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Determination of personal carbon footprint in aviation and tourism axis: Cappadocia Airport case

Selçuk GÜRÇAM*

Independent Researcher, Iğdır, Türkiye

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ABSTRACT

Global average temperatures are increasing in direct proportion to the increase in carbon dioxide (CO_2). A significant part of this increase comprises the aviation and tourism sectors. In particular, the rapid growth of the aviation industry and its relationship with tourism development constitutes an indispensable problem for the future in the fight against the climate crisis. In this study, it has been revealed that the aviation industry is not innocent at all regarding the climate crisis when combined with tourism. The study examined flights' average personal carbon footprint to Cappadocia Airport between 2016 and 2019. The Cappadocia region stands out because it is an important tourism region of Turkiye and is located right in the middle of Turkiye. In the review, 2019 was the period with the highest emissions of 27,464.08 tons CO_2. On the other hand, 2017 was the year that emitted the least, with 8121,29 tons CO_2. The personal carbon footprint from total flights was 61,951 kg CO_2. While the individual carbon footprint was the highest in 2016 with 70,617 kg CO_2, 2019 was the year with the lowest personal carbon footprint with 56,419 kg CO_2. As a result, while there is a direct proportion between the number of flights and the total increase in CO_2, the personal carbon footprint has changed according to the number of passengers. Transportation preferences should be reviewed considering the location of the Cappadocia region and Turkiye's transportation policy.

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INTRODUCTION

Greenhouse gases (GHG) originate from various sectors. Among these, the aviation sector stands out in terms of rapid growth, although its rate is low. Between 1970 and 2019, there was a 77% improvement in passenger energy density, expressed in British Thermal Units, with improvements in the engine and design sector, efficiency in air traffic operations, denser seat configurations, and more passengers. Especially in the last 20 years, the growth in the commercial aviation sector has been more than the growth in total emissions. However, with the increased demand, the increase in destinations, the increase in the number of aircraft, and the increasing impact of the sector on global trade and economy, there has been a rapid increase in emissions from aviation [1]. According to the International Council for Clean Transport, emissions from all commercial operations increased by 29% between 2013 and 2019, reaching 918 million metric tons [2].

***Corresponding author.**
*E-mail address: selcukgrcm@gmail.com

According to the International Civil Aviation Organization, by 2050, GHG emissions from the aviation sector may increase by two to four times compared to 2015 emission levels [3]. The rapid recovery and growth in the sector after the COVID-19 epidemic, especially the increase in demand, stands as the biggest obstacle to controlling emissions in the commercial aviation sector [1]. The first of the individual measures to be implemented for this purpose is the calculation of the carbon footprint. All responsible countries and institutions, especially those that are party to the Paris Agreement, should take measures to reduce their carbon footprints. Knowing the carbon footprint, as measured by carbon dioxide (CO_2) emissions caused by human actions and understanding what it takes to minimize it is essential to combat the climate crisis individually. Airports are constantly overflowing, and the density is much higher, especially in summer. More than 1.1 billion passengers flew in the United States of America (USA) alone in 2019, both domestically and internationally. Each individual who makes these flights has left an individual carbon footprint on the climate crisis. Although people have carbon footprints because of different efforts, the carbon footprint resulting from air travel is at the top of these [4].

Another area that is intertwined with the aviation industry in terms of carbon footprint is the tourism industry. Tourism is one of the most extensive economic activities of the global economy, with 1.4 billion tourists in 2018. GHG from tourism correspond to 8% of global emissions. Improvements in the fight against the climate crisis, especially in other sectors, have not been observed in the tourism sector [5].

In this study, the aviation sector, which proliferates in terms of the climate crisis and causes global warming in direct proportion to this growth, has been examined. With the study, the personal carbon footprint originating from the aviation sector has been handled specifically for Cappadocia Airport in Turkiye. As a result of the study, it is seen that although it provides great economic, tourism, and commercial returns, it is not very innocent in terms of the environment. Cappadocia Airport was considered because its location attracts attention in terms of tourism, and it is located at a middle point that can be considered equidistant from every average region of Turkiye. This could enable the use of alternative vehicles that could result in fewer emissions. In the study, the personal carbon footprint resulting from air travel to Cappadocia Airport between 2016–2019 was determined and discussed at the political level. It is especially important to consider the years 2016–2019 in terms of revealing the real development of the aviation industry before COVID-19. In addition, this study differs from studies that only examine total emissions in terms of bringing together different disciplines in which Turkiye's transportation policy is evaluated on the axis of aviation and tourism in a single study and evaluating emissions per passenger. For example, [6] tried to determine the emission values to determine the effect of Iğdır Airport on air pollution in Iğdır province, [7] studied the emissions from total flights to Muğla Airports to studies measuring the effect of aviation on air quality [8, 9]. For this reason, this study will be a pioneer in contributing to future studies by addressing personal carbon footprints within the scope of aviation and tourism sectors.

CARBON FOOTPRINT, AVIATION AND TOURISM

The carbon footprint is generally calculated as a one-year CO_2 equivalent and is expressed as the weight in tons of CO_2 emissions produced [10]. In short, it is the number of GHG produced by human actions [11, 12]. According to Mike Berners-Lee, the author of The Carbon Footprint of Everything, it is defined as the sum of all GHG emissions necessary for producing or producing a product [13]. Youmatter [10], on the other hand, defined it as GHG that arise due to the lifestyles and actions of individuals.

The transportation sector approaches around 14% of global emissions (including non-CO_2) gases, while consumers burn fossil fuels, which account for about a quarter of CO_2 emissions [14]. In particular, the transportation sector is one of the most extensive parts of the individual carbon footprint in rich countries that use it frequently. For example, using a bicycle instead of a car for short-haul journeys reduces the carbon footprint from transportation by 75%, while using a train instead of a car for medium-haul journeys reduces the carbon footprint by 80%, and traveling by train instead of a domestic flight reduces its carbon footprint by 84% reduces. Factors such as the distance of travel, the occupancy of public transportation, and the rate of fuel used (such as fossil fuels or electric vehicles) also affect the carbon footprint when using public transportation. However, walking or cycling for short and medium-distance trips are the vehicles with the lowest carbon footprints. The electricity generation source used in a region also affects the carbon footprint. For example, if electricity is provided through nuclear energy or renewable energy, rather than a thermal power plant where electricity is produced from coal, then it is more efficient to use electric vehicles or prefer rail transportation. For example, in France, which produces 90% of its electricity from low-carbon sources (70% of nuclear energy), on average, if Eurostar rail transportation is preferred instead of traveling by plane for short distance journeys, there will be a 96% reduction in carbon footprint [15].

Traveling by plane or alone by car is the means of transportation with the most carbon impact. The distinction between the two depends on the distance traveled. For example, if traveling to a medium-distance destination is less than 1000 km, traveling by plane causes a larger carbon footprint. However, if the distance is more than 1000 km and you are traveling by car alone, then the plane causes less carbon footprint. For example, traveling alone between London and Edinburgh with a distance of 500 km will cause around 100 kg CO_2 equivalent, while traveling by plane will have 128 kg CO_2 equivalent, and if this distance is done by train, it will have 21 kg CO_2 equivalent [15]. According to the European Environment Agency (Fig. 1), the transport sector produces the most CO_2/gram emissions per passenger kilometer of air travel.

Tourism has a share of 8% of global GHG emissions. Transportation is the main source of greenhouse gas emissions from tourism. In terms of carbon footprint, airplanes and cars produce the most CO_2 per passenger, while tour buses, ferries, and trains are other carbon footprint causes. Most of this carbon footprint from tourism consists of visitors from high-income countries, especially from the USA. More precisely, as the incentives for air travel increase, ticket prices get cheaper, and people can afford to travel, the tourism-related carbon footprint will also increase. Tourism emissions from vehicles increased by more than 60% between 2005 and 2016 [17]. The sectoral distribution of the personal carbon footprint resulting from global tourism is shown in Figure 2.

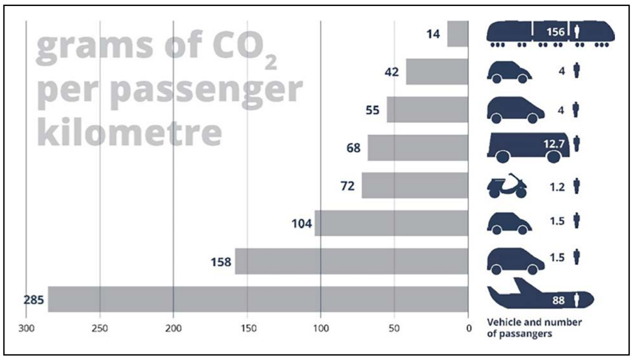

Figure 1. CO_2/gram per passenger kilometer [16].

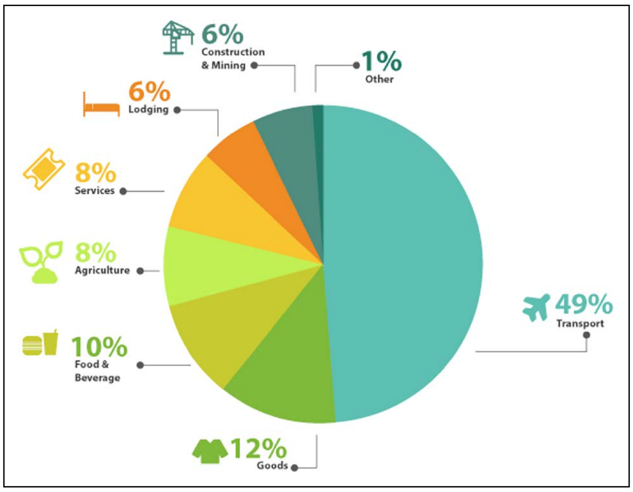

Figure 2. Carbon footprint of global tourism (2018) [17].

CASE STUDY: CAPPADOCIA REGION AND CAPPADOCIA AIRPORT

Cappadocia consists of a region that emerged because of the erosion of soft layers formed by ash and lava 60 million years ago by wind and rain for millions of years. This region, rich in tourism hosts millions of tourists, is a region where history and nature integrate most beautifully in the world [18, 19]. In 2019, 3 million 834 thousand 134 tourists visited the museums and ruins in Turkiye's favorite tourist region, Cappadocia. The number of people visiting the tourist centers in Cappadocia in 2019 increased by 30% compared to the previous year, which was considered the "*golden year*" in the region, 73% compared to 2017 and 157% compared to 2016 [20].

The existing airport of Cappadocia, which appeals to such a vast region, also has many valuable and important qualities. Nevşehir Cappadocia Airport is an airport that was put into service for domestic and foreign tourists in 1998 (Fig. 3). Additionally, Nevşehir Cappadocia Airport has 3500 m^2 of common-use area. In addition to this feature, there is a domestic and international terminal with an annual passenger capacity of 700,000. Additionally, there is a concrete runway of 3000x45 m, 110 PCN strength, and a concrete apron of 240x120, 110 PCN strength, with a capacity of 5 aircraft [21–23].

In addition to all this information, it will be possible to clearly say that Nevşehir Cappadocia Airport hosts hundreds of thousands of domestic and foreign tourists annually in certain periods.

MATERIAL AND METHOD

In this study, all of the real-time data used to determine the average passenger carbon footprint of all flights to Nevşehir Cappadocia Airport between 2016–2019 were officially obtained from the General Directorate of Civil Aviation. Flights between 2016–2019 include both domestic and international flights. In addition, these data could not be used since there were no flights due to the renovations made at the airport between May 1 and October 31, 2017. In this study, the Tier 1 method, one of the three methods recommended by the Intergovernmental Panel on Climate Change (IPCC), was used in carbon footprint calculations. In the Tier 1 method, calculations made with the amount of fuel according to the type of fuel burned from the national energy statistics and only the assumed emission factors are sufficient. In this study, CO_2 emissions produced during the period from starting the engine to stopping are taken into account. The steps to be followed in determining the personal carbon footprint from flights are: Tj (fuel consumption), Ef (emission factor), n (number of occupied seats), and CFP (CO_2 emissions per person). Firstly, total CO_2 emission is given in equation (1), while personal carbon footprint is given in equation (2). [25–27]:

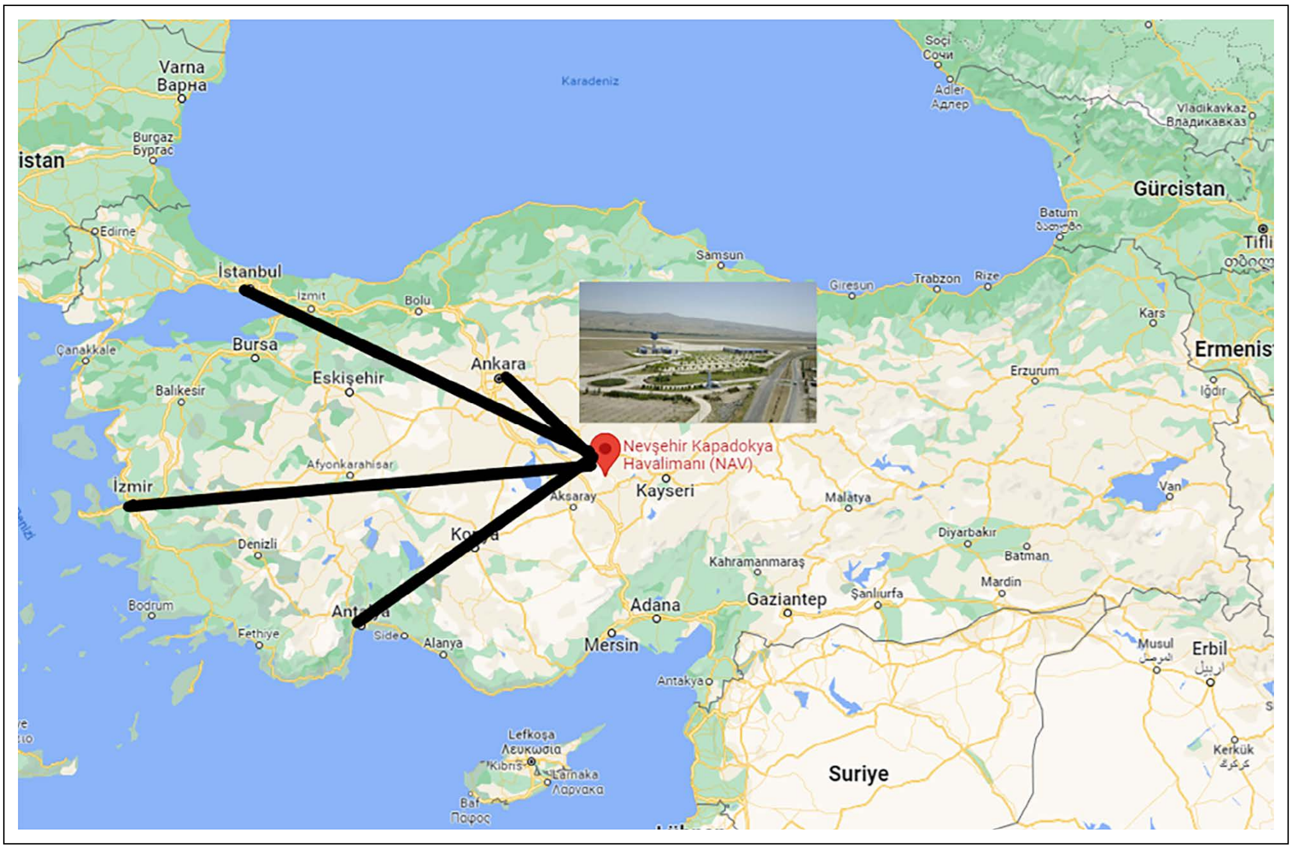

Figure 3. Location of Cappadocia Airport in Turkiye (edited using Google maps) [24].

$$\sum CO_2 = Tj \; x \; Ef \tag{1}$$

$$\text{CFP} = \frac{Tj \; x \; Ef}{n} \tag{2}$$

The emission factor here is 3.157, which refers to the CO_2 produced due to the combustion of 1 kg of fuel. That is, burning 1 kg of fuel causes 3.157 kg of CO_2 [28, 29].

RESULTS

Table 1 gives numerical data for determining the personal carbon footprint resulting from flights to Cappadocia Airport between 2016–2019.

When Table 1 was examined, the year with the highest number of flights to Cappadocia Airport between 2016–2019 was 2019, and the year with the least number of flights was 2017 when the renovation works were considered. While the month with the most flights was October 2019, with 340 flights, the month with the least flights (excluding the dates closed due to renovations) was February 2017, with 123 flights. On a total basis, it is seen that the number of flights increased between May and October. Additionally, while domestic and international flights occurred in all years, domestic flights showed a more regular distribution. While the most international flights were in 2018, with nine flights, the least was in 2017 and 2019, with seven flights. While most of the domestic flights were realized in 2019 with 3092 flights, the lowest number of domestic flights were realized in 2017 with 924.

As shown in Table 2, the year with the highest fuel consumption in flights to Cappadocia Airport between 2016–2019 was 8699.45 tons, while the minor fuel consumption was in 2017 with 2572,48 tons. The general reason that determines the maximum and minimum fuel consumption is the number of flights. Similarly, the month with the highest fuel consumption in all years was October 2019, with 922,59 tons, while the month with the lowest fuel consumption was February 2017, with 348.68 tons. Generally, there is a direct correlation between the number of flights and fuel consumption.

Table 3 tabulates the total number of passengers flying on a monthly and annual basis between 2016 and 2019. When Table 3 was examined, the highest number of passengers were transported to Cappadocia Airport in 2019, with 486,782, while the least number of passengers were carried in 2017, with 123,352. Similarly, the month with the highest number of passengers in all years was October 2019, with 53,818 passengers, while the month with the least number of passengers was February 2017, with 16,530 passengers. Generally, there is a direct proportion between the number of flights and the number of passengers.

Table 1. Total number of domestic and international flights between 2016 and 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2016-Dom	152	192	163	251	332	297	323	309	258	210	160	170	2825
2016-Int	1	1	0	0	0	0	2	2	2	0	0	0	
2017-Dom	164	119	152	194	0	0	0	0	0	0	147	148	931
2017-Int	2	4	1	0	0	0	0	0	0	0	0	0	
2018-Dom	148	148	172	240	244	239	0	254	244	245	164	164	2271
2018-Int	2	1	3	0	0	1	0	1	1	0	0	0	
2019-Dom	182	164	192	257	286	290	272	289	317	340	263	240	3099
2019-Int	0	2	2	0	0	0	1	1	1	0	0	0	

Table 2. Average fuel consumption (tons) from monthly and annual flights between 2016 and 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2016	436.21	553.35	427.69	689.79	886.59	777.77	899.14	870.64	730.59	575.26	440.93	450.03	7737.99
2017	464.60	348.68	415.57	524.55	0	0	0	0	0	0	403.99	415.09	2572.48
2018	426.99	431.63	516.58	666.11	663.37	672.05	0	723.94	704.10	696.09	459.38	452.15	6412.39
2019	512.20	478.01	529.53	757.64	840.81	838.63	756.49	828.47	890.31	922.59	699.97	644.80	8699.45

Table 3. The total number of passengers flying on a monthly and annual basis between 2016 and 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2016	18.196	23.652	19.650	30.965	41.754	31.306	37.322	40.264	32.805	27.740	21.468	20.807	345.929
2017	21.935	16.530	19.328	26.226	0	0	0	0	0	0	19.629	19.704	123.352
2018	21.794	21.807	24.429	36.442	33.335	33.868	0	39.443	39.272	40.169	25.494	23.375	339.428
2019	27.165	25.161	30.279	44.672	44.796	46.435	45.736	49.353	52.373	53.818	35.294	31.700	486.782

Table 4. Average CO_2 (tons) emissions from monthly and annual flights between 2016 and 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2016	1377.11	1746.92	1350.21	2177.66	2798.96	2455.41	2838.58	2748.61	2306.47	1816.09	1392.01	1420.74	24.428.77
2017	1466.74	1100.78	1311.95	1656.00	0	0	0	0	0	0	1275.39	1310.43	8121.29
2018	1348.00	1362.65	1630.84	2102.90	2094.25	2121.66	0	2285.47	2222.84	2197.55	1450.26	1427.43	20.243.85
2019	1617.01	1509.07	1671.72	2391.86	2654.43	2647.55	2388.23	2615.47	2810.70	2912.61	2209.80	2035.63	27.464.08

Table 5. Average personal carbon footprint CO_2 (kg) from monthly and annual flights between 2016 and 2019

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
2016	75.682	73.859	68.712	70.326	67.034	78.432	76.056	68.264	70.308	65.468	64.841	68.281	70.617
2017	66.867	66.592	67.878	63.143	0	0	0	0	0	0	64.974	66.505	65.838
2018	61.851	62.486	66.758	57.705	62.824	62.644	0	57.943	56.601	54.707	56.886	61.066	59.641
2019	59.525	59.976	55.210	53.542	59.255	57.016	52.217	52.995	53.666	54.119	62.611	64.215	56.419

As can be seen in Table 4, the highest CO_2 (ton) emission was realized in 2019 with 27,464.08 tons CO_2, while the lowest CO_2 (ton) emission was 8121.29 tons CO_2 in 2017. The highest CO_2 (ton) emission was in October 2019 with 2912.61 tons CO_2, while the least CO_2 (ton) emission was in February 2017 with 1100.78 tons CO_2. The results in this table show that there is a direct relationship between the number of flights and CO_2 (ton) emissions.

Within the framework of these findings, a total of 80,258.23 tons CO_2 emissions were made according to equation (1). According to equation (2), the value of 61,951 kg CO_2 per person is reached. However, annually, the highest individual average carbon footprint was 70.617 kg CO_2 in 2016, whereas the most diminutive personal average carbon footprint was 56,419 kg CO_2 in 2019. June 2016 was the month with the highest personal average carbon footprint of 78,432 kg CO_2, while the lowest private average carbon footprint was recorded in July 2019 with 52,217 kg CO_2. These carbon footprint data are given in Table 5.

DISCUSSION AND CONCLUSION

ICAO's Carbon Offset Reduction Plan for International Aviation (CORSIA) is more of a balancing program than an emission reduction. Since factors such as not taking essential steps in the Conference of the Parties (COP/26–COP/27) meetings and being away from carbon neutrality expected in 2050, alternative fuels and technological developments are the only expectations for the aviation industry in the short and medium term, the aviation industry is constantly behind a smoke screen is growing. It increases the sector's share in the climate crisis and, frankly, it cannot be stopped except for global problems. For example, the International Air Transport Association (IATA) predicts that European air travel volumes will reach pre-pandemic levels again by 2024 [30].

Although the aviation sector has a small share in the global total CO_2 emissions, it has a large share in terms of personal carbon footprint. This issue is considered one of the greatest injustices in the world. This is just like the countries with historical responsibilities with the largest climate crisis share. Because according to frequently cited estimates, 80% of people worldwide have not traveled by plane. There are also differences between the countries in terms of domestic flights. The biggest reason for this is, of course, the development indices encountered in domestic flights and the average individual carbon footprints of the countries. The use of domestic flights is increasing according to the development levels in these countries. For example, a person using domestic flights in the USA emits an average of 386 kilograms of CO_2 per year, while in Australia, 267 kg, 209 kg in Norway, 174 kg in New Zealand, and 168 kg in Canada. In most countries in Africa, Asia, and Eastern Europe, emissions per capita are less than one kg. Although this ratio is 0.8 kg on average, it is 0.14 kg in Rwanda [31].

In terms of the findings obtained in the study, although there is a direct correlation between the total emission rates and the number of flights in general, this direct ratio did not show itself in the personal carbon footprint. Having the lowest carbon footprint, especially in the year with the most flights, is an issue related to the total number of passengers rather than the total number of flights. Because as the passenger capacity of the aircraft increases, the average personal carbon footprint decreases. This is a matter of how many passengers the planes carry rather than the number of planes taking off and landing. Considering the flights to the Cappadocia region, domestic flights come to the fore. This brings Turkiye's national transportation policy to the fore in this regard. From the perspective of Turkiye or the working axis, the Turkish aviation sector is growing rapidly. This situation will rapidly increase the share of the aviation sector in the national greenhouse gas rate. Therefore, Turkiye should go through a major change in transportation preferences. As long as it maintains its air and land transport policy, it will fail to tackle the climate crisis and green transformation. Therefore, by investing in rail transport, Turkiye should determine a cleaner transportation choice as a vision in the fight against the climate crisis. This is the reason why Cappadocia airport is discussed in this study. Although the Cappadocia region is located in the heart of Turkiye (4 h from Ankara, 7.5 h from Istanbul, 11 h from Izmir, and 7.5 h from Antalya), it has adequate transportation (the nearest train station is in Kayseri) network does not have. The fact that people do not have sufficient transportation networks causes them to prefer the airline. This increases both the total emissions and the personal carbon footprint. In other words, traveling to Cappadocia from one point in Turkiye as a family or as an individual, instead of choosing an airline, is much more innocent than choosing airline transportation. Considering that most flights are made from Istanbul (759 km), traveling by car will be more beneficial in terms of both overall emissions and personal carbon footprint. Additionally, the increase in the frequency of travel with the rise in the carbon footprint of people living in developed countries and the increase in the welfare level of people living in Turkiye is the same issue. Because the level of welfare and the increase in the transportation network bring the preference for air transportation to the fore, for this reason, railroad transportation in Turkiye should be built quickly, especially in tourism regions where human flow is intense. Like a spider web, tourism regions should be connected to central cities and each other. Thus, it is inevitable that transportation preferences to change and transportation (freight) preferences change. This will enable a cleaner transport system. Otherwise, the intense human flow will continue to increase in these regions, and thus, transport emissions will increase rapidly.

For many, travel is a way of seeing the world, while for others, it is a means of transportation for work. Whatever the reason for flying, it is important to remember how it contributes to the person's overall carbon footprint and what can be done to save money. We also need to be more realistic about our contributions to the climate crisis. Especially since we cannot change the air transportation system with a magic wand, we must evaluate our duties realistically. This is both in general and in Cappadocia;

a) Choosing an airline that uses newer, more energy-efficient aircraft will contribute more to reducing its carbon footprint.

b) Airplanes use much energy during take-off and landing, which causes more emissions. Therefore, non-stop flights will save more fuel per flight and cause less carbon footprint.

c) Flying in business or private seats cause four times more carbon emissions than other economy seats. Therefore, preferring frequent-seat aircraft or flying in economy class seats will cause less carbon footprint.

d) It is also beneficial for light travel in terms of the climate crisis and personal carbon footprint. This is because the weight of the aircraft significantly affects the use of fuel to stay in the air during take-off and flight. This will affect the emissions rates.

e) Considering the location of Cappadocia, driving alone is generally more environmentally friendly than flying, especially at distances below 1000 km.

In short, traveling by plane is unsustainable, and if we can and should make more environmentally friendly choices that help make the world cleaner, it is also true that it is time to act. Passenger numbers have been increasing exponentially recently, and more and more people are using planes due to low-cost airlines' offers that allow us to reach new destinations in small quantities.

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DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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