

Investigation of Landing-Takeoff related greenhouse gas emissions at Samsun Çarşamba Airport

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Abstract

The importance of this study is underscored by its quantification of carbon footprint values associated with the takeoff and landing phases, which represent the highest greenhouse gas emissions at airports. The most significant factor in greenhouse gas emissions at airports comes from airplanes. Therefore, the Landing-takeoff (LTO) cycle is important in the aviation sector. The LTO cycle represents the entire process of aircraft climbing to an altitude of 3000 feet, cruising, and landing. Since the LTO cycle is closely related to the amount of carbon dioxide emitted, the carbon emission amounts at Samsun-Çarşamba Airport have been calculated according to the IOC's tier-2 method based on the LTO cycle. The total LTO value for the year 2023 has been determined to be 13,316. The highest LTO value was recorded in July at 1336. There is no significant difference in the emission amounts among the aircraft models. However, the aircraft model with the highest number of LTO is the Boeing 738, and its carbon emissions are also higher than the others. For the year 2023, the total equivalent carbon dioxide amounts, including CO₂, N₂O, and CH₄, have been determined to be 22,757 eCO₂ tons/year.

Keywords: Samsun-Çarşamba, LTO, Airport, Carbon footprint, Greenhouse gas, Climate change.

Samsun Çarşamba Havalimanı'nda İniş-Kalkış, ile İlişkili Sera Gazı Emisyonlarının Araştırılması

Öz

Bu çalışmanın önemi hava alanlarında en fazla sera gazı salınımının gerçekleştiği iniş-kalkış anlarından kaynaklı karbon ayak izi değerlerinin vurgulanmasıdır. Havalimanlarında sera gazı salınımlarında en önemli etken uçaklardan kaynaklanmaktadır. Bu nedenle havacılık sektöründe İniş-Kalkış (LTO) döngüsü önemlidir. LTO döngüsü, uçakların 3000 feet yüksekliğe çıkış, seyir ve iniş arasındaki tüm süreci temsil eder. LTO döngüsü salınan karbondioksit miktarı ile yakından ilişkili olduğundan, Samsun-Çarşamba havalimanında LTO döngüsüne göre IOC'nin tier-2 metodu ile karbon salınım miktarları hesaplanmıştır. 2023 yılı toplam LTO değeri 13316 olarak tespit edilmiştir. En yüksek LTO değerine Temmuz ayında 1336 olarak çıkmıştır. Uçak modellerinin emisyon miktarları arasında önemli bir farklılık yoktur. Ancak en fazla LTO sayısına sahip uçak modeli Boeing 738 olup karbon salınım miktarları da diğerlerinden daha fazladır. 2023 yılı için CO₂, N₂O ve CH₄ ile birlikte toplam eşdeğer karbon dioksit miktarları 22757 eCO₂ ton/yıl olarak belirlenmiştir.

Anahtar Kelimeler: Samsun-Çarşamba, LTO, Havalimanı, Karbon ayak izi, Sera gazı, İklim değişimi.

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1. Introduction

Generally, in aircraft engines designed as reciprocating (piston) engines and gas turbine engines, CO₂, NO_x, CH₄, CO, SO_x, NMVOCs, and PM emissions occur during combustion. These emissions are generated from pre-departure activities, departure activities, cruise activities, emergency activities, arrival activities, post-arrival activities, and maintenance activities during flight operations. In Figure 1, the selection of methods for total fuel consumption and emission estimates from flight sources is made using a decision tree approach for emissions (EMEP.2019).

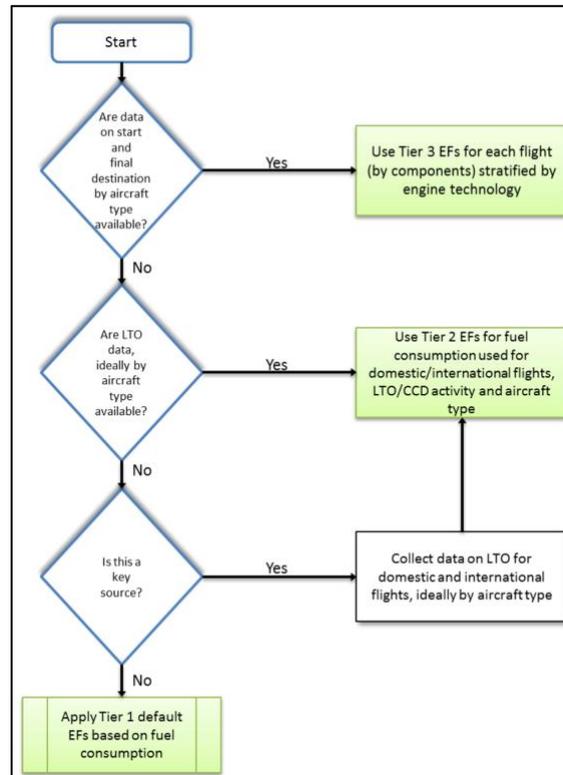


Figure 1. Select the Tier Method Using the Decision Tree (EMEP.2019)

Studies on carbon footprint assessment related to greenhouse gases represent a critical area of inquiry in the context of climate change. Consequently, the requirement for all institutions to calculate their carbon footprint is pivotal, as it constitutes the initial step in mitigating global warming.

The transportation sector significantly contributes to carbon dioxide emissions, with air travel being a primary source. Within air travel, the phases of takeoff and landing account for the largest carbon footprint. Calculating the carbon footprint associated with takeoffs and landings in civil aviation addresses a crucial gap, as these phases are characterized by the highest carbon dioxide emissions, contingent upon the aircraft type. This study aims to underscore the carbon dioxide emissions occurring during takeoffs and landings.

The Landing-Takeoff (LTO) cycle is used to refer to the cycle that encompasses all operational stages performed by an aircraft during its landing at or takeoff from an airport, typically at altitudes below 3,000 feet (approximately 1,000 meters). The LTO cycle is used by organisations such as the International Civil Aviation Organisation (ICAO) specifically to assess the emission-related impacts of aircraft engines. The LTO cycle (Figure 2) is as follows: the first phase is taxi, where the engine operates at idle or low power, and the aircraft moves from the airport terminal or parking position to the runway (taxi-out) or from the runway to the terminal/parking position after landing (Taxi-in). The second stage is the Take-off phase, where the engines operate at full power for a short and intense period, and the aircraft lifts off the ground and begins its initial climb. The third phase is the climb-out phase, where the engines operate at high climb power and the aircraft climbs to a certain altitude (generally 3000 feet for ICAO standard) immediately after takeoff. The fourth phase, on the other hand, is the approach phase, during which the engines operate at low or idle power and generally involve the final manoeuvres before landing and descent towards the runway.

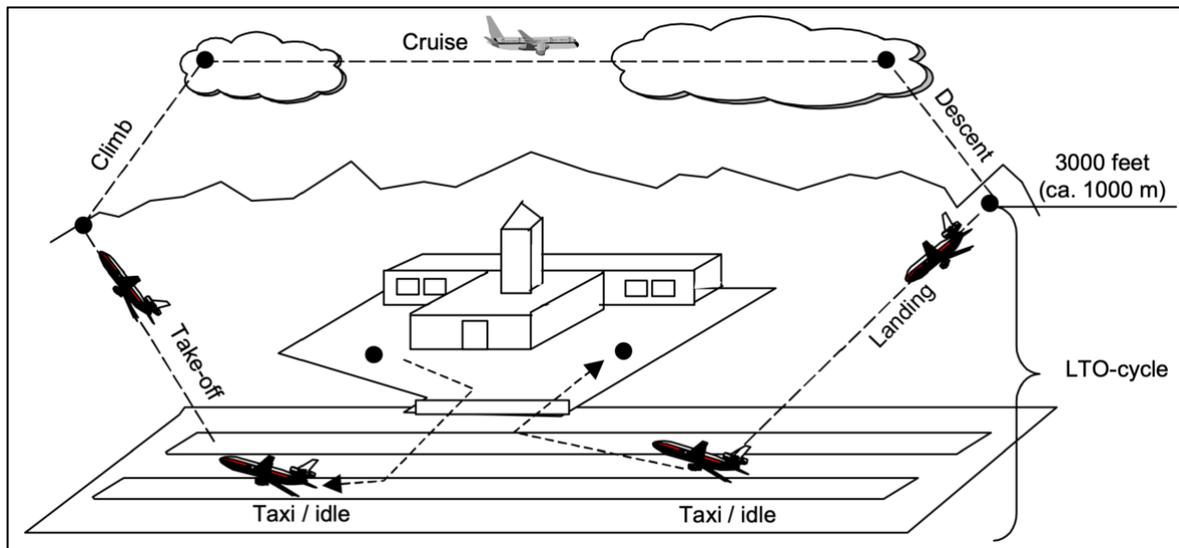


Figure 2. Standard LTO Cycle (EIG. 2006)

Based on data from different airports, the amounts of carbon dioxide emissions are summarized in Table 1, both in terms of data and calculations.

In this study, carbon dioxide data related to LTO were calculated using the Tier-2 method, taking into account the emission factors determined by the IPCC for different aircraft models. Additionally, separate carbon dioxide equivalent conversions for N₂O and CH₄ have been made according to the IPCC's global warming potentials.

Table 1. Comparisons of aircraft GHG at airports based LTO (Tier-2, Scope 3)

Airport	Year	LTO Cycle	eCO ₂ ton/year	Reference
Hial, İskoçya	2022	26568	74777 ⁺	(RE&E.2022)
Aberdeen, UK	2021	1159*	32461	(RE&E.2021)
Edinburg, İskoçya	2021	17469*	49167	(RE&E.2021b)
Lanseria, Güney Africa	2020	24095*	67817	(Chimhau, T. 2022)
Glasgow, İskoçya	2024	26179*	73681	(RE&E. 2024)
Chengdu Shuangliu, Çin	2014	270000	759924 ⁺	(Lu et al. 2018)
Dalaman, Türkiye	2017	56777	93411	(Akyüz et al. 2019)
Antalya, Türkiye	2024	149836*	421718	(Fraport Tav. 2024)
Trabzon, Türkiye	2023	8355	23515 ⁺	(Karaman, F. 2025)
Ordu, Giresun	2023	3103	8733 ⁺	(Karaman, F. 2025)
Çarşamba, Türkiye	2023	13316	22757	This study

*: According to average emission factors, the average LTO calculation has been made only for carbon dioxide.

+ : According to average emission factors, the average eCO₂ calculation has been made only for carbon dioxide.

2. Materials and Methods

2.1. General Information about Samsun Çarşamba Airport

Samsun Çarşamba Airport is located in the Çarşamba district, which is in the eastern part of Samsun province, with geographical coordinates of 41°15'56"N, 36°32'55"E. In 1998, the airport officially opened. The total size of the terminal building is 11,500 m². It is located approximately 25 km away from the center of Samsun. The airport is 12–15 kilometers away from the coast. There are residential areas and agricultural lands around it. Samsun Çarşamba Havalimanı da Yeşil Kuruluş sertifikası bulunan havalimanlarından bir tanesidir. Samsun Çarşamba Airport is also one of the airports that have the Green Organization Certificate. Figure 3 shows the map of Samsun Çarşamba Airport (URL-1).



Figure 3. Samsun-Çarşamba Airport (Yandex.2025).

Samsun Çarşamba Airport has less air traffic compared to airports in other major cities. The annual flight numbers for 2023 at Samsun Çarşamba Airport are provided in Table 2.

Table 2. Samsun Çarşamba Airport 2023 LTO (Landing-Takeoff) Flight Count

Month	Number of Aircraft Landings	Number of Aircraft Taking Off
January	497	494
February	406	405
March	488	491
April	525	527
May	580	576
June	584	578
July	669	667
August	592	593
September	614	612
October	645	647
November	547	546
December	517	516
Total	6664	6652

The types and numbers of aircraft landing at Samsun Çarşamba Airport in 2023 are shown in Figure 4.

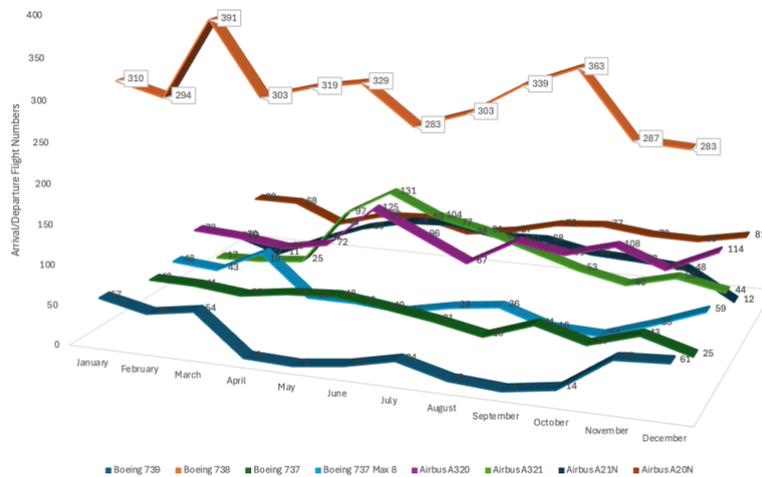


Figure 4. Samsun Çarşamba Airport Arrival/Departure Flight Numbers and Models

In the Tier-1 approach, fuel quantities and total LTO counts are considered for domestic and international flights. General aircraft emission factors are used for aircraft fleet types. General equation for Tier-1;

$$E_{pollutant} = AR_{fuel\ consumption} \times EF_{pollutant} \tag{1}$$

where

$E_{pollutant}$: is the annual emission of pollutant for each of the LTO and CCD phases of domestic and international flights

$AR_{fuel\ consumption}$: is the activity rate by fuel consumption for each of the flight phases and flight types

$EF_{pollutant}$: is the emission factor of pollutant for the corresponding flight phase and flight type

The Tier 2 approach can be applied if it is possible to obtain information about LTO by aircraft type, but there is no information about CCD distances. For this methodology, information is required about the types of aircraft used in both domestic and international aviation, as well as the number of LTO performed by various types of aircraft. Tier 1 and Tier 2 methodologies, Figure 5. As seen, it is based on LTO data and the amount of fuel sold or used.

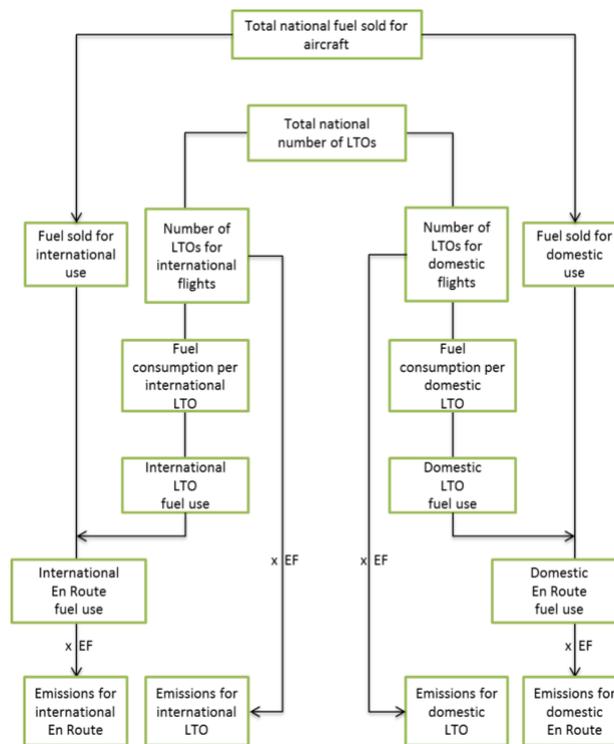


Figure 5. Estimation of aircraft emissions using the Tier 1 and Tier 2 methodologies (IPCC, 2007)

3. Results and Discussion

The IPCC's Tier-2 method calculates the aircraft's carbon footprint using the LTO cycle. The calculation considers LTO cycles based on aircraft types, but it does not take into account the cruising activities of the aircraft, which occur above 3000 feet (914 meters) altitude and are referred to as cruise altitude. We calculated the emission quantities using the IPCC-determined emission factors (IPCC, 2007) (Table 3). We have calculated the CO emission values annually for each type of aircraft.

Table 3. Aircraft landing and takeoff (LTO) emission factors by brand and model type (IPCC, 2007)

Aircraft Models	Fuel consumption (kg/LTO)	Emission Factors (kg/LTO)		
		CO ₂	CH ₄	N ₂ O
Boeing 737	870	2780	0.45	0.1
Boeing 737 Max 8	870	2780	0.45	0.1
Boeing 738	880	2780	0.07	0.1
Boeing 739	880	2780	0.07	0.1
Airbus A20N	770	2440	0.06	0.1
Airbus A21N	960	3020	0.14	0.1
Airbus A321	960	3020	0.14	0.1
Airbus A320	770	2440	0.06	0.1

In order to apply the Tier-2 method, the number of LTO cycles and the type of aircraft engine used must be known, and the emission values published by the IPCC for different aircraft types are used. The formula used in the Tier-2 approach is provided below;

$$Emission\ Amount\left(\frac{kg}{LTO}\right) = Landing\ and\ Takeoff\ Count\ (LTO) \times Emission\ Factor\ (EF) \quad (2)$$

In Table 4 and Figure 6, the carbon emission amounts of all greenhouse gases from the aircraft's LTO cycle for the year 2023 are provided. Simultaneously, we have determined the equivalent carbon dioxide amounts based on global warming potentials(GIP). The equivalent carbon dioxide amounts per annual LTO for each type of aircraft have also been calculated in tons according to the Tier-2 method. At Samsun-Çarşamba Airport, the average equivalent carbon dioxide per LTO for the year 2023 has been determined to be 2.79 tons of eCO₂/year.LTO. The similar results of the equivalent carbon dioxide amounts per LTO for the aircraft models indicate that there is no significant difference in the carbon emissions of the aircraft.

Table 4. Aircraft landing and takeoff (LTO) emission factors by brand and model type (IPCC, 2007)

Aircraft Models	LTO/year	tone CO ₂ /year	tone CH ₄ (CO ₂)/year	tone N ₂ O(CO ₂)/year	tone eCO ₂ /year	tone eCO ₂ /year.LTO
B739	339	942.4	1.0	9.0	952.35	2.81
B738	3804	10575.1	10.6	10.1	10686.58	2.73
B737	433	1203.7	1.2	11.5	1216.43	2.90
B737 Max 8	406	1128.7	1.1	10.8	1140.58	2.81
A320	1062	2591.3	3.0	28.1	2622.40	2.47
A321	749	2262.0	2.1	19.8	2284.00	3.05
A21N	592	1787.8	1.7	15.7	1805.19	3.06
A20N	830	2025.2	2.3	22.0	2049.52	2.47
Total					22757	

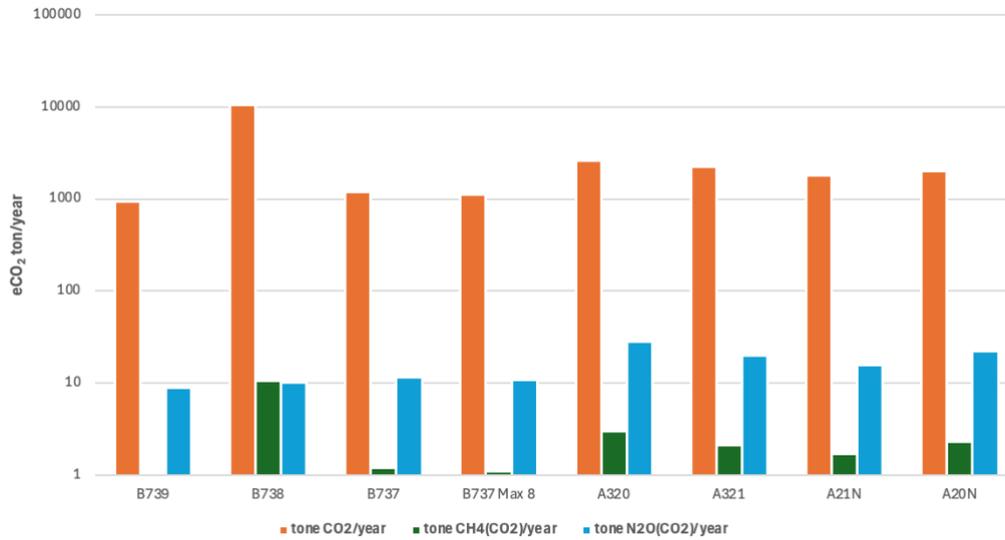


Figure 6. Annual Emission Values from Passenger Aircraft (for only LTO)

4. Conclusions

The amount of carbon dioxide (CO₂) produced during the landing and takeoff (LTO) cycles of aircraft is the most significant source of carbon dioxide at an airport. Although there are different standards and methods for determining these emissions, the tier-2 method approach of the IPCC has been adopted in this study. In this method, the emission factors of aircraft models, fuel quantities, and the number of LTO cycles are taken into account. Additionally, aircraft and engine types, operational procedures, airport traffic, and meteorological conditions are effective in emission release for LTO. Samsun-Çarşamba Airport is a medium-density airport, and the equivalent carbon dioxide amount calculated for the year 2023, based on three different greenhouse gases, is 22757 tons eCO₂/year. In the aviation sector, it is extremely important to understand the relationship between LTO cycle carbon emissions and strategies for reducing, managing, and mitigating environmental impacts, as well as developing sustainable airports.

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Authors' Contributions

Andaç Akdemir: Supervision, Conceptualization, Methodology, Statistical Analysis, Validation, Writing, Original draft preparation,

Gökçe Talı: Literature review data collection, compilation, and calculation,

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

The author declares that this study complies with Research and Publication Ethics.

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