similar NO_x emission values. As a result, the emission values caused by all aircraft types during the landing phase on the LTFJ-LTAI and LTAI-LTFJ routes show different values. The disparities in emissions are mainly due to the fact that the airports are located at different elevations, as is the case during the approach phase.

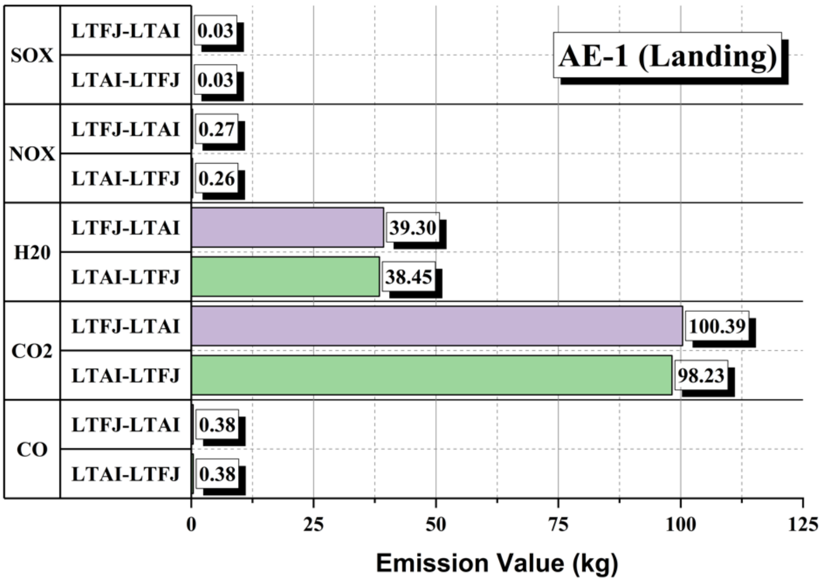

Figure 17. Landing phase emission values for wide-body aircraft (AE-1)

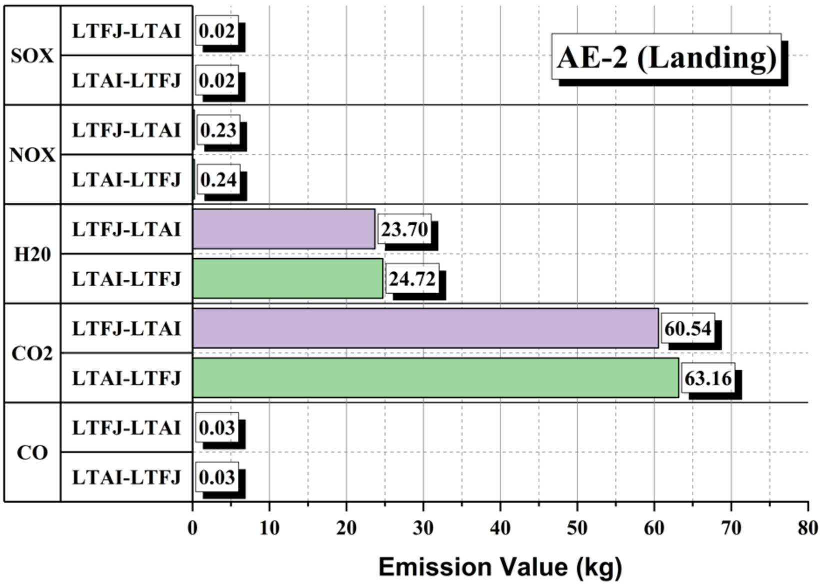

Figure 18. Landing phase emission values for narrow-body aircraft (AE-2)

Figure 19 shows the total values of emissions caused by aircraft during flights on two different routes (LTAI-LTFJ and LTFJ-LTAI) for different aircraft types (AE-1 and AE-2). When the AE-1 aircraft completes its flight on the LTAI-LTFJ and LTFJ-LTAI routes, it generates an average of 24954 kg of total emissions. In order to transport the same number of passengers as the AE-1 aircraft, two AE-2 aircraft (denoted as AE-2(x2)) are required to operate on the same routes. Under these conditions, the combined emissions produced by the AE-2(x2) aircraft amount to 17618 kg on average. This comparative analysis indicates that, the total emissions per passenger for the AE-2 configuration are lower than those for the AE-1 aircraft.

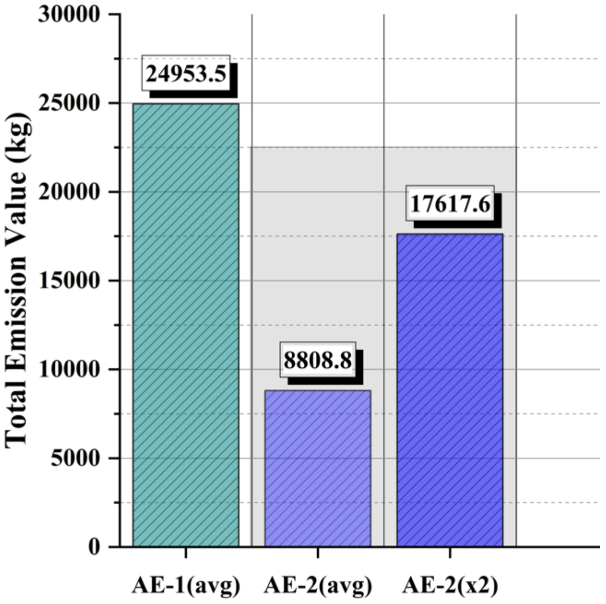

Figure 19. Total emission values for all aircraft models (AE-1, AE-2 and AE-3)

4. Conclusion

This study emphasizes the importance of aircraft selection in terms of environmental sustainability and operational efficiency in the aviation sector and analyses the effects of these selections on emission values at different flight phases in detail. In this context, different flight scenarios between the LTFJ and LTAI airports using the AE-1 and AE-2 aircraft types are examined. AE-1 consumes approximately 5636 kg of fuel on the LTAI-LTFJ route and 5627 kg on the LTFJ-LTAI route. The AE-2 aircraft consumes 1995 kg of fuel on the LTAI-LTFJ route and 1990 kg on the LTFJ-LTAI route. The AE-2 aircraft exhibits a more efficient performance compared to the AE-1. The fact that the difference in consumption of the AE-2 aircraft between the two routes is quite low shows that the engine provides consistent performance under different operational conditions. The examinations reveal that the AE-1 have high fuel consumption values during short-haul flights. In other words, this type of aircraft is not environmentally or operationally efficient for short flights. Moreover, emission calculations show that a flight of an AE-1 aircraft emits 24954 kg emission values (CO_2, SO_X, H_20, CO, and HC). When two narrow-body aircraft (AE-2) are flown to meet the same passenger demand, the total amount of emissions is seen as 17618 kg emission values. Considering the flight phases, the cruise phase is the one that results in the highest fuel consumption and emissions, regardless of the aircraft model. To illustrate, while the AE-1 aircraft releases an average of 11600 kg of CO_2 emissions during the cruise phase, the AE-2 aircraft emits an average of 4244 kg of CO_2. The impact of airport elevation on fuel consumption and emissions, particularly during the landing phase, is another significant finding of the study. The fact that LTFJ and LTAI airports have different elevation levels affects the fuel consumption of the same aircraft type during the landing phase and causes differences in emission values. The study's findings highlight that the importance of aircraft selection is crucial for attaining operational and environmental sustainability. Airlines aiming to reduce fuel consumption and emissions can more precisely determine fleet management strategies by utilising web-based sophisticated modelling tools like IMPACT. Future studies could analyse commercial turbofan aircraft performing long-range flights and compare the results with those presented herein. Additionally, the influence of various operating factors, such as changing cruise altitudes, air traffic density, and atmospheric conditions, can be examined to improve emission estimates and optimize fuel efficiency recommendations.

Ethics in Publishing

There are no ethical issues regarding the publication of this study

Author Contributions

Vehbi Emrah Atasoy: Performed the computations, analyzed the results, and wrote the manuscript.

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