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FINAL BACHERLOR'S DEGREE
DEGREE IN AEROSPACE ENGINEERING

Air traffic and Sustainability Constraints and Paradigms: A Comprehensive Study on the Effects on Spanish Tourism and the Role of High-Speed Trains

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I am referring to this that he put: I hereby submit for examination and defense my bachelor's thesis prepared at the end of my studies at CTU Prague, Faculty of Transport. I declare that I have prepared the submitted thesis independently and that I have listed all sources of information used in accordance with the Methodological Instruction on the Observance of Ethical Principles in the Preparation of bachelor's Theses. I have no serious reasons against the use of this scholarly work within the meaning of Article 60 of Act No. 121/2000 Coll. on Copyright, on Rights Related to Copyright and on Amendments to Certain Acts (Copyright Act).

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I would also like to thank my family and friends for their unconditional love, understanding and constant support. Their sacrifice and encouragement have been fundamental pillars on my way to the completion of this project.

Statement

I hereby submit for examination and defense my bachelor's thesis prepared at the end of my studies at CTU Prague, Faculty of Transport. I declare that I have prepared the submitted thesis independently and that I have listed all sources of information used in accordance with the Methodological Instruction on the Observance of Ethical Principles in the Preparation of bachelor's Theses. I have no serious reasons against the use of this scholarly work within the meaning of Article 60 of Act No. 121/2000 Coll. on Copyright, on Rights Related to Copyright and on Amendments to Certain Acts (Copyright Act).

Abstract

Air connectivity boosts tourism and facilitates trade, as well as social network and insertion, and instigate the exchange of knowledge and ideas. It also supports economic competitiveness, increment productiveness, increases efficiency, and encourages innovation.

The present bachelor's degree Final Project exposes how Spanish Tourism can be affected by the new regulations in order to achieve Environmental Sustainability and CO2 emissions reduction, comparing between domestic and international traffic in Spanish Airports.

Based on the study described above, secondly, it is developed research of how High-Speed Train works in Spain. In addition, conducting an analysis of CO2 emissions of both means of transport, taking into account the technologies that are currently being developed or implemented.

Keywords

Civil aviation, Air traffic Tourism, Sustainability, Eco-passengers, High-Speed Train



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DOCUMENT 1.

Air Traffic in Spain and Sustainability Regulations

AIR TRAFFIC AND SUSTAINABILITY
CONSTRAINTS AND PARADIGMS:
A COMPREHENSIVE STUDY ON THE EFFECTS ON SPANISH
TOURISM AND THE ROLE OF HIGH-SPEED TRAINS

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Basic concepts and Definitions

ICAO – International Civil Aviation Organization

IATA – International Air Transport Association

EASA – European Union Aviation Safety Agency.

Passenger seats km – is the number of occupied seats multiplied by the distance flown, or cargo capacity or volume.

Seats available km – is the number of seats offered multiplied by the distance flown - seat-kilometers.

Passenger-kilometer – pkm Passenger-kilometer is a unit of measurement that equals the transport of one passenger over a distance of one kilometer.

CO₂ – carbon dioxide

Carbon footprint – emissions - is the sum of greenhouse gas emissions expressed in CO₂e.

GHG – Greenhouse Gases

CAS – Sustainable Aviation Fuels

ATM – Air Traffic Management

MBM – Market-based Instruments

Document 1. Air Traffic in Spain and Sustainability Regulations

1. Previous Considerations

Air travel in Spain has experienced significant growth over the past few decades, driven by increased demand for domestic and international air travel. However, this growth has not been without challenges, especially in terms of sustainability and mitigating associated environmental impacts.

1.1. Introduction

Spain is one of the world's most popular tourist destinations, attracting millions of visitors from all over the globe each year. Spain's tourism industry is a key component of the country's economy, generating significant revenue and providing employment opportunities for many people. The industry has experienced steady growth in recent years, with the number of international visitors to Spain reaching a record high in 2019.

One of the primary draws for tourists in Spain is the country's beautiful beaches. With a coastline stretching over 8,000 kilometers, Spain has a vast array of beaches to choose from, ranging from the calm waters of the Mediterranean to the rugged Atlantic coastline. Visitors can enjoy water sports, sunbathing, and relaxing in beachside cafes and restaurants.

Spain is also home to several world-renowned cities, each with its own unique character and charm. Madrid, the country's capital, is known for its art museums, lively nightlife, and historic landmarks such as the Royal Palace and the Prado Museum. Barcelona, on the other hand, is famous for its stunning architecture, including the works of Gaudi, as well as its lively street life and beaches.

In addition to its beaches and cities, Spain has a wealth of cultural and historical attractions that attract visitors from around the world. The country is home to numerous UNESCO World Heritage Sites. Spain is also famous for its food and wine, with each region offering its own unique culinary traditions and specialties.

1.2. Purpose

In recent years, the search for a more sustainable aviation has been and continues to be one of the main objectives of the entire aerospace industry. In the same way, the world is more aware of the new paradigms of sustainability and more effective means of transportation are being sought.

It is for this reason that this research sees fit to analyze the benefits of aviation in tourism and the Spanish economic power in order to carry out a study on how this can be affected by the new paradigms and policies of sustainability.

1.3. Coverage

In order to carry out the research, data has been collected from the most important sources of information, such as INE, EUROCONTROL, AENA, Government of Spain, etc.

In general, data has been collected for 2019, being a good year for world aviation and not being affected by the big drop in statistics suffered during COVID-19.

First, we studied both the source destinations and the main destinations in Spain, both within the peninsula and on the islands, where the number of available means of transport is reduced by half.

In the same way it is important to study the reasons that lead any tourist to choose Spain as his destination, or those that do not. In addition to analyzing the population target, types of families, economic situation of the family, age, or sex. In order to analyze how a reduction in tourist airlift could affect the country's economic power and other benefits of aviation.

As well as a theoretical review of possible solutions for a more sustainable aviation.

2. Civil Aviation Industry in Spain

Spain's air traffic industry has seen significant growth in recent years, with an increasing number of airlines operating in the country and more direct flights to and from destinations all over the world (*IATA Economics*, s. f., 2019).

Spain is also a popular destination for low-cost airlines, with companies such as Ryanair and EasyJet offering flights to a range of destinations throughout the country. This has helped to make air travel more accessible and affordable for both domestic and international travelers.

In recent years, Spain's air traffic industry has faced challenges posed by the COVID-19 pandemic, with many airlines suspending flights and airports implementing measures to protect the health and safety of travelers. Overall, Spain's air traffic industry plays a vital role in connecting the country to the rest of the world and facilitating both business and leisure travel.

Spain is a popular travel destination for tourists from all over the world, and as a result, the country sees a significant amount of air traffic. The principal source destinations of Spain's air traffic can vary depending on the time of year, but there are a few main locations that consistently rank high in terms of the number of flights and passengers they receive.

2.1. Tourism in Spain

When carrying out our research, it is important to have a global vision of tourism in Spain, both to understand why Spaniards travel, as well as to understand why they do not travel and thus be able to understand how the new paradigm of sustainability affects the decision of whether to travel or not and in what way (means of transport, domestic or international).

Spain ended the year 2019 with the arrival of 83.7 million international tourists, a 1.1% increase compared to 2018, while spending increased by 2.8% to reach 92.278 billion euros (*Ministerio De Industria, Comercio Y Turismo - España Cierra 2019 Con Un Nuevo Récord De Turistas Internacionales Y Un Gasto Superior a Los 92.200 Millones De Euros*, n.d.).

In 2019, the main source markets were the United Kingdom, with over 18 million international tourists, a 2.4% decrease compared to the previous year; Germany, with nearly 11.2 million (-2.1%); and France, with 11.1 million tourists (-1.2%). Among the other countries of residence, noteworthy growth was experienced by the United States (+12.6%), Russia (+6.9%), and Ireland (+6.0%).

In terms of domestic destinations, Catalonia received the highest number of tourists, with approximately 19.4 million. It was followed by the Balearic Islands with around 13.7 million and the Canary Islands with over 13.1. It is worth noting the growth of Madrid, which received 7,638,375 tourists in 2019.

An additional 10% of domestic travelers are choosing airplanes, and one out of every five travelers transported by air within the EU either departs from or has Spain as their destination (*España En Cifras 2019*, n.d.).

2.2. Economic Power

The globalization of the tourism industry has contributed significantly to employment and GDP worldwide (Hamaguchi, 2021), with Spain's tourism industry being a vital part of the country's economy.

Spain's well-developed air traffic industry, advanced infrastructure, and strategic location make it an important hub for air traffic in Europe. The air transport industry in Spain provides jobs to 269,000 people across airlines, airport operations, on-site businesses, aircraft manufacturing, and air navigation services (IATA, 2019), while supporting 163,000 more jobs by sourcing local goods and services.

Additionally, foreign visitors arriving by air and spending their money in the country are said to support 1.2 million more jobs. The combined contribution of airlines and its supply chain to the Spanish economy is estimated at \$35.1 billion, while spending by foreign tourists adds a whopping \$78.1 billion to the GDP, bringing the total to \$113.2 billion.

Air transport provides significant benefits to passengers, shippers, and their respective businesses, and also stimulates foreign direct investment, resulting in the creation of productive assets that generate long-term GDP flows, making it a crucial economic flow.

When examining the economic impact, it's important to distinguish between explicit expenses (direct costs) and implicit expenses (hidden costs).

Explicit expenses include tangible costs directly associated with air traffic tourism, such as airline tickets, hotels, restaurants, transportation, and admission fees. These expenses contribute directly to various sectors, such as airlines, hotels, and restaurants, boosting their revenues.

Hidden or indirect costs are referred to as implicit expenses. These costs encompass the development and upkeep of infrastructure, concerns regarding the environment, and the preservation of cultural heritage. In order to cater to the increasing number of tourists, Spain must make investments in several areas. These include expanding airports, enhancing the quality of roads and public transportation, as well as adopting greener practices.

In order to address environmental issues, it is necessary to allocate resources towards sustainable modes of transportation and energy-efficient infrastructure. Similarly, for the maintenance of cultural heritage, funds must be allocated to the restoration of historical sites and the implementation of educational programs. By taking into account both types of expenditures, Spain can effectively and sustainably harness the economic advantages of air traffic tourism.

2.3. Principal Airports

Spain boasts a diverse and extensive network of airports that connect it to destinations around the world. These airports play a key role in facilitating tourism, trade, and business activities, making them vital elements of the country's infrastructure.

Spain's main airport operator, Aena, manages a network of airports across the country, serving both domestic and international flights. According to Aena's reports from 2019 (AENA, 2019), the Table 1 shows an analysis of the flow of passengers in Spain's airports based on the number of passengers:

Table 1. Flow of passengers according to Destination Airport (2019)

<i>According to destination Airport</i>	<i>2019</i>		
	<i>Total passengers</i>	<i>% Vertical</i>	<i>Annual Variation</i>
Total	94.478.446	100%	3,5%
Adolfo Suárez			
Madrid-Barajas	22.544.276	23,9%	7,4%
Barcelona	19.287.538	20,4%	5,3%
Málaga	8.418.525	8,9%	4,1%
Tenerife Sur	4.987.773	5,3%	-0,2%
Alicante	6.654.853	7,0%	7,3%
Gran Canarias	3.612.397	3,8%	-7,8%
Valencia	3.140.210	3,3%	10,4%
Lanzarote	2.488.413	2,6%	- 2,8%
Palma de Mallorca	11.118.676	11,8%	1,0%
Fuerteventura	1.951.687	2,1%	-13,5%
Resto of airports	10.274.098	10,9%	2,0%

This investigation will distinguish destinations within the peninsula and destinations outside of it, analyzing them separately in the following sections. According to a study by the Directorate General of Civil Aviation (Gobierno de España, 2019), Madrid, Catalonia, and the Canary Islands were the Autonomous Communities with the largest passenger movements. Together they accounted for 58% of total traffic in 2019.

2.3.1. Peninsular airports

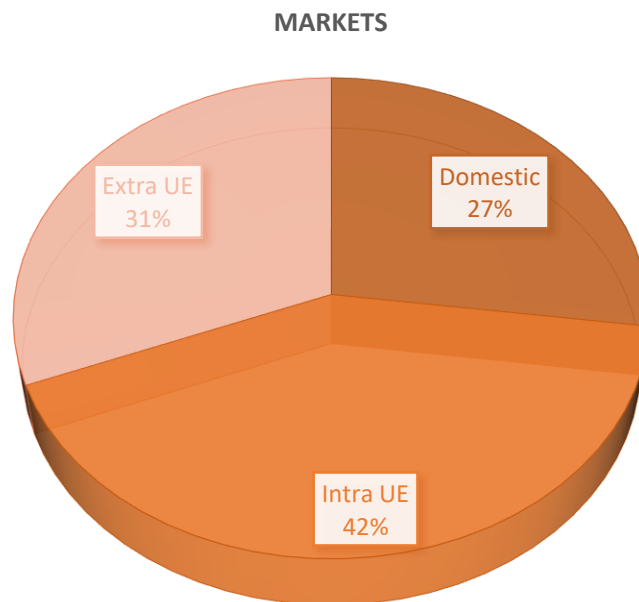
Air traffic is mainly concentrated in Madrid and Barcelona airports, in 2019 they accounted for 41.6% of total passenger movements. It should be noted that in 2019 the increase in traffic at Spanish airports was widespread.

Adolfo Suárez Madrid-Barajas Airport

Spain's busiest airport is Adolfo Suárez Madrid-Barajas Airport, located in the country's capital city. The airport serves as a major hub for airlines such as Iberia and Air Europa and handles millions of passengers each year.

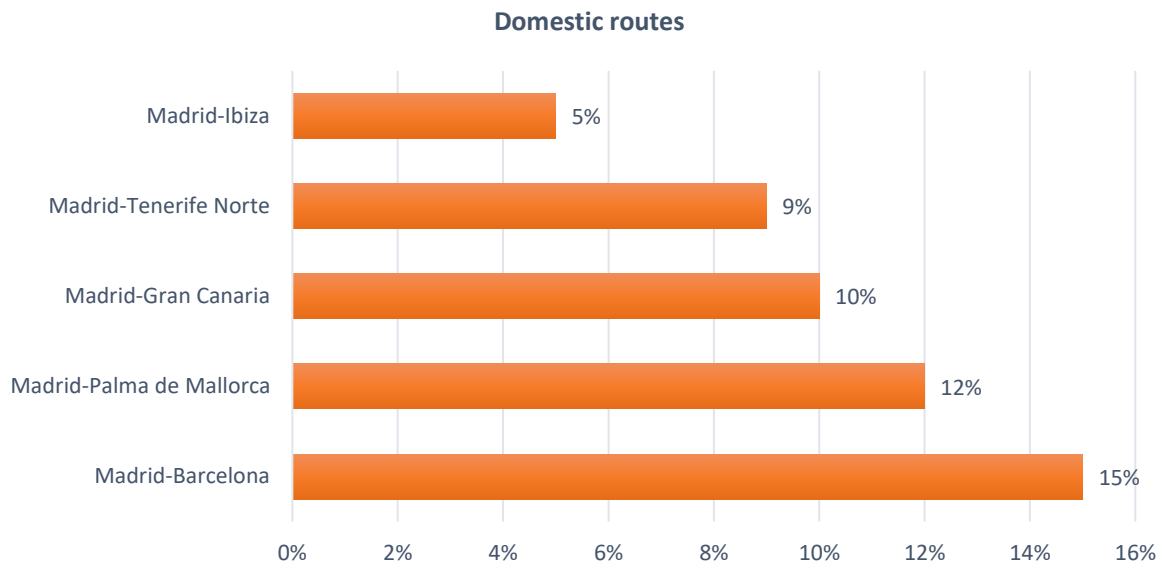
A study of air traffic in Spain (Gobierno de España, 2019) showed that in 2019 Madrid-Barajas Airport was the busiest, with 61.7 million passengers, representing a 6.6% increase over 2018.

Figure 1. Flow of Passengers in Madrid Airport depending on the Market (2019)



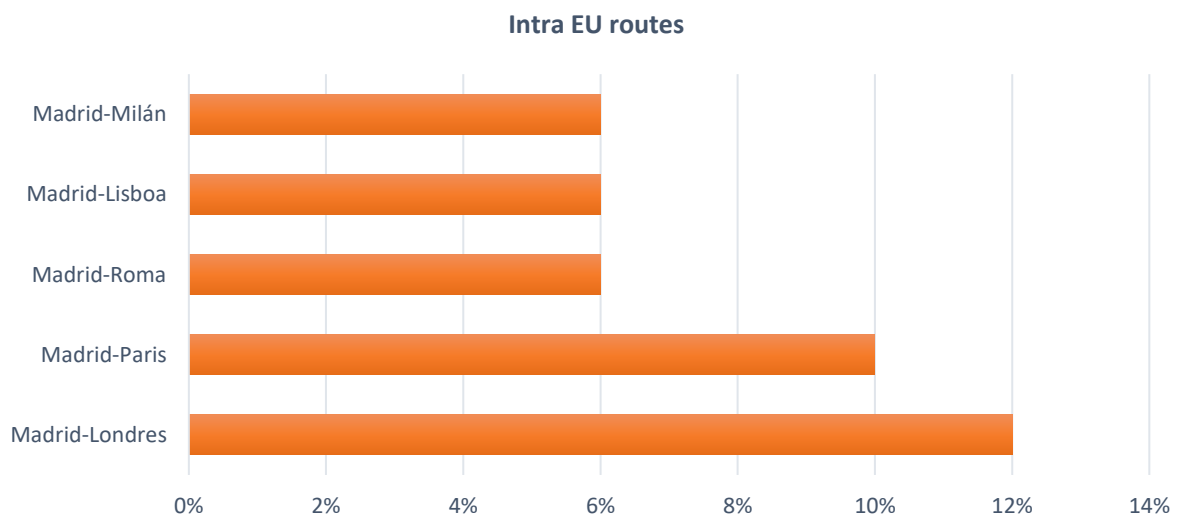
The domestic market accounted for 27.1% of the market share, with the Madrid-Barcelona route being the most popular. Barcelona and Ibiza experienced 4% growth in passenger numbers.

Figure 2. Domestic Routes in Madrid Airport (2019)



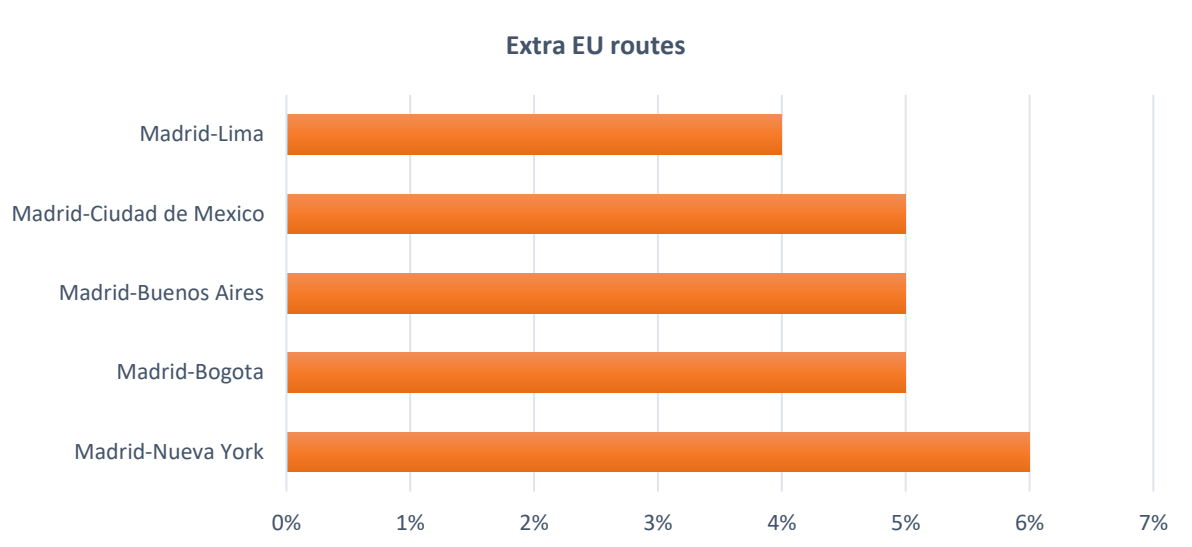
The majority of traffic at Madrid was international (72,9%), with London and Paris being the main EU destinations, accounting for 22% of commercial passenger traffic at Madrid Airport. The route that grew the most was Madrid-Milan, with a 9% increase in passenger movements.

Figure 3. Intra EU Routes in Madrid Airport (2019)



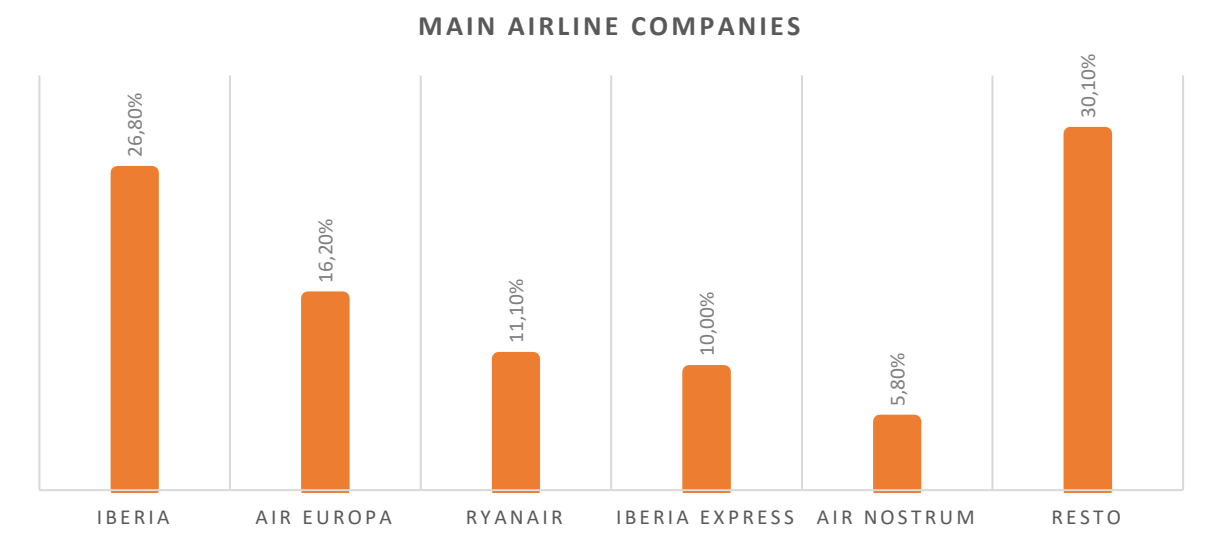
The route with New York also saw an 18% increase in the foreign market.

Figure 4. Extra EU Routes in Madrid Airport (2019)



In 2019, 139 commercial airlines operated at Madrid-Barajas Airport, with Iberia being the most used with a 26.8% share. The top three carriers accounted for 54.1% of passenger movements.

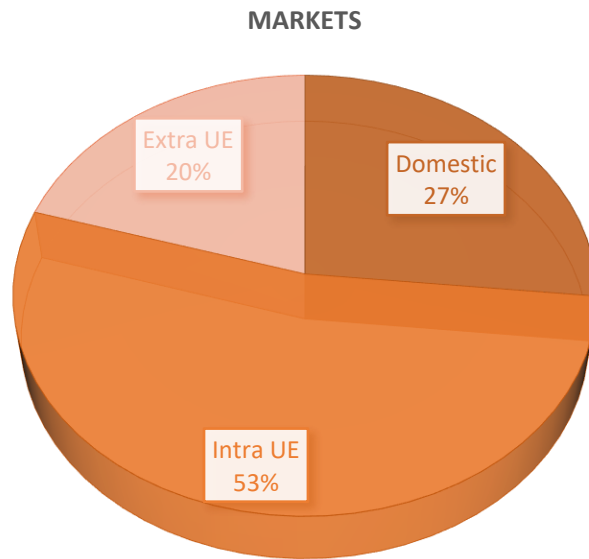
Figure 5. Main Airline Companies in Madrid Airport (2019)



Josep Tarradellas Barcelona-El Prat Airport

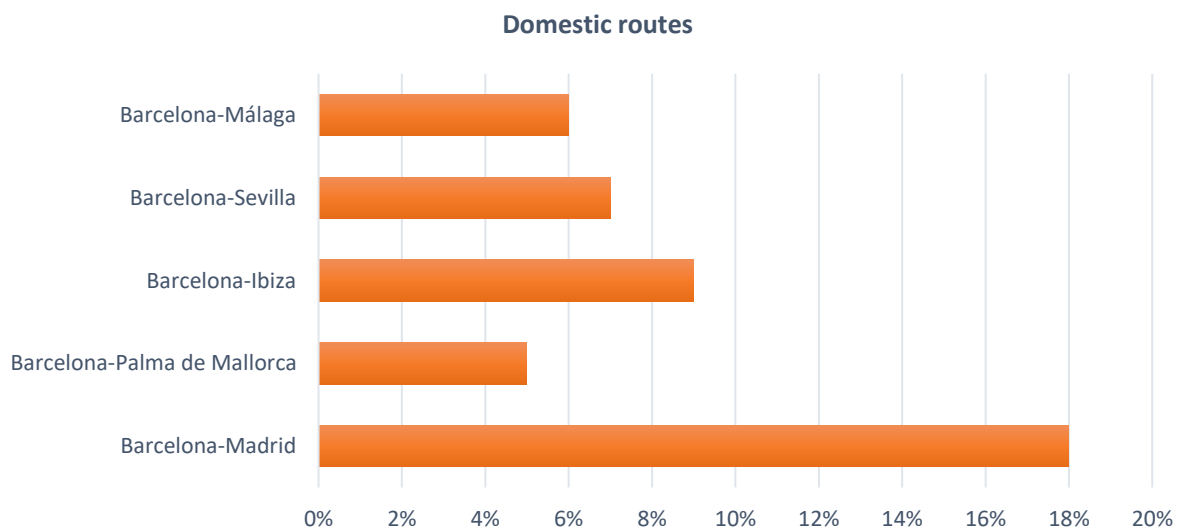
Other major airports in Spain include Barcelona-El Prat Airport, located in the country's second-largest city. In 2019 (Gobierno de España, 2019), Barcelona airport handled 52.7 million passengers, an increase of 5% compared to 2018. The number of operations also increased by 2.7%, while commercial cargo traffic grew by 2.5% and mail traffic increased by 28.8%.

Figure 6. Flow of Passenger depending on the Market in Barcelona Airport (2019)



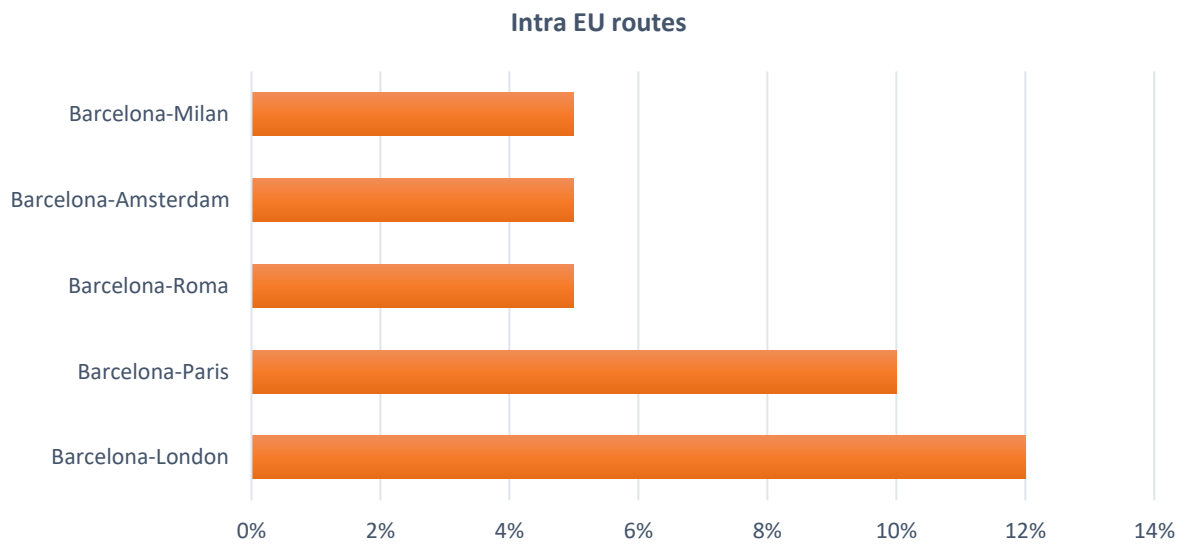
The domestic market accounted for 26.6% of passenger traffic at Barcelona airport. The Madrid-Barcelona route accounted for 18% of the market share. Compared to 2018, passenger traffic on the route to Malaga increased by 8%.

Figure 7. Domestic Routes in Barcelona Airport (2019)



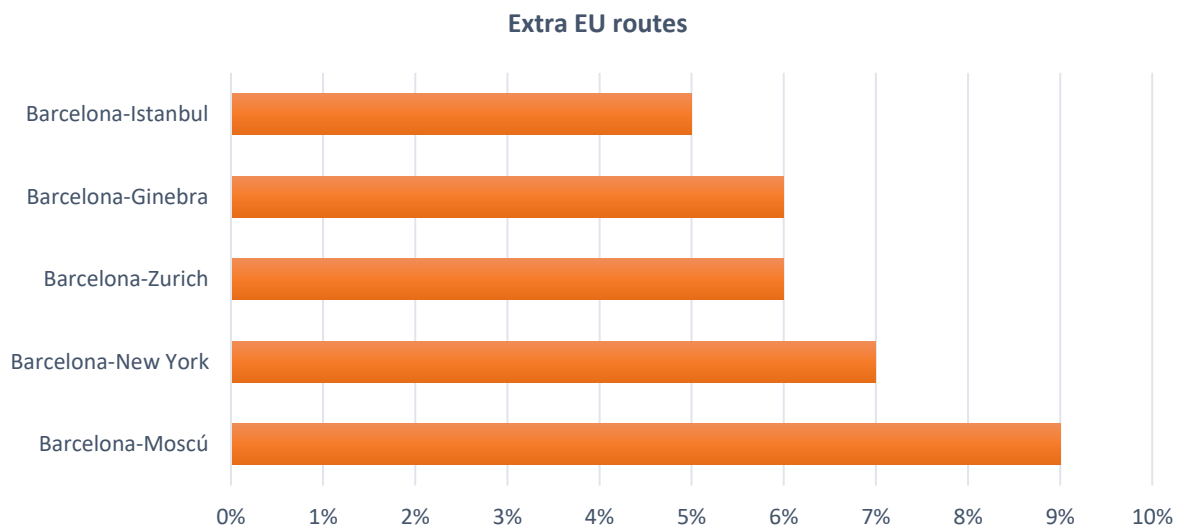
53.1% of commercial traffic at Barcelona airport was with destinations within the European Union. London and Paris were the main destinations within the EU, accounting for 22% of the total passenger traffic at the airport. Milan was the route that experienced the most growth during this period, with an increase of 8% compared to 2018.

Figure 8. Intra EU Routes in Barcelona Airport (2019)



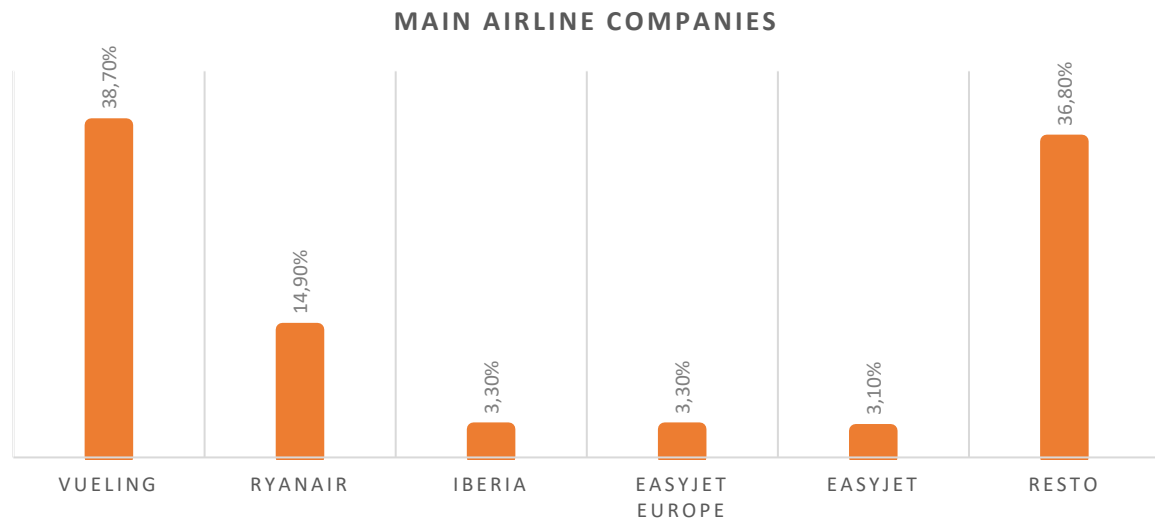
For the second year in a row, the route between Barcelona and New York had the highest growth in passenger traffic in the extra-EU market, with an increase of 13% compared to 2018. The destinations in this market were widely distributed.

Figure 9. Extra EU Routes in Barcelona Airport (2019)



In 2019, 148 commercial companies operated at the airport. The top two companies by commercial traffic volume accounted for 53.6% of passenger traffic. Vueling was the most prominent company, with a 38.7% market share.

Figure 10. Main Airline Companies in Barcelona Airport (2019)



2.3.2. Non-peninsular airports

Spain is a country with a rich diversity of regions, including islands and territories outside the Iberian Peninsula. These regions have their own airports, some of which experience significant air traffic and passenger movement.

It is considered important to distinguish between peninsular and non-peninsular airports, as the latter are currently only accessible by air and sea transport. In addition, it is important to note that airports such as those studied above, such as Madrid and Barcelona, serve as connections to access the islands.

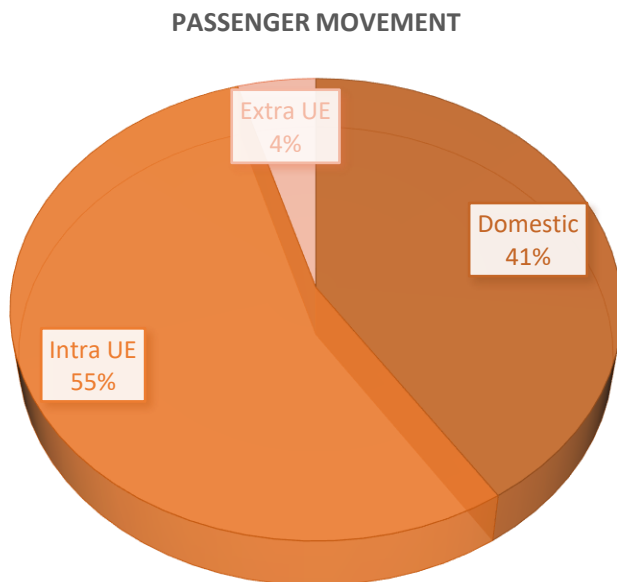
Airports of Canarias Islands

A Spanish archipelago off the coast of North Africa, the Canary Islands are a beloved tourist hotspot. Their year-round sunshine, striking beaches, and distinct terrain attract numerous visitors. Consequently, the islands' airports are bustling with a high volume of air traffic and passenger movement.

The Canary Islands play a crucial role as a hub for air traffic between Europe, Africa, and the Americas. International flights to and from the islands are frequent, with major airlines including Ryanair, TUI Airways, and easyJet providing regular services across Europe and beyond.

An increasing number of private jet and general aviation operators find the Canary Islands an attractive destination. These operators frequently rely on the archipelago's airports to transport passengers to and from global locations.

Figure 11. Flow of Passengers depending on the Market in Canary Islands

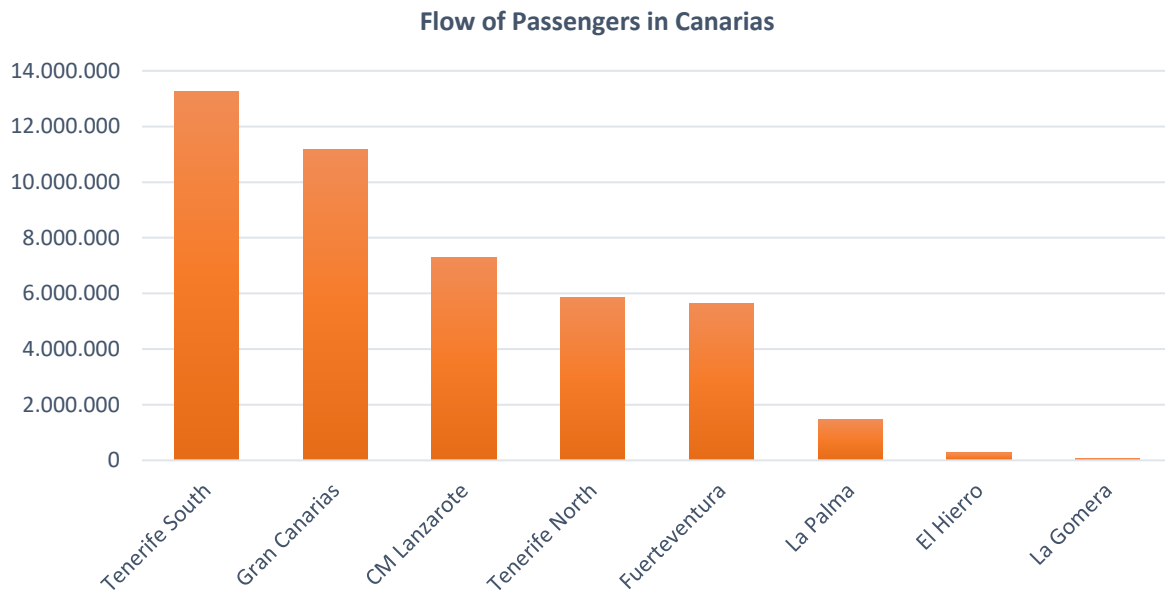


Tenerife Sur Airport is the busiest airport in the Canary Islands, handling more than 13 million passengers in 2019 (Gobierno de España, 2019). Other airports in the region, such as Gran Canarias and Lanzarote, also see heavy traffic, especially during the peak holiday season.

Table 2. Flow of Passengers depending on the Market in Canary Islands' Airports

	<i>Domestic</i>	<i>Intra-EU</i>	<i>Extra-UE</i>	<i>Total</i>
<i>Tenerife South</i>	5.986.430	6.181.175	1.093.800	13.261.405
<i>Gran Canarias</i>	1.144.537	9.363.741	660.228	11.168.506
<i>CM Lanzarote</i>	2.285.149	4.892.290	115.281	7.292.720
<i>Tenerife North</i>	5.758.926	51.039	30.518	5.840.483
<i>Fuerteventura</i>	1.707.046	3.799.740	128.544	5.635.330
<i>La Palma</i>	1.115.226	348.831	19.663	1.483.720
<i>El Hierro</i>	268.899	1	0	268.900
<i>La Gomera</i>	77.425	12	0	77.437

Figure 12 Flow of Passengers in Canary Islands' Airports



Information about the number of passengers per island depending on the type of traffic can also be obtained, being Tenerife the busiest for every type of traffic (Sector Servicios, n.d.). Being the main source destinations United Kingdom and Germany.

Table 3. Traffic of Passenger depending on the Island and Type of Traffic (2019)

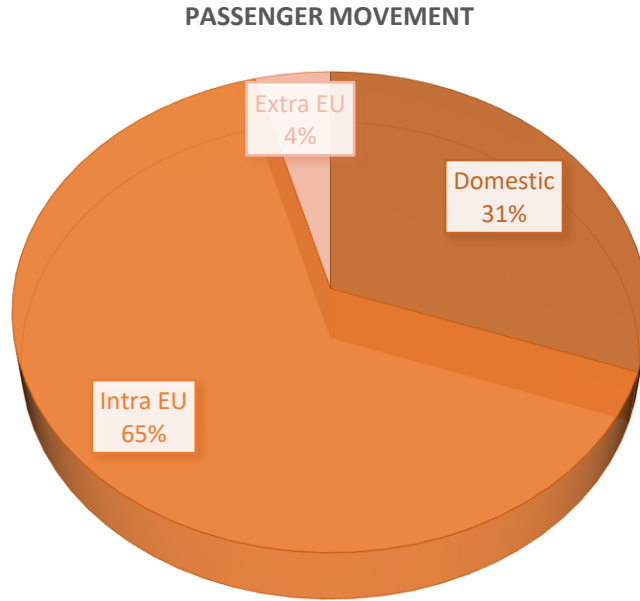
2019	TOTAL	Lanzarote	Fuerteventura	Gran Canaria	Tenerife	La Palma
<i>TOTAL</i>	17.737.398	3.024.456	2.299.861	5.148.953	7.004.738	259.390
<i>PENINSULA</i>	4.481.822	535.944	350.107	1.537.638	1.975.634	82.499
<i>INTERNATIONAL</i>	13.255.576	2.488.512	1.949.754	3.611.315	5.029.104	176.891

Airports of Baleares Islands

The Mediterranean's Balearic Islands are a tourist hotspot, attracting millions of visitors annually. This has led to a notable increase in air traffic and passenger movement at the islands' airports.

Due to their strategic placement in the Mediterranean, the Balearic Islands serve as a crucial hub for air traffic between Europe, Africa, and the Middle East. International flights, from famous airlines such as Ryanair, easyJet, and Vueling, are numerous in the islands' airports, catering to destinations across Europe.

Figure 13. Flow of Passengers depending on the Market in Balearic Islands



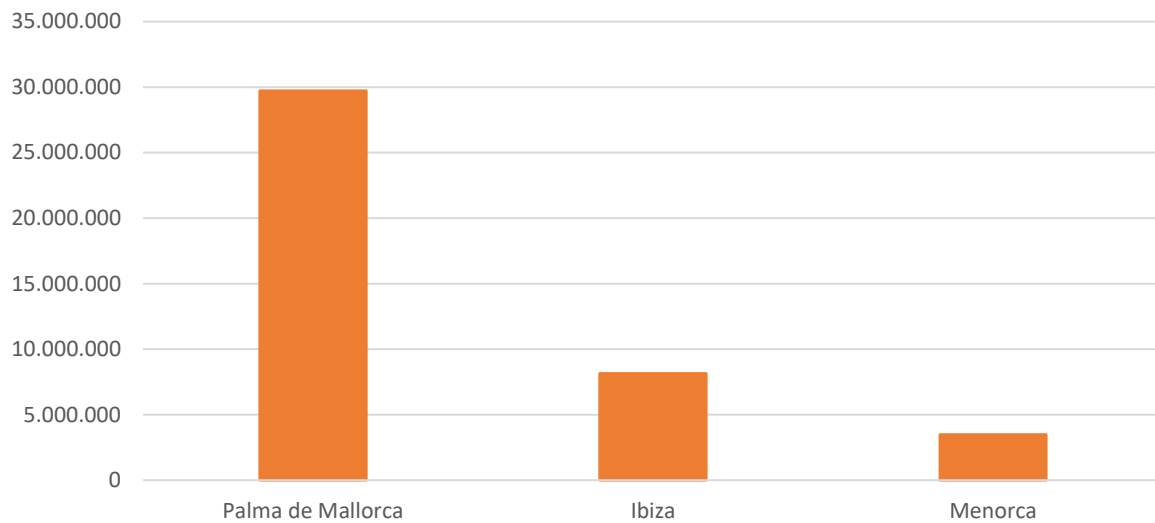
The Balearic Islands' primary airport, Palma de Mallorca Airport, is responsible for the bulk of passenger traffic and to serve as a connection to carry the flow of passengers to the other two islands.

As one of Spain's busiest airports, it processed over 29 million passengers in 2019 (Gobierno de España, 2019). During peak summer season, other airports like Ibiza Airport and Menorca Airport also welcome a substantial number of passengers.

Figure 14. Flow of Passengers depending on the Market in Balearic Islands' Airports

	<i>Domestic</i>	<i>Intra-EU</i>	<i>Extra-UE</i>	<i>Total</i>
<i>Palma de Mallorca</i>	7.494.766	20.699.020	1.527.337	29.721.123
<i>Ibiza</i>	3.330.991	4.653.939	170.705	8.155.635
<i>Menorca</i>	1.796.370	1.650.122	48.533	3.495.025

Figure 15. Flow of Passengers in Balearic Islands' Airports



Information can also be obtained on the number of passengers per island depending on the type of destination (*Datos Estadísticos: Economía: Turismo: Gasto Y Perfil De Los Turistas (EGATUR)*, n.d.).

Table 4. Flow of Passengers by the Island and type of Traffic (2019)

Air traffic	Palma	Mallorca	Ibiza	Total
Spain	3.723.331	893.574	1.656.488	6.273.393
Germany	4.992.355	77.946	315.194	5.385.495
United Kingdom	2.795.178	503.541	963.105	4.261.824
Italy	257.677	104.821	433.148	795.646
France	448.922	60.646	158.302	667.870

2.3.3. Tourist-dedicated Airports

Spain has a variety of Tourist-dedicated airports located in popular vacation spots throughout the country, offering a range of amenities and services to ensure a comfortable and enjoyable travel experience visitor (Halpern & Molde University College, 2011).

Major Tourist-dedicated airports include Ibiza Airport, Palma de Mallorca Airport, Malaga Airport, and Gibraltar Airport. Additionally, other airports throughout Spain cater to the needs of visitors in popular destinations such as Barcelona, Valencia, and Alicante.

Understanding tourism determinants is of paramount importance because of its crucial economic role (United Nations World Tourism Organization, 2010), especially in countries in

which this sector accounts for a great share of the economy. In the following parts a domestic and international analysis of the tourism sector in Spain will be made.

2.4. Domestic Tourism

Tourism is a significant contributor to the Spanish economy, accounting for 14.9% of the GDP and 15.1% of the labor force. While international tourism is often highlighted, domestic tourism actually makes up the majority of trips taken by Spanish residents and accounts for 91.1% of the total trips made, 82.4% of overnights, and 67.7% of total tourism expenses (Business Media B.B., 2012).

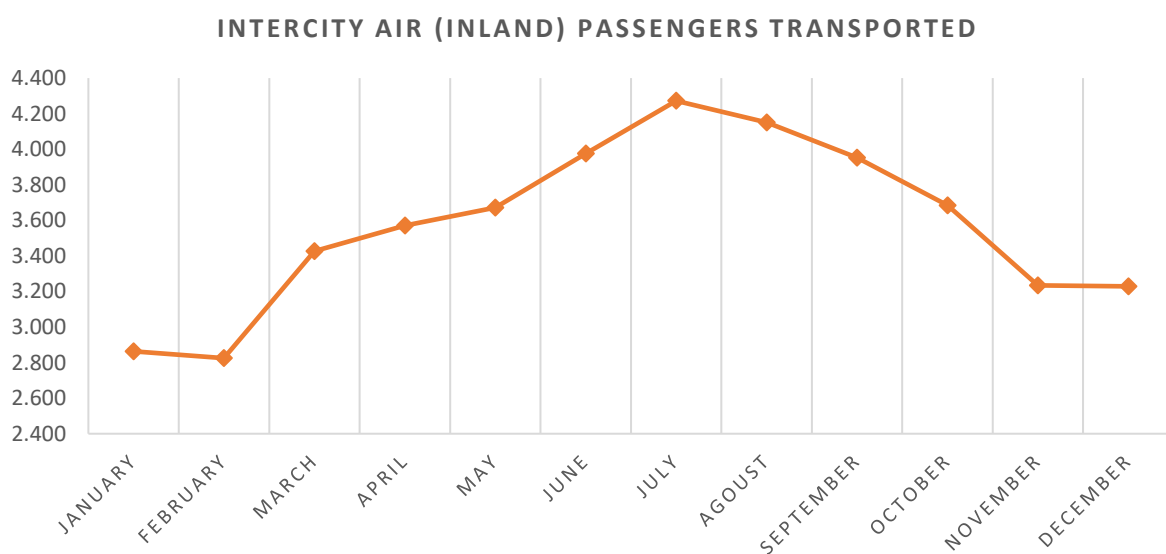
A study conducted by Alvarez-Diaz et al. found that factors such as GDP per capita in the province of origin, relative prices between origin and destination provinces, population in the province of origin, and distance between origin and destination provinces were all significant drivers of domestic tourism at both the provincial and aggregated levels.

The study also found that climatic and meteorological factors, such as temperature, were important in explaining local tourism flows, as well as the existence of natural amenities and recreational activities in the destination province.

Additionally, the study noted the competitive effect between provinces, as the existence of natural amenities in a particular province can attract more visitors and impact the tourism flows of neighboring provinces.

The National Statistics Institute also provides data and graphs about the evolution of intercity air passenger transport on a monthly basis during 2019.

Figure 16. Inland Flow of Passengers Transported during 2019



The Figures 17 and 18 differentiate between peninsular and inter-island air transport and show more clearly the seasonality of tourism in Spain.

Figure 17. Peninsular Flow of Passengers Transported during 2019

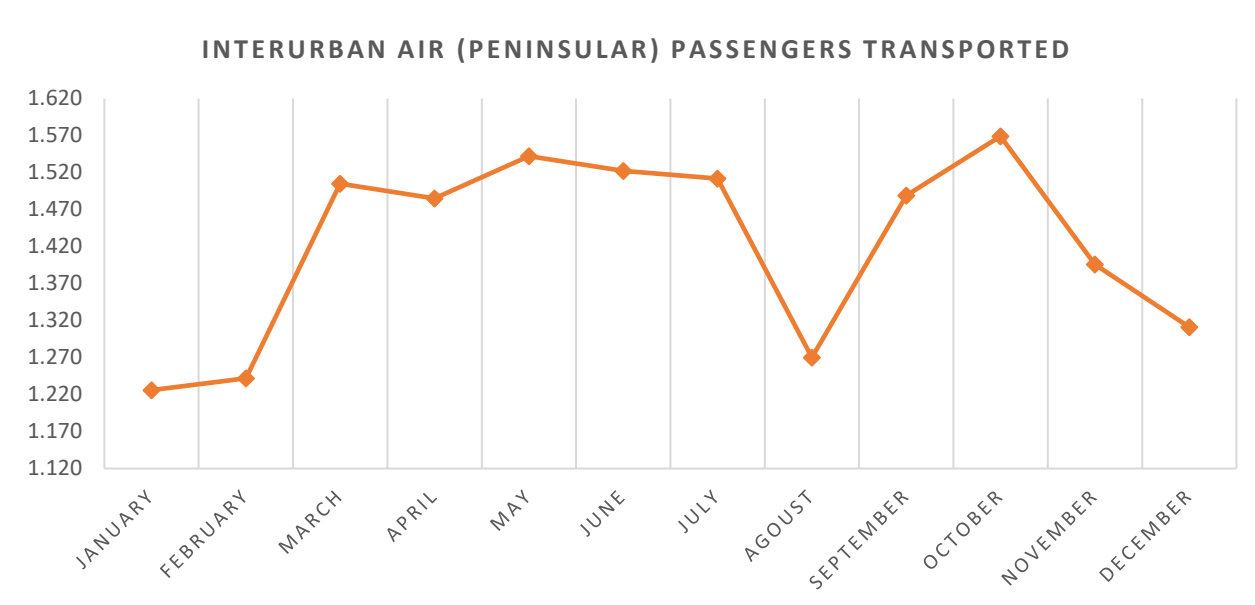
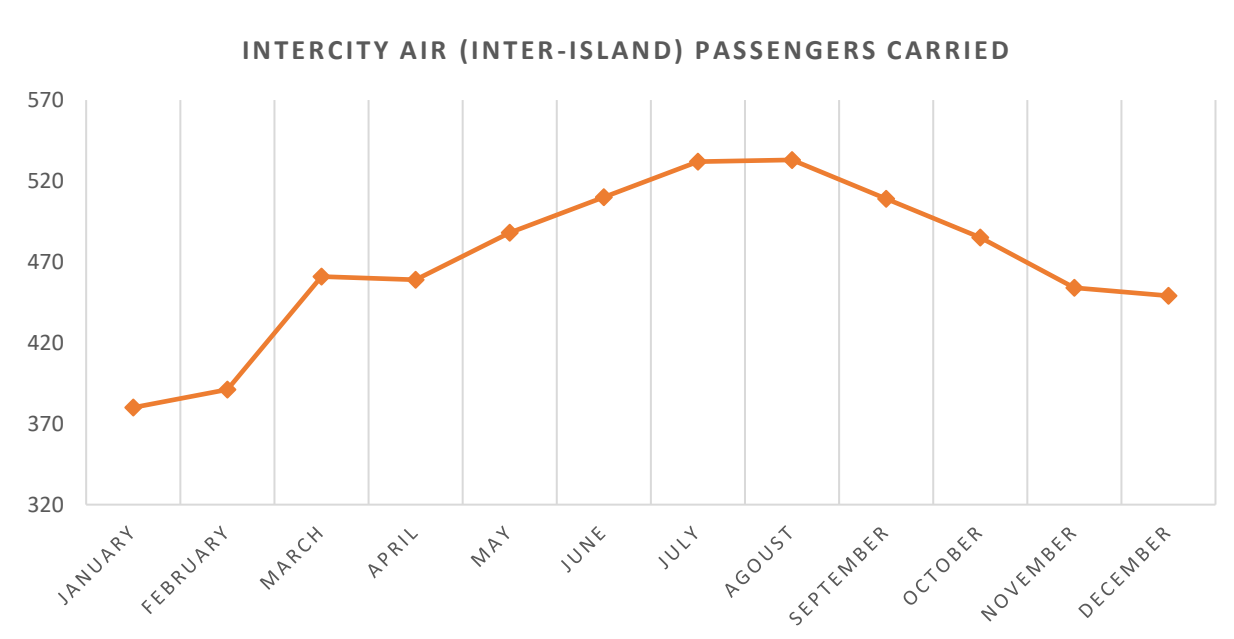


Figure 18. Peninsular Flow of Passengers Transported during 2019



The main domestic air routes in Spain are shown in Table 3 (Gobierno de España - Ministerio de Transporte, Movilidad y Agenda Urbana, 2021).

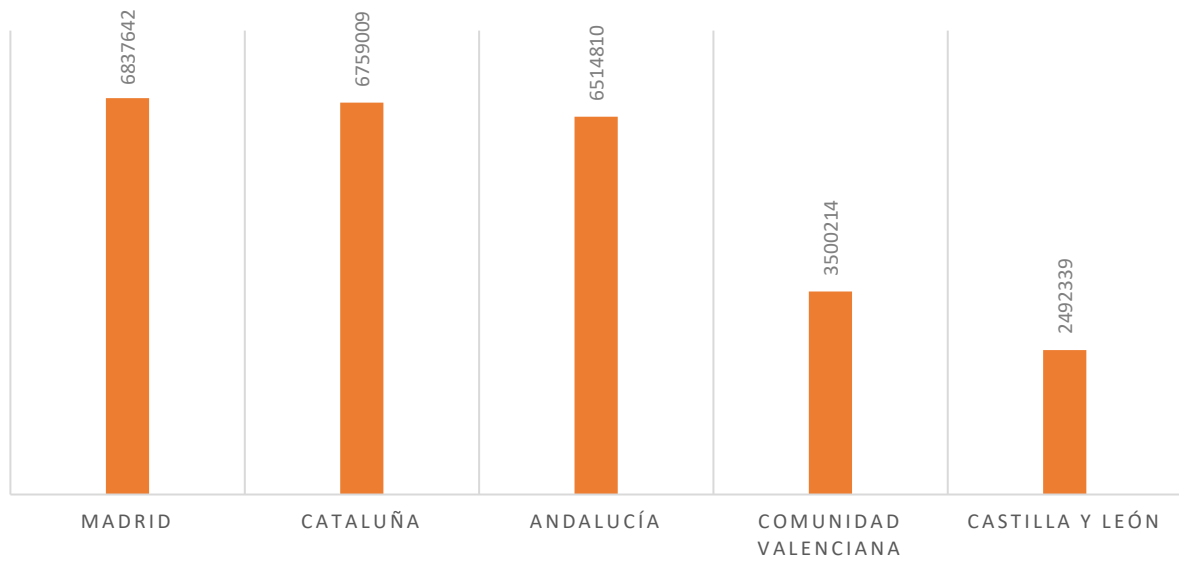
Table 5. Main Passenger air transport relations (2019-2018)

<i>Origin</i>	<i>Destination</i>	<i>2018</i>	<i>2019</i>	<i>Var. 2019-2018</i>
<i>MAD</i>	<i>BCN</i>	1235778	1293015	+4,6%
<i>BCN</i>	<i>MAD</i>	1232769	1281769	+4,0%
<i>PMI</i>	<i>BCN</i>	1021425	1092848	+7,0%
<i>BCN</i>	<i>PMI</i>	1014456	1081209	+6,6%
<i>PMI</i>	<i>MAD</i>	992137	1008304	+1,6%
<i>MAD</i>	<i>PMI</i>	975188	986831	+1,2%
<i>LPA</i>	<i>MAD</i>	816193	834907	+2,3%
<i>MAD</i>	<i>LPA</i>	800639	824208	+2,9%
<i>TFN</i>	<i>MAD</i>	746725	750945	+0,6%
<i>MAD</i>	<i>TFN</i>	740402	743114	+0,4%
<i>IBZ</i>	<i>BCN</i>	588729	604738	+2,7%
<i>BCN</i>	<i>IBZ</i>	586715	601820	+2,6%
<i>SVQ</i>	<i>BCN</i>	492045	523047	+6,3%
<i>BCN</i>	<i>SVQ</i>	486671	521994	+7,3%
<i>TFN</i>	<i>LPA</i>	496536	501392	+1,0%
<i>LPA</i>	<i>TFN</i>	494231	500059	+1,2%
<i>MAH</i>	<i>BCN</i>	404865	422497	+4,4%
<i>BIO</i>	<i>MAD</i>	408960	422231	+3,2%
<i>IBZ</i>	<i>MAD</i>	405005	421175	+4,0%
<i>BCN</i>	<i>MAH</i>	402641	415349	+3,2%

2.4.1. Source destination

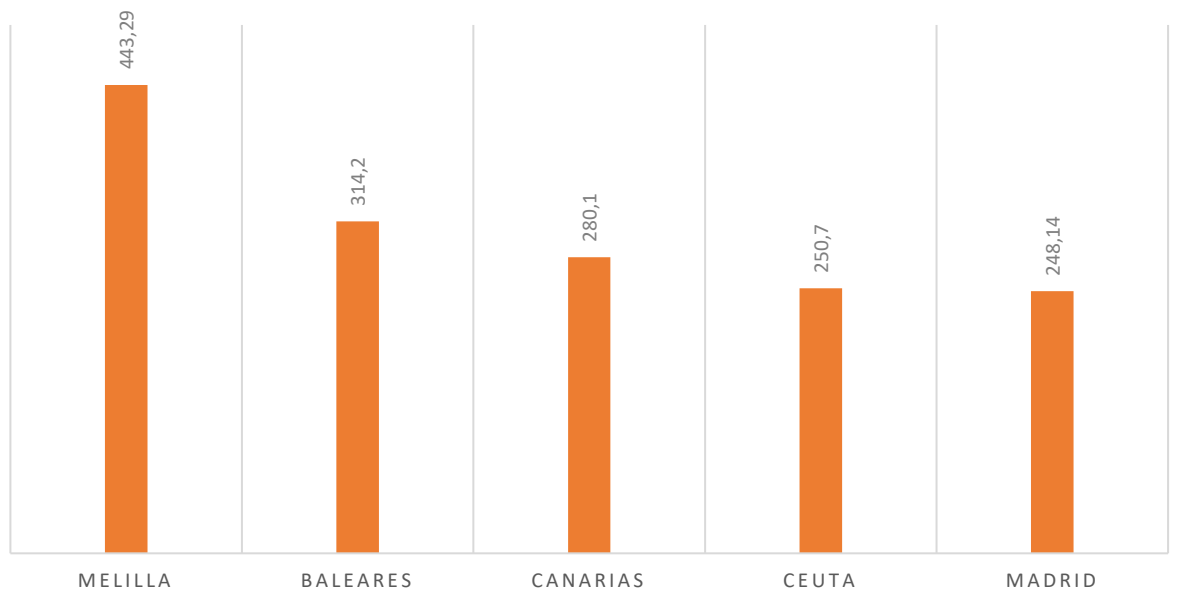
When we talk about resident tourists, more than 40 million trips were made during the fourth quarter of 2019 (*Indicadores de turismo por CCAA*, s. f.). The Autonomous Community that made the most domestic tourism trips in the last quarter of 2019 was the Community of Madrid as can be seen in the Figure 19.

Figure 19. Number of trips by autonomous community of residence (2019)



In the last quarter of 2019, the national average expenditure per person exceeded 222€. When talking about average expenditure per person, the autonomous community of Melilla is in the top one, followed by Baleares, Canarias, Ceuta, and Madrid.

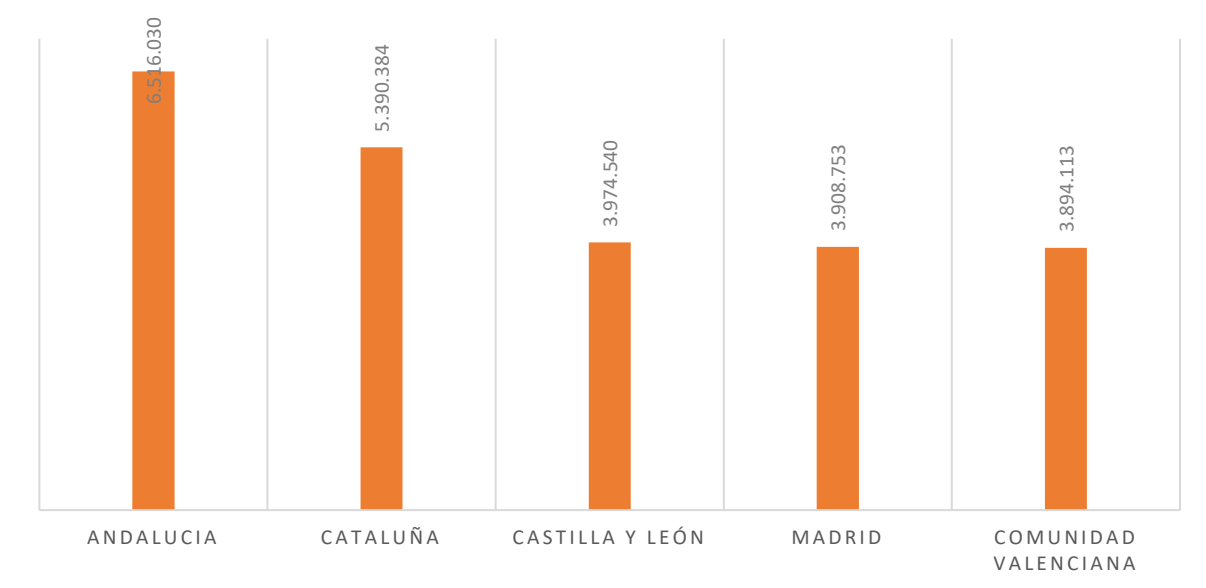
Figure 20. Average expenditure per person by autonomous community of residence (2019)



2.4.2. Autonomous communities of destination

When it comes to resident tourists, statistics indicate that the number of domestic trips exceeds 36 million (*Indicadores de turismo por CCAA*, s. f.). Data on the total number of flights by destination Autonomous Community show Andalusia as the first, followed by Catalonia, Castilla y León, Madrid, and the Valencian Community.

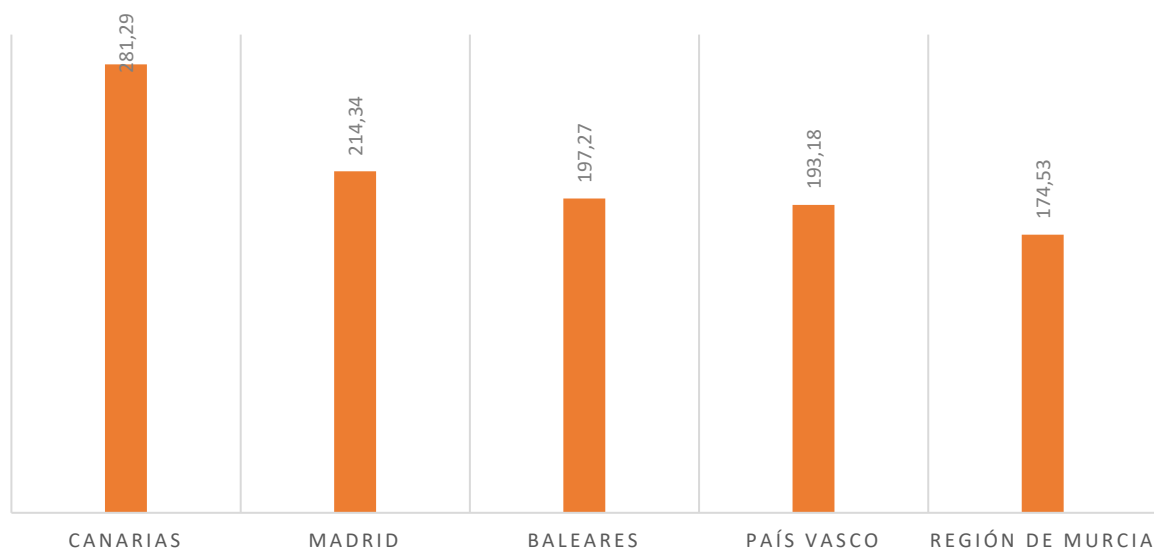
Figure 21. Number of Trips by Autonomous Community of Destination



Also, the resident tourism survey conducted by the Spanish national statistics institute provides data on the average expenditure per person nationally, being these 165,15 euros by autonomous community in the last quarter of 2019.

The Canary Islands is the leading autonomous community in terms of average expenditure per person in the fourth quarter of 2019, followed by the Balearic Islands, the Basque Country, Madrid, and the Principality of Asturias.

Figure 22. Average Expenditure per person by Autonomous Community of destination (2019)



2.5. International Tourism

Based on the December 2019 report about international air passengers (Gobierno de España et al., 2018), Spain welcomed 6.1 million international air passengers, signifying an 2.9% year-on-year increase.

Of these passengers, 54.9% opted for low-cost carriers, registering a 4% rise, whereas traditional airline passengers only grew by 1.5% to make up the remaining 45.1%. Thus, the growth in total international passengers was primarily driven by low-cost carriers.

2.5.1. Source destinations

In December (Government of Spain et al., 2019), Portugal showed the highest growth, while Germany had the largest decrease.

The UK accounted for 20.5% of total arrivals, with an increase of 1.8%, while Germany accounted for 13.3% of total arrivals, with a reduction of 9.3%. Italy sent 9.6% of international passengers and experienced growth of 5.1%, while France accounted for 7.7% of total arrivals and grew by 5.7%.

The most significant increases were in Valencia, Andalusia, and Catalonia, while the most significant decreases were in the Canary Islands and Murcia. British airports were the starting point for 29.8% of the passengers who arrived in Spain, while Italy sent 13% of them.

The principal source destinations of Spain's air traffic are varied and diverse, reflecting the country's popularity as a travel destination and its strong ties to its European neighbors.

The Table 3 shows a study of inbound passengers by air in 2019 according to origin market.

Table 6. Flow of Passenger coming to Spain According to Source Market (2019)

<i>According to source market</i>	<i>Total passengers (2019)</i>
<i>Total</i>	94.478.446
<i>Unit Kingdom</i>	22.384.150
<i>Germany</i>	14.496.930
<i>Italy</i>	8.137.334
<i>France</i>	7.009.617
<i>Netherlands</i>	4.385.248
<i>Belgium</i>	3.115.668
<i>Switzerland</i>	3.200.860
<i>Portugal</i>	2.797.835
<i>United States</i>	2.494.084
<i>Sweden</i>	1.839.270
<i>Irland</i>	2.323.855
<i>Other countries</i>	22.293.595

For our research it is not only important to study the flow of passengers on actual flights, but also the air capacity with respect to seats on scheduled flights for international flights arriving from the main source destinations.

Based on the statistics provided by AENA (Gobierno de España [Ministerio de Industria, Comercio y Turismo] & Secretaría de estado de turismo, 2019), most of the main markets are decreasing their air capacity in 2019 with respect the previous year. Growth in France, United States and above all Portugal stood out.

In the cumulative period from January to October 2019, passengers arriving in Spain on international flights increased by 3.6% compared to the same period last year, with Portugal and the United States being the markets that experienced the highest growth rates.

In the Table 4 it can be seen the seat capacity on planned flights and a comparison between passengers on flights in 2018 and 2019.

Table 7. Air Capacity for Income Tourism

	<i>AIR CAPACITY</i>		
	<i>Seats on scheduled flights</i>	<i>Passengers on flights carried out</i>	
	<i>Dec-Feb</i>	<i>Year 2018</i>	<i>Year 2019</i>
<i>Total</i>	20.773.701	91.255.881	94.478.446
<i>Unit Kingdom</i>	3.986.782	21.985.041	22.384.150
<i>Germany</i>	2.763.437	14.805.335	14.496.930
<i>Italy</i>	1.986.456	7.651.016	8.137.334
<i>France</i>	1.655.513	6.606.637	7.009.617

<i>Netherlands</i>	929.577	4.363.317	4.385.248
<i>Switzerland</i>	728.312	3.204.235	3.200.860
<i>Belgium</i>	707.685	3.018.319	3.115.668
<i>Portugal</i>	846.357	2.415.590	2.797.835
<i>United States</i>	523.911	2.201.561	2.494.084
<i>Sweden</i>	426.436	1.926.991	1.839.270
<i>Denmark</i>	376.173	1.715.991	1.549.048

2.5.2. Autonomous Communities of Destination

In terms of international air traffic (Government of Spain et al., 2019), Madrid received the highest number of international arrivals, accounting for 28.8% of the total, while the Canary Islands followed closely behind, accounting for 22% of international air traffic. In the same year, Spain was the second most visited country in the world, with over 82 million international visitors, and its autonomous communities were popular destinations due to their unique cultures, stunning landscapes, and rich histories.

According to data from the Spanish airport Operator AENA, other communities, apart from Madrid, have also taken a large part of the international tourism. The Table 5 shows the flow of international passengers by autonomous community of destination, on monthly basis in December 2019 and the accumulated during this year.

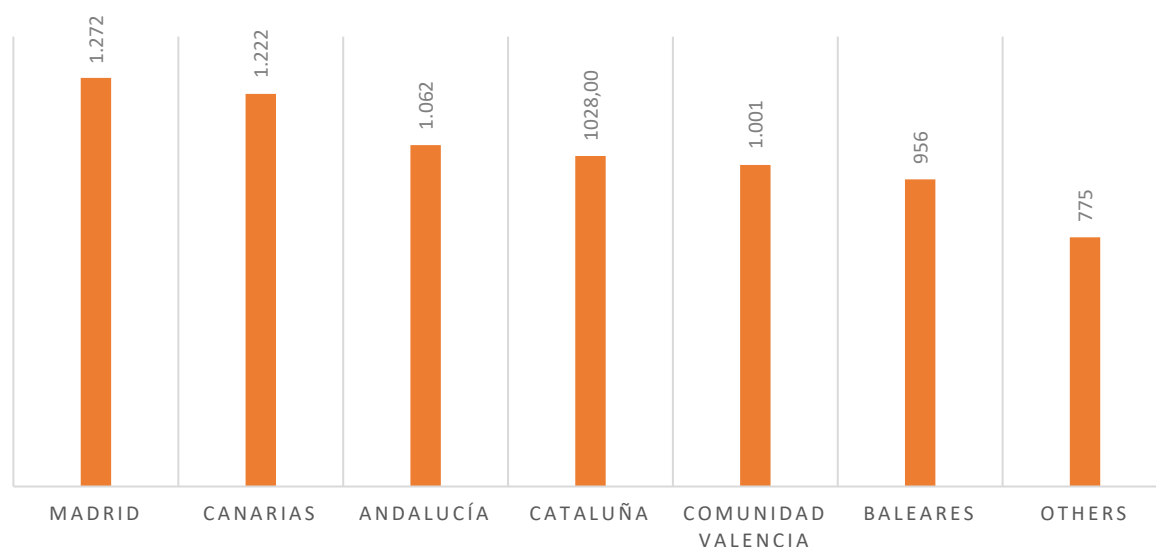
Table 8. Flow of Passengers According to Autonomous Community of Destination (2019)

<i>According to Autonomous community of destination</i>	<i>Total passengers</i>
Total	94.478.446
Madrid (C. de)	22.544.434
Cataluña	20.769.861
Canarias	13.258.093
Andalucía	11.017.235
C. Valenciana	9.795.063
Baleares	14.369.595
Resto of communities	2.724.165

The statistical survey of tourist movements at the border (Dexeus, 2023) and the tourist expenditure survey (Serrano, 2023) provide us with information about the average expenditure per person in Spain by non-resident tourists. In February of 2020 the average expenditure per person was more than 1000€.

When it comes to the average expenditure per person and per autonomous community, the community of Madrid tops the list with 1272€ per person in February of 2020.

Figure 23. Average Expenditure per Person and Autonomous Community



The aforementioned surveys also indicate that the average duration of trips in Spain by non-resident tourists during February 2020 was 7.13 days.

In the following points, a more exhaustive and detailed study will be made by community previously shown in the table during 2018 (Gobierno de España [Ministerio de Industria, Comercio y Turismo] & Secretaría de Estado de Turismo, 2019).

Community of Madrid

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2019), of more than 7 million of tourist, the percentage of tourists residing abroad with main travel destination Madrid choose the area route as the most used access route to Spain, with 93%.

Turespaña also provide data on the number of flights, exceeding 130.000, and the number of seats, 26.899.898. Being the main market the United States with 11.3%, followed by Italy, France, United Kingdom, and Germany with 8.6%, 7.5%, 7.4% and 5.5%, respectively.

The principal airports of origin can be found in the Table 6.

Table 9. Flow of Passengers by Airport of Origin in the Community of Madrid (2019)

Airports	Number of passengers	Percentage %
Amsterdam/Schiphol	575.496,00	2,55%
Fiumicino Roma	640.163,00	2,84%
Lisbon (Lp) Lis Lisbon	776.786,00	3,44%
Orly Paris	673.790,00	2,89%
Paris/Charles De Gaulle	564.370,00	2,50%

Statistics are also obtained on the annual evolution of tourists residing abroad with destination Madrid received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 24. Annual Evolution of Tourist in Madrid FRONTUR (INE, 2019)

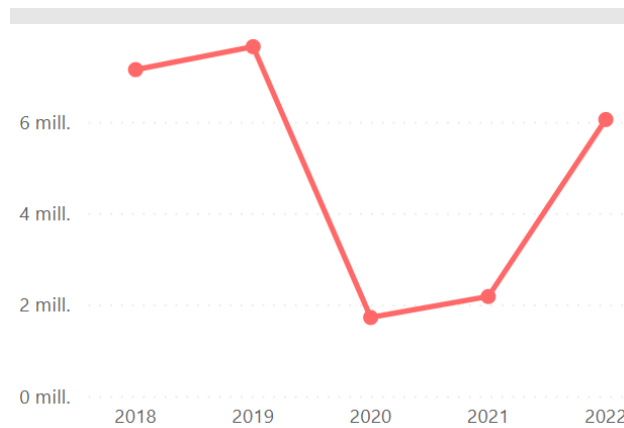
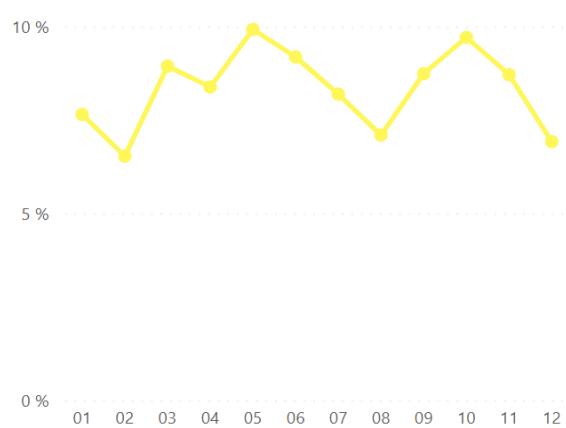
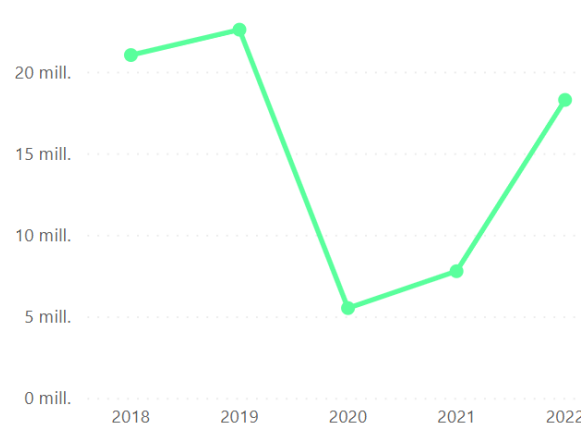


Figure 25. Seasonality (% tourists) in Madrid FRONTUR (INE, 2019)



AENA provides the annual number of passengers arriving in Madrid on direct connection flights from abroad in the last 5 years, having its peak in 2019 with 22 million passengers.

Figure 26. Seasonality (% tourists) in Madrid FRONTUR (INE, 2019)



Canarias

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2019), the percentage of tourists residing abroad with main travel destination Canarias choose the area route as the most used access route to Spain, with 99.9%.

Turespaña also provide data on the number of flights, exceeding 78.000, and the number of seats, 15.133.492. Being the main market the Unite Kingdom with 37.1%, followed by Germany with 19,1%.

The principal airports of origin can be found in the Table 7.

Table 10. Flow of Passengers by Airport of Origin in Canarias (2019)

Airports	Number of passengers	Percentage %
Birmingham Inti	491.954,00	3,66%
Dusseldorf	584.419,00	4,35%
London/Gatwick	771.759,00	5,74%
Manchester Inti (Eg) Man	959.156,00	7,14%
Stansted (Eg) Stn London	504.276,00	3,75%

Statistics are also obtained on the annual evolution of tourists residing abroad with destination Canarias received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 27. Seasonality (% tourists) in Canarias FRONTUR (INE, 2019)

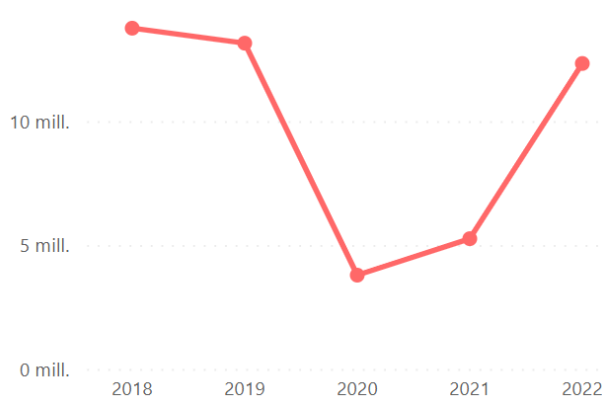
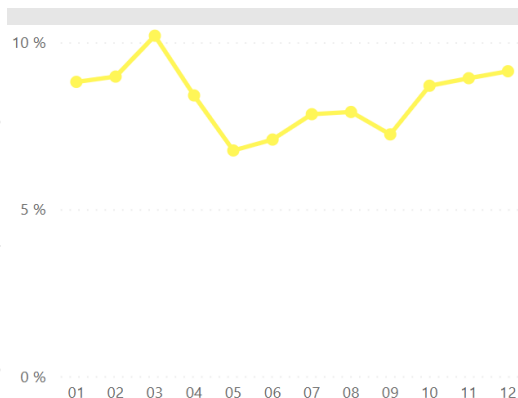
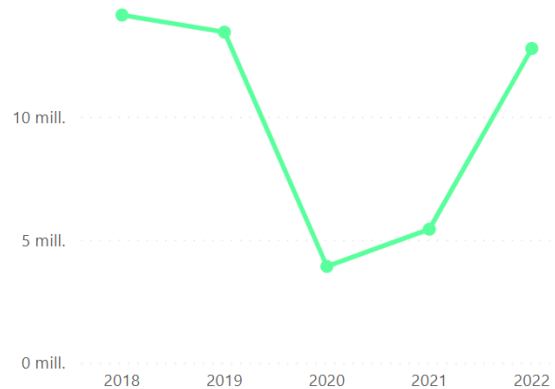


Figure 28. Annual Evolution of Tourist in Canarias FRONTUR (INE, 2019)



AENA provides the annual number of passengers arriving in Canarias on direct connection flights from abroad in the last 5 years, having its peak in 2018 with 14 million passengers.

Figure 29. Annual evolution of passengers in Canarias (AENA, 2019)



Cataluña

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2019), the percentage of tourists residing abroad with main travel destination Cataluña choose the area route as the most used access route to Spain, with 72.5%.

Turespaña also provide data on the number of flights, exceeding 129.000, and the number of seats, 24.732.271. Being the main market the France with 21.1%, followed by United Kingdom, United States, Germany, and Italy, with 10.4%, 7.8%, 7.4% and 6.2%, respectively.

The principal airports of origin can be found in Table 30.

Figure 30. Flow of Passengers by Airport of Origin in the Cataluña (2019)

Airports	Number of passengers	Percentage %
Amsterdam/Schiphol	736.119,00	3,53%
Brussels	511.350,00	2,46%
Fiumicino Roma	702.900,00	3,37%
London/Gatwick	818.776,00	3,93%
Paris/Charles De Gaulle	690.628,00	3,32%

Statistics are also obtained on the annual evolution of tourists residing abroad with destination Cataluña received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 31. Seasonality (% tourists) in Cataluña FRONTUR (INE, 2019)

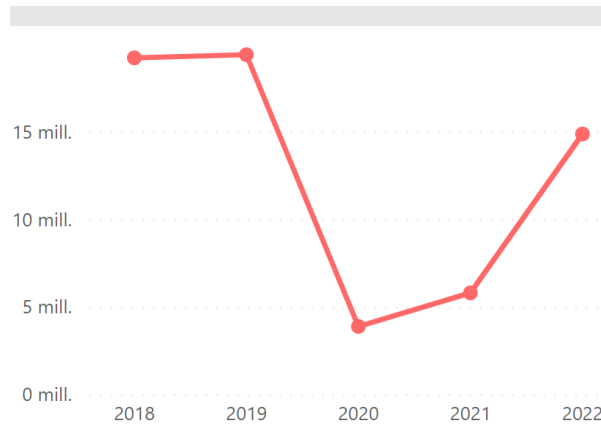
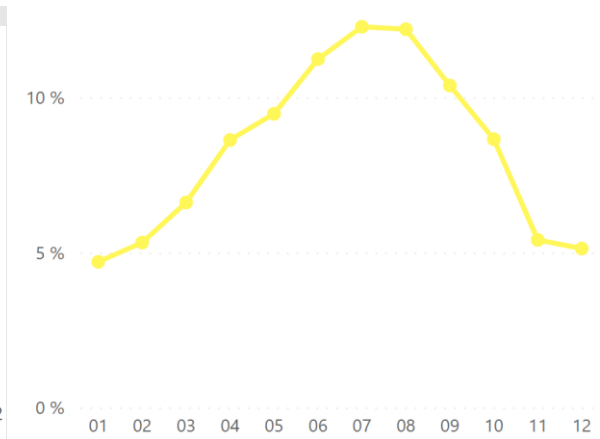
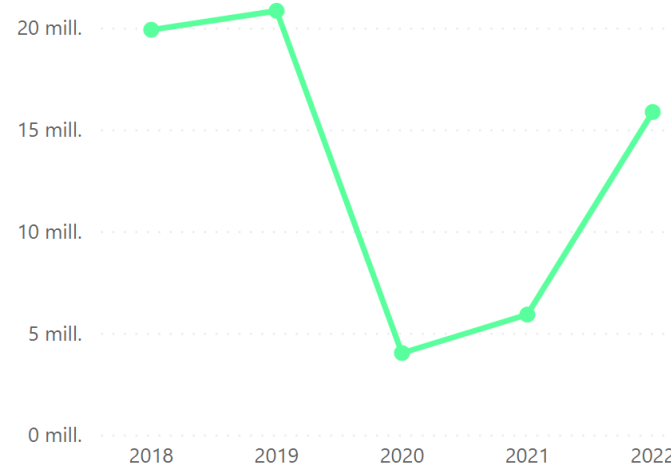


Figure 32. Annual Evolution of Tourist in Cataluña FRONTUR (INE, 2019)



AENA provides the annual number of passengers arriving in Cataluña on direct connection flights from abroad in the last 5 years, having its peak in 2019 with 21 million passengers.

Figure 33. Annual evolution of passengers in Cataluña (AENA, 2019)



Andalucía

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2019), the percentage of tourists residing abroad with main travel destination Andalucía choose the area route as the most used access route to Spain, with 81.3%.

Turespaña also provide data on the number of flights, exceeding 71.000, and the number of seats, 12.575.288. Being the main market the United Kingdom with 25.1%, followed by France, Germany, and Netherlands, with 10.6%, 9.3% and 5.1%, respectively.

The principal airports of origin can be found above:

Table 11. Flow of Passengers by Airport of Origin in Andalucía (2019)

Airports	Number of passengers	Percentage %
Amsterdam/Schiphol	402.556,00	3,64%
London/Gatwick	789.590,00	7,14%
Manchester Intl. (Eg) Man	381.808,00	3,45%
Paris/Charles De Gaulle	353.257,00	3,19%
Stansted (Eg) Stn Londres	377.620,00	3,41%

Statistics are also obtained on the annual evolution of tourists residing abroad with destination Andalucía received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 34. Annual evolution of passengers in Andalucía (AENA, 2019)

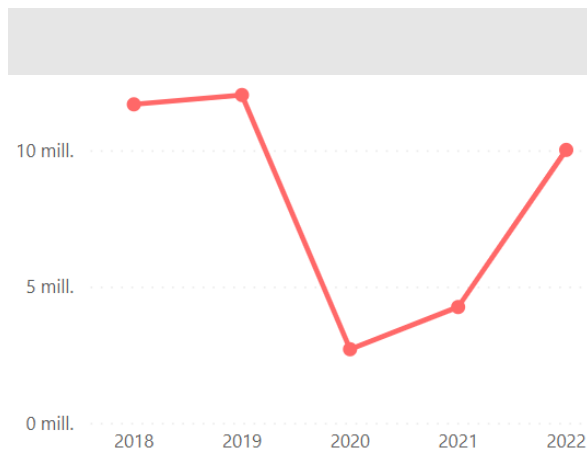
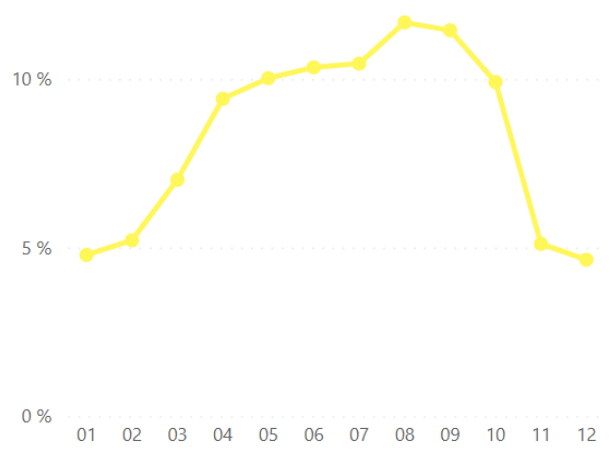
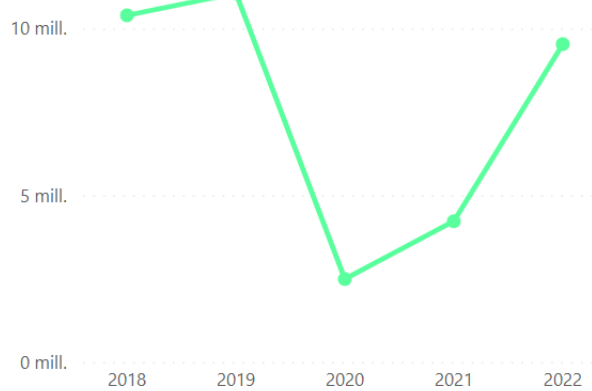


Figure 35. Annual Evolution of Tourist in Andalucía FRONTUR (INE, 2019)



AENA provides the annual number of passengers arriving in Andalucía on direct connection flights from abroad in the last 5 years, having its peak in 2019 with 11 million passengers.

Figure 36. Annual evolution of passengers in Andalucía (AENA, 2019)



C. Valenciana

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2019), the percentage of tourists residing abroad with main travel destination C. Valenciana choose the area route as the most used access route to Spain, with 79.5%.

Turespaña also provide data on the number of flights, exceeding 55.000, and the number of seats, 11.189.744. Being the main market the United Kingdom with 23.9%, followed by France, Germany, Netherlands, and Belgium with 17.2%, 6.3%, 6.2% and 5.6%, respectively.

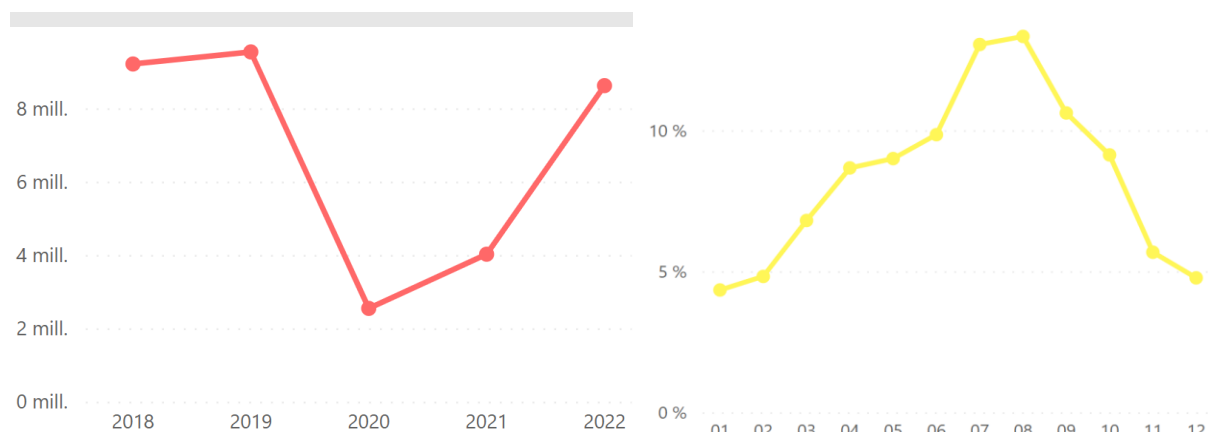
The principal airports of origin can be found in the Table 8.

Table 12. Flow of Passengers by Airport of Origin in the C. Valenciana (2019)

Airports	Number of passengers	Percentage %
Amsterdam/Schiphol	404.713,00	4,13%
Brussels	318.170,00	3,25%
London/Gatwick	596.701,00	6,09%
Manchester Intl. (Eg) Man	396.331,00	4,04%
Nottingham/East Midlands	223.304,00	2,28%

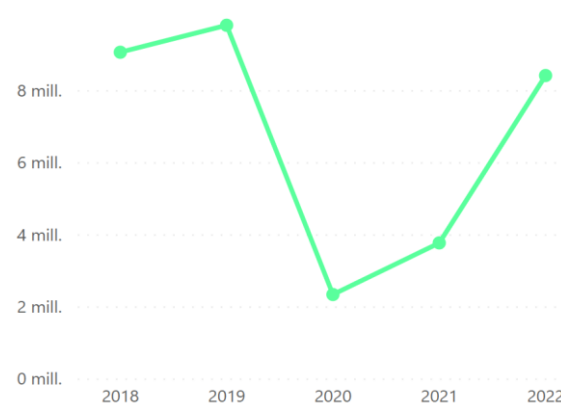
Statistics are also obtained on the annual evolution of tourists residing abroad with destination C. Valenciana received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 37. Annual evolution of passengers in C. Valenciana (AENA, 2019) Figure 38. Annual Evolution of Tourist in C.Valenciana FRONTUR (INE, 2019)



AENA provides the annual number of passengers arriving in C. Valenciana on direct connection flights from abroad in the last 5 years, having its peak in 2019 with almost 10 million passengers.

Figure 39. Annual evolution of passengers in C.Valenciana (AENA, 2019)



Baleares

According to an estimate by Turespaña based on FRONTUR microdata (INE, 2018), the percentage of tourists residing abroad with main travel destination Baleares choose the area route as the most used access route to Spain, with 99.5%.

Turespaña also provide data on the number of flights, exceeding 93.000, and the number of seats, 16.393.442. Being the main market the Germany with 33.1%, followed by Unite Kingdom, France, and Italy, with 27.0%, 5.6%, and 5.3%, respectively.

The principal airports of origin can be found in the Table 10.

Table 13. Flow of Passengers by Airport of Origin in Balears (2019)

Airports	Number of passengers	Percentage %
Dusseldorf	882.488,00	6,12%
Frankfurt Main	630.646,00	4,37%
London/Gatwick	646.816,00	4,48%
Manchester Intl. (Eg) Man	609.613,00	4,22%
Munich	505.666,00	3,50%

Statistics are also obtained on the annual evolution of tourists residing abroad with destination in Balears received in the last 5 years and the percentage of tourists according to the month in which they have traveled with respect to the total number of tourists received in the year.

Figure 40. Annual evolution of passengers in Balears (AENA, 2019)

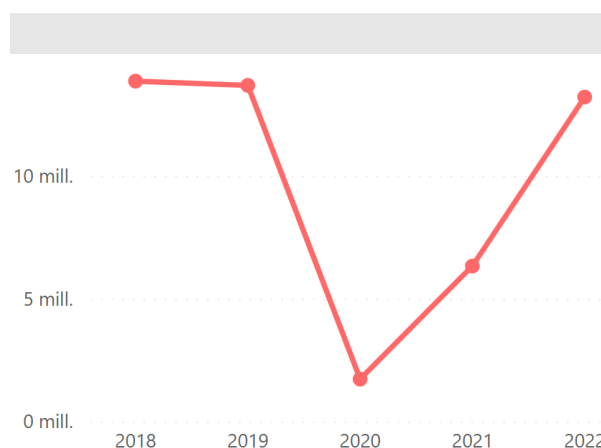
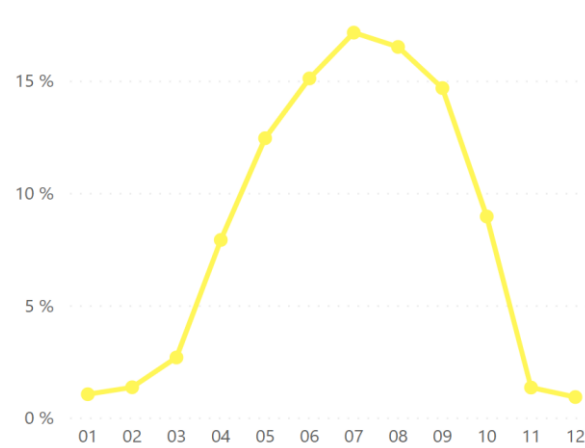
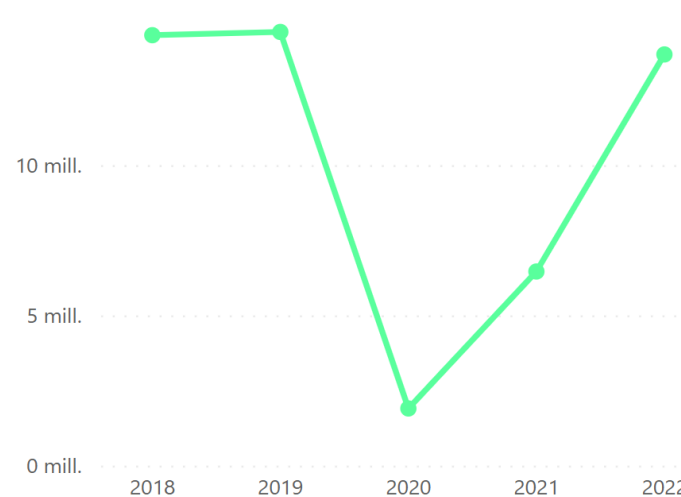


Figure 41. Annual Evolution of Tourist in Balears FRONTUR (INE, 2019)



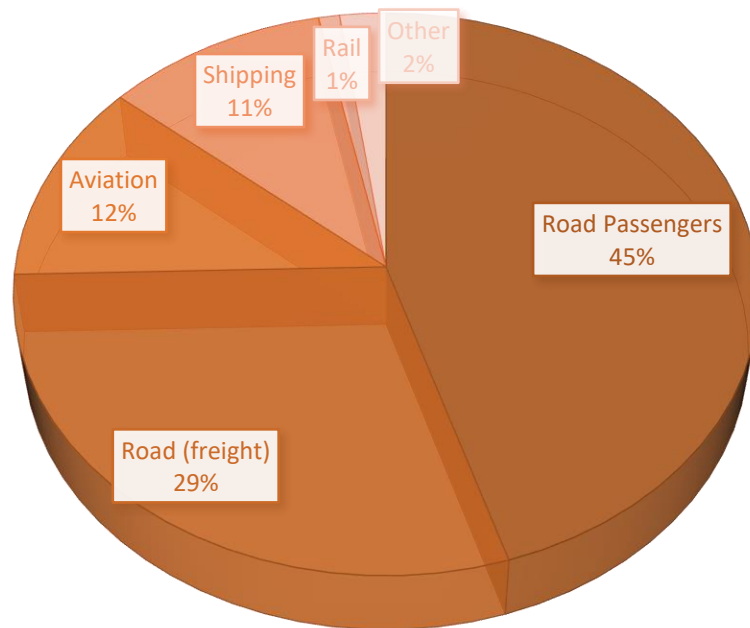
AENA provides the annual number of passengers arriving in Balears on direct connection flights from abroad in the last 5 years, having its peak in 2019 with almost 15 million passengers.

Figure 42. Annual evolution of passengers in Balears (AENA, 2019)



3. Environmental Sustainability in Air Transportation

According to the International Energy Agency (IEA, 2021) transportation is responsible for approximately 24% of global carbon dioxide emissions. This represents about one-fifth of all emissions worldwide. The figure provided by the agency illustrates the impact of transportation on the global economy.



Tourism is confronted with a formidable challenge in the form of greenhouse gases discharged through aviation, which is essential for the industry (Hamaguchi, 2021). Governments have presented the aviation industry with emission permits trading options to address this issue, but the effects of this policy on tourism and the environment remain uncertain. The tourism industry has been growing at an average rate of 4% annually, leading to the development of carbon dioxide-intensive industries. Air traffic tourism account for around 2,5% of global CO₂ emissions (*Climate Change and Flying: What Share of Global CO₂ Emissions Come From Aviation?*, 2020).

According to the United Nations World Tourism Organization (UNWTO) and the United Nations Environment Programme (UNEP, 2008), climate change could have a severe impact on the sustainability of tourism, including submergence of island countries with beach resorts and reduced snowfall in cold countries with ski resorts.

Therefore, governments of tourism-oriented countries must prioritize both innovative tourism-led growth and sustainable tourism through decarbonization and policies that promote both.

While tourism-induced growth leads to GDP growth and economic proliferation through a knock-on effect in manufacturing, it is likely to be incompatible with sustainable

tourism due to environmental quality degradation and economic development through the dam effect.

3.1. Tourism demand and climatic determinants

Research by Song and Li (2008) shows that tourism demand estimation and forecasting mostly focuses on economic factors. However, Eugenio-Martin (2003) proposes a new framework for analyzing travel decision-making, which utilizes utility theory within the tourism context and accounts for different perspectives and a more comprehensive range of explanatory variables.

It is important to note that tourists have varied tastes and choosing a final destination is not an isolated decision, but one of many choices that depend on tourists' preferences and the attributes of the available alternatives.

The choice of destination is considered one of the most complex stages of the decision-making process, with many variables that can affect such decisions. Furthermore, recent literature reviews suggest that temperature is the most commonly used climate variable in explaining tourist decisions.

Tourism markets such as winter sports and sun, sea and sand mass tourism are particularly vulnerable to changes in climate, and more research is needed to fully understand the impact of climate change on this industry.

The most common quantitative method to assess climate change's impact on tourism demand involves estimating tourist numbers by evaluating the physical conditions necessary to facilitate tourism activities and quantifying the relationship between tourism demand and specific climatic variables to anticipate future climate scenarios. Cross-sectional analysis is frequently preferred when analyzing the role of climate in determining tourism flows.

The new paradigm of sustainability is having a significant impact on air traffic tourism. This shift is reflected in several trends in the air travel and tourism industry, such as increased demand for sustainable travel options, growing awareness of the carbon footprint of air travel, and pressure on airlines to adopt more sustainable practices.

There are several climate determinants that can make a person decide not to travel using a plane, such as extreme weather events, climate change concerns, air quality, natural disasters, and personal values.

Additionally, factors related to climate change and environmental sustainability, such as carbon footprint, sustainable travel options, environmental impact of travel, and ethical considerations, may influence a person's decision to travel by plane.

Overall, the new paradigm of sustainability is leading to significant changes in the air traffic tourism industry as travelers and industry players seek to address the environmental impacts of air travel and promote more sustainable practices.

3.1.1. Flygskam

In Sweden, there exists a movement called Flygskam, which translates to "The Shame of Flying" (Magazine, 2020). The purpose of this movement is to persuade individuals to avoid using airplanes due to the significant amount of CO₂ emissions that come with air travel. Climate activist Greta Thunberg has played a significant role in popularizing this movement.

Flygskam, or "flight shame," is not simply a matter of expression in Sweden. It is a declaration of purpose that has resulted in concrete reductions in air travel. Swedavia, a Swedish government-run entity that manages ten airports across the country, experienced an overall decline of 4% in users in 2019 when compared to the prior year, with passenger numbers dropping from 42 million to 40 million. Domestic flights were especially impacted, with a 9% decrease in users (Lund, 2020). Meanwhile, state-owned train operator SJ achieved a record 32 million passengers during the same timeframe.

According to a survey conducted by the Swiss bank UBS between July and August 2019 among over 6,000 air travelers in the United States, France, the United Kingdom, and Germany, a growing number of people are beginning to feel ashamed of flying, with one out of every five respondents stating that they had canceled at least one flight in the past year due to weather.

During the aviation industry summit in Seoul held in June of 2019, one of the topics discussed was the possible hindrance to future growth in aviation caused by what the International Air Transport Association (IATA) terms as "The Shame of Flying." The IATA has publicly recognized this issue, indicating its potential impact on the industry's expansion (Green, 2019).

Although passenger traffic has not really been affected, it is not only that it can be extrapolated to Spain, but it may also affect the arrival of Swedish tourists to Spain. In 2019, they exceeded 2 million and 2.5% in market share and with Canary Islands, Andalusia and Balearic Islands as main destinations (Secretaría de Estado de Turismo & TURESPAÑA, 2020).

During 2019, a survey was conducted in Sweden by researchers Maria Wolrath Söderberg and Nina Wormbs (Wolrath Söderberg, 2021). The survey comprised 673 individuals who had either decreased their air travel significantly or altogether ceased it. The result of this study provides us with insight into the factors and motivations driving this movement.

According to the authors, the most commonly cited reason for the shift in behavior was knowledge and understanding. However, this understanding was not merely the product of acquiring information, but rather stemmed from a realization of the pressing nature of the issue.

The significance of guilt and the desire for consistency were also highlighted by those who were interviewed, as emphasized by the researchers. Their motivation to do "the right thing" stems from their perception of the climate crisis as a moral and just issue.

This notion of justice extends not only to their peers but also to future generations, prompting them to question why their personal preferences should contribute to the destruction of others' futures.

3.1.2. Eco-Passenger

The transport sector is responsible for more than a quarter of global greenhouse gas emissions. What's more, emissions from the transport sector have grown faster than any other sector over the past few decades, and this trend is set to continue (*EcoPassenger*, n.d.).

The International Union of Railways (UIC) strives to play its part in raising road users' awareness of the consequences of our everyday travel choices, supporting decision-making on how to promote sustainable choices, by challenging existing practices and in doing so, total energy The energy chain is considered, including energy life cycle costs.

Then, Eco-Passenger is an easy-to-use online calculator that compares energy consumption, CO2 emissions and exhaust emissions of passenger transport by plane, car, and train.

3.2. Spain Situation

It is positive to see that Spain is ranked highly in terms of environmental, economic, and social sustainability (Instituto de Turismo de España & Ministerio de Industria, Comercio y Turismo, 2022), with particular recognition of its growth in sustainable tourism.

The Spanish government has recognized sustainable development as a major challenge, and there is growing demand from society for the preservation of the environment (Gobierno de España & OACI, s. f.). In response, both European and national regulations have been implemented to ensure the proper functioning of transportation systems and the protection of the environment.

The International Civil Aviation Organization (ICAO) has established strategic objectives to minimize the adverse environmental effects of civil aviation activities, which align with the United Nations' Sustainable Development Goals (SDGs). The Spanish Directorate General of Civil Aviation (DGAC) is addressing these challenges by utilizing various tools provided in current regulations to achieve greater sustainability in the development of civil aviation while maintaining the highest levels of safety, efficiency, and regularity.

It is worth noting that there were almost 6,000 environmental claims and complaints in 2019 in Spain, and over 1,000 requests for environmental information (AENA, 2019).

Additionally, over 10,000 people were exposed to noise, and greenhouse gas emissions were 136,430, although there has been a significant reduction compared to previous years.

3.2.1. Source Destinations' Regulations

As we have observed during the project, the main source destinations outside Spain are European, specifically the United Kingdom, Germany, Italy and France.

As we have observed in the previous point, both Spain and the rest of the countries within the European Union are regulated by the ICAO (Environmental Protection, n.d.). A multilateral platform for cooperation in the environmental protection of international aviation and over the years, national governments participating together under the Chicago Convention, commonly known as 'ICAO Member States', have focused their environmental collaboration on climate change and aviation emissions, aircraft noise and local air quality.

To achieve these goals, new global aviation standards are being developed, which focused on international aviation and prioritized ICAO environmental protection resources in airframe, propulsion, optimization of flight procedures to reduce fuel consumption, increased production of sustainable aviation fuel and clean energy. In addition, the implementation of the carbon offset reduction scheme for international aviation CORSIA.

Although each country also has its own regulations and policies, we can highlight the recent situation in France. As they explain to us in National Geographic (Cardona, 2021), 'France approves banning short-haul domestic continental flights'. This affects those domestic flights that can be done by train in less than 2.5 hours.

In reality, it would apply to two of France's 108 domestic routes: Paris Orly and Bordeaux, Lyon, and Nantes. Although a ban on flights with train connections of less than four hours, and even a ban on the construction of new airports and the expansion of existing ones, are also being considered.

3.2.2. Incoming Tourism in the Islands

Domestic

During the research it has been possible to observe the importance of island tourism in Spain, with Palma de Mallorca Airport (Balearic Islands) and Tenerife North Airport, being the main airport for domestic flights to the Canary Islands, being some of the busiest in Spain and the Canary Islands and Balearic Islands being some of the favorite destinations in Spain.

Based on Table 4, on the main domestic air routes, Madrid and Barcelona airports are the main source destinations for the Canary Islands and Balearic Islands.

Table 14. Principal Domestic Routes to Islands by Air

<i>Origin</i>	<i>Destination</i>	<i>Passengers</i>
<i>BCN</i>	<i>PMI</i>	1.081.209
<i>MAD</i>	<i>TFN</i>	743.114

The only other option to access the islands by sea transport. The main routes to access Tenerife and Palma de Mallorca are those shown in the Table 15.

Table 15. Principal Domestic Routes to Islands by Boat

<i>Origin</i>	<i>Destination</i>	<i>Passengers</i>
<i>Barcelona</i>	<i>Palma de Mallorca</i>	1.081.209
<i>Cádiz</i>	<i>Santa Cruz of Tenerife Port</i>	743.114

In order to compare both means of transport, a comparison was made between both means of transport and their main access route, taking into account different indicators (Table 16, Table 17).

To obtain information on air routes, we used the website FLights.From.com (Worldwide Routes and Flights from All Airports - FlightsFrom.com, n.d.) and Google Flights (Google, n.d.) and for sea routes, the information offered by shipping companies such as Trasmediterránea (Armas, n.d.). It is important to note that the data provided by these sources are estimates and averages based on their historical data.

Table 16. Comparasion of means of Transports for Baleares

	<i>Origin</i>	<i>Destination</i>	<i>Distance (km)</i>	<i>Duration (min)</i>	<i>Duration (hours)</i>	<i>Weekly Availability (days)</i>	<i>Capacity (Per Operation)</i>	<i>Ticket Price (One way) €</i>	<i>Ticket Price (Round-trip) €</i>	<i>CO2 Emissions (Per Person) kg</i>
<i>Air Transport</i>	<i>BCN</i>	<i>PMI</i>	203	63	1,05	7	165-218	14-40	25-60	34,00
<i>Maritim Transport</i>	<i>Barcelona Port</i>	<i>Palma de Mallorca Port</i>	283	438	7,30	5	605-847	38-56	43-64	15,40

Table 17. Comparison of means of Transports for Canarias

	Origin	Destination	Distance (km)	Duration (min)	Duration (hours)	Weekly Availability (days)	Capacity (Per Operation)	Ticket Price (One way) €	Ticket Price (Round-trip) €	CO2 Emissions (Per Person) kg
Air Transport	MAD	TFN	1780	183	3,05	7	180-293	45-120	115-230	119,00
Maritim Transport	Cádiz Port	Santa Cruz of Tenerife Port	1552	2940	49,00	5	605-847	117-176	213-218	81,00

Although it can be observed that maritime routes are more sustainable in terms of CO2 emissions, tourists still prefer to use air transport for reasons such as the length of the journey or the slight difference in prices, which are higher on routes to the Canary Islands.

International

As this research has shown, United Kingdom and Germany are the main source destinations for both, Canary Islands and Balearic Islands, since it is physically impossible to access the islands, it will be study how making a scale in Spain to use maritime transport may or may not be more beneficial than opting for a direct flight.

For the Balearic Islands we will consider Dusseldorf Airport (Germany) and London/Gatwick Airport (UK) as they are the airports with the highest number of passenger flows in 2019 (Table 13).

Table 18. Sea connections for international flights to the Balearic Islands

Origin	Scale	Destination	Distance (km)	Duration (min)	Duration (hours)	Ticket Price (Round-trip) €	CO2 Emissions (Per Person) kg
DUS		PMI	1347	144	2,40	150-225	142,00
DUS	Barcelona Port	Palma de Mallorca Port	1454	570	9,50	172-299	101,40
LGW		PMI	1316	153	2,55	65-165	102,00
LGW	Barcelona Port	Palma de Mallorca Port	1398	567	9,45	118-239	105,40

As can be seen in Table 18, there is a large increase in travel time and a small increase in trip price when including a stopover and attempting to include maritime transport. In contrast, the emissions for each transport are very similar, concluding that there is no benefit for

sustainability and greenhouse gas reduction by including maritime transport versus a direct flight.

For the Canary Islands, the airports with the highest tourist traffic in 2019 (Table 10) are Dusseldorf Airport (Germany) and Manchester Intl (Eg) Airport (UK). Although, this time Tenerife South Airport will be defined as the destination since it is the one destined for international flights.

But as the portal of tourism in Spain indicates, the maritime connections with the Canary Islands are only made through the port of Cadiz and the port of Huelva, not having airports, it would be necessary to resort to nearby airports such as the Airport of Seville.

It would be interesting to study other routes and connections with other Spanish ports and take into account the distances from the airports to the ports for more accurate duration data.

3.3. Commitments and Policies for Sustainable Aviation

There are commitments and policies both internationally and nationally that directly affect Spanish tourism in relation to civilian tourism, some of the most important of which are outlined below.

3.3.1. WayPoint 2050

Waypoint 2050, the International Air Transport Association's (IATA) strategic initiative, aims to make aviation carbon neutral by 2050. With the goal of reducing greenhouse gas emissions, it promotes the development and introduction of cleaner and more efficient technologies in aviation (Waypoint 2050, n.d.).

It also highlights the importance of sustainable airport infrastructure and fosters collaboration between industry, government, and international organizations. To achieve these goals, she advocates for consistent global policies and regulations that encourage sustainable practices in aviation.

3.3.2. Zero net CO2 emissions by 2050

The goal of net zero carbon emissions by 2050 is an all-or-nothing fight against climate change. It will need global proficiency in key areas such as energy, transport, agriculture, and industry («Cero emisiones netas de CO2 en 2050», s. f.).

Goals include reducing energy carbon emissions, boosting transportation, achieving maximum energy efficiency, sustainably managing agriculture and forests, and transforming innovation and developing technology, among others. Cooperation and compromise between different actors, as well as effective statesmen and international actors, are essential for cooperation.

3.3.3. CORSIA

Carbon Offset and Reduction Scheme for International Aviation is a program initiated by the International Civil Aviation Organization (ICAO) to reduce carbon dioxide emissions from international aviation (Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), n.d.).

The goal is to achieve carbon-neutral growth through the purchase of Certified Emission Reduction Units (ERUs) to offset excess emissions. CORSIA has several phases, the first being voluntary and the second being mandatory for states above certain air traffic thresholds.

Airlines covered by CORSIA must offset their emissions by purchasing ERUs from emissions reduction programs. The program sets standards and guidelines to ensure the quality of URE and has a monitoring and compliance system. CORSIA promotes the environmental sustainability of international aviation and encourages collaboration among stakeholders.

3.3.4. Turespaña's Strategic Marketing Plan

The Spanish Tourism Institute has proposed 'Turespaña's Strategic Marketing Plan' which outlines the strategic orientations for Turespaña's activities for the period of 2021-2024 (Instituto de Turismo de España & Ministerio de Industria, Comercio y Turismo, 2022).

Spain was a leading tourist destination prior to the pandemic, but had weaknesses such as territorial, temporal, and motivational concentration and a problem with its image associated with overcrowding and lack of sustainability in some destinations.

The plan has two main objectives, the first being to recover quality international tourism demand in the shorter term, and the second to identify and attract a more profitable tourist who contributes to the sustainability of the destination in the longer term.

It also includes other campaigns 'You Deserve Spain' 2022 launched by The Spanish Government, aimed at maintaining Spain's leadership as a holiday destination, by appealing to positive emotions and unique vacation experiences (Gobierno de España & OACI, s. f.).

3.3.5. Integrated National Energy and Climate Plan

The Integrated National Energy and Climate Plan (PNEC) of Spain outlines the country's objectives, policies, and measures to achieve its commitment to reduce greenhouse gas emissions and promote renewable energy sources (*Integrated National Energy and Climate Plan 2021-2030 - Climate Change Laws of the World*, s. f.).

The plan has a horizon of 2030 and aims to reduce GHG emissions by at least 20% compared to 1990 levels. In the transport sector, the PNEC sets targets and measures to reduce emissions, including the promotion of low-emission transport modes, cleaner fuels, and energy-efficient vehicles.

Sustainable tourism practices and the development of alternative modes of transportation to air travel, such as high-speed rail, are also emphasized. The PNEC also includes specific targets and measures related to the aviation sector, such as the development of a sustainable aviation fuels market, the promotion of electric and hybrid aircraft, and the improvement of air traffic management systems.

3.3.6. Spanish Circular Economy Strategy

The Spanish Circular Economy Strategy was approved in 2018 to promote a circular economy model in Spain that reduces waste and minimizes environmental impacts (*Circular economy: definition, importance, and benefits | News | European Parliament*, 2015).

In the transport, tourism, and air traffic sectors, the strategy aims to promote sustainable practices, such as using low-emission transport modes, promoting circular materials, developing sustainable urban mobility solutions, managing airport waste using circular economy principles, and developing circular business models in the aviation sector. The strategy includes specific targets for waste reduction, eco-design, and circular business models in these sectors.

3.4. Sustainable Aviation's Strategies

According to the European Aviation Environment Report 2022, the path to decarbonisation of aviation requires a multifaceted approach. EAER 2022 focuses on five main areas where environmental protection can be improved (Informe Medioambiental Sobre La Aviación Europea 2022 - Análisis De Escenarios Históricos Y Futuros Sobre El Tráfico Aéreo, El Ruido Y Las Emisiones | EASA, 2022).

3.4.1. Technology and design

Over the last 10 years, new aircraft designs such as the Airbus A320neo, A350, Boeing 737MAX and 787 have been designed with noise tolerances below the latest Chapter 14 standards.

While certification activity for conventional aircraft has decreased, certification activity for drones and urban air mobility aircraft has increased. EASA develops noise certification standards specifically for these aircraft types.

Engine manufacturers are investigating how to reduce non-volatile particulate (nvPM) emissions in new engine designs. Engine emissions and aircraft noise/CO₂ standards define the scope for dealing with noise, air quality and climate change. The Pipistrel Velis Electro became the first all-electric aircraft certified by EASA in 2020, while the Airbus A330-900neo was the first globally certified under the new aircraft CO₂ emissions standard in 2021, although certified CO₂ data remains limited.

3.4.2. Sustainable Aviation Fuels (CAS)

Currently, Sustainable Aviation Fuels (SAF) make up an insignificant fraction of the total aviation fuel consumption in the EU, amounting to less than 0.05%. In order to combat this issue, the European Commission has proposed a mandate for SAF blending at EU airports. According to the proposal, the minimum percentage of SAF used would gradually rise from 2% in 2025 to a significant 63% in 2050.

Meeting the mandate would require the aviation industry to procure about 2.3 million tonnes of SAF by 2030, followed by 14.8 million tonnes by 2040 and 28.6 million tonnes by 2050.

The implementation of drop-in SAF is a critical component in the endeavor to reduce carbon emissions in the aviation industry. Its importance lies in the fact that it can be readily utilized with existing aircraft fleets and fuel infrastructure. Currently, SAF that has been certified is able to be mixed with fossil-based jet fuel up to a maximum of 50%. However, there are ongoing conversations regarding the possibility of SAF being used at 100% capacity by the year 2030.

At present, it is true that SAF (sustainable aviation fuel) is more costly than jet fuel derived from fossil fuels. However, as production of SAF increases and reaches greater economies of scale, it is anticipated that cost savings will occur. The pricing of SAF is dependent on various factors, such as the method of production, the associated expenses, and the fluctuations of the energy market.

3.4.3. Air Traffic Management (ATM) and Airlines

The European Green Deal requires a comprehensive and collaborative approach to achieve greener operations in the short term. The estimated amount of extra fuel burned on flights in the Network Manager region was between 8.6% and 11.2% in 2019. The European ATM Plan of Action aims to reduce the average CO₂ emission per flight by 5-10% by 2035 compared to 2017.

However, the goal of the Single European Sky (SES) in environmental performance was not achieved during the Reference Period 2 (2015-2019). Despite some success in 2020, certain Member States still failed to meet their environmental goals due to the pandemic's effects on air travel. The current indicator of flight route-related performance needs to be re-examined in order to consider the actual amount of CO₂ released.

The improvements in efficiency that were observed in 2020 should be maintained through "green" principles of recovery, such as utilizing dynamic air space limitations and optimized flight planning. The practice of storing fuel in the tanks of ECAC flights led to savings for the airlines, however, this resulted in an unnecessary consumption of 286,000 tons of fuel in 2018.

3.4.4. Airports

The Environmental Portal was introduced by EASA in 2020, which allows for the sharing of Aircraft Noise Certificate data alongside the ANP Database for Aircraft Noise and Performance data. Roughly 50% of operations in Europe adhered to the most recent Chapter 14 noise standard in that same year.

However, the approval and implementation of Performance Based Navigation transition plans have been delayed, creating obstacles in achieving environmental advantages. As the aviation industry adapts to environmental challenges and develops new markets, airport infrastructure must also adapt accordingly.

By 2030, the Zero Pollution Action Plan of the European Green Deal aims to reduce the number of people who are chronically disturbed by transport noise by 30% and enhance air quality, decreasing premature deaths caused by air pollution by 55% compared to 2017.

3.4.5. Market-based Instruments (MBM)

The EU Emissions Trading System (EU ETS) led to a decrease of 159 million tons of CO₂ emissions in the aviation industry from 2013-2020. CORSIA, the international scheme for offsetting, saw an increase in participation with 107 states participating in 2022.

The rules of accounting were stipulated to prevent the double counting of emission reductions under CORSIA and the Paris Accord. International cooperation and EU-sponsored actions have augmented environmental protection efforts. Discussions are ongoing in Europe regarding additional carbon pricing in the aviation sector.

4. Conclusions

- I. Transportation, particularly aviation, is a significant contributor to global carbon dioxide emissions, accounting for approximately 24% of total emissions and about one-fifth of all emissions worldwide. The tourism industry, heavily reliant on air travel, faces a challenge in addressing greenhouse gas emissions associated with aviation. Governments have introduced emission permit trading options for the aviation industry, but the impact of these policies on tourism and the environment remains uncertain.
- II. Sustainable tourism is essential to balance economic growth with environmental preservation, and governments of tourism-oriented countries must prioritize both innovative tourism-led growth and sustainable tourism through decarbonization and supportive policies. Tourism demand estimation and forecasting should consider not only economic factors but also factors related to utility theory, tourists' preferences, and the attributes of available alternatives.
- III. The "flight shame" movement, known as "Flygskam" in Sweden, has gained popularity, encouraging individuals to avoid air travel due to its significant carbon emissions. The movement has resulted in concrete reductions in air travel, with some airports experiencing decreased passenger numbers, while train operators have seen increased passengers.
- IV. Factors such as extreme weather events, climate change concerns, air quality, natural disasters, and personal values can influence individuals' decisions not to travel by plane.
- V. Spain, as a popular tourist destination, has recognized the importance of sustainable tourism and implemented regulations and policies to ensure proper functioning of transportation systems and environmental protection.
- VI. The International Civil Aviation Organization (ICAO) and national governments are working on global aviation standards and initiatives to minimize the adverse environmental effects of civil aviation and promote sustainable practices.
- VII. France has approved a ban on short-haul domestic continental flights that can be completed by train in less than 2.5 hours, aiming to reduce air travel and promote more sustainable transportation options.
- VIII. Island tourism in Spain, particularly in the Balearic and Canary Islands, heavily relies on air transport due to limited maritime connections. Despite the slightly lower emissions of maritime transport, tourists still prefer air travel due to factors like journey length and price.

- IX. Initiatives such as Waypoint 2050 and CORSIA aim to make aviation carbon neutral by 2050, promoting the development of cleaner technologies and the purchase of certified emission reduction units to offset excess emissions.
- X. The strategic orientations outlined in Turespaña's Strategic Marketing Plan emphasize the importance of sustainable tourism and the preservation of the environment in Spain's tourism activities.
- XI. These conclusions highlight the significant impact of transportation, particularly aviation, on greenhouse gas emissions and the urgent need for sustainable practices and policies in the tourism industry. They also emphasize the role of individual choices, government regulations, and international cooperation in achieving a more sustainable and environmentally friendly approach to travel and tourism.



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DOCUMENT 2.

Air Transport and High-Speed Rail

AIR TRAFFIC AND SUSTAINABILITY
CONSTRAINTS AND PARADIGMS:
A COMPREHENSIVE STUDY ON THE EFFECTS ON SPANISH
TOURISM AND THE ROLE OF HIGH-SPEED TRAINS

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Peter Vittek

José María Mateu Céspedes

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Document 2. Air Transport and High-Speed Rail

1. Previous Considerations

In the field of transportation, both air travel and bullet trains have proven to be popular and efficient options for long-distance travel. In this study, we will examine and compare air transport and high-speed trains, analyzing their features, advantages, and limitations to understand the pros and cons of both.

1.1. Introduction

Many experts argue that the advancement of high-speed passenger rail service is a promising solution for reducing carbon emissions and a substitute for intercity air travel. Previous studies conducted in Europe that explored the effects of high-speed trains on air travel predominantly focused on market share for specific city pairs, analyzed primarily through travel time and price (Clewlow et al., 2014).

However, there has been minimal attention given to the overall reduction of short-haul air travel demand due to high-speed trains or the possible consequences of high-speed rail on system-wide air travel demand.

While it is true that faster rail travel has caused a decrease in short-haul air travel, the specific characteristics of cities and airports play a critical role in determining the extent to which air and rail travel are substituted for each other.

1.2. Purpose

This article focuses on the situation of high-speed trains in Spain. In addition, the role of trains in achieving more sustainable transport will be analyzed, as well as how it affects passenger flows in air transport and the economic strength of Spain.

To achieve more sustainable aviation and transport, examine how these two modes of transport can coexist in the Spanish tourism industry.

The findings have important implications for future transport and energy policy as attention grows to the impact of transport on climate.

1.3. Coverage

For this purpose, after having analyzed the rail transport infrastructure in Spain and its role in the country's tourism, we will analyze how some regulations may force rail transport to replace air transport.

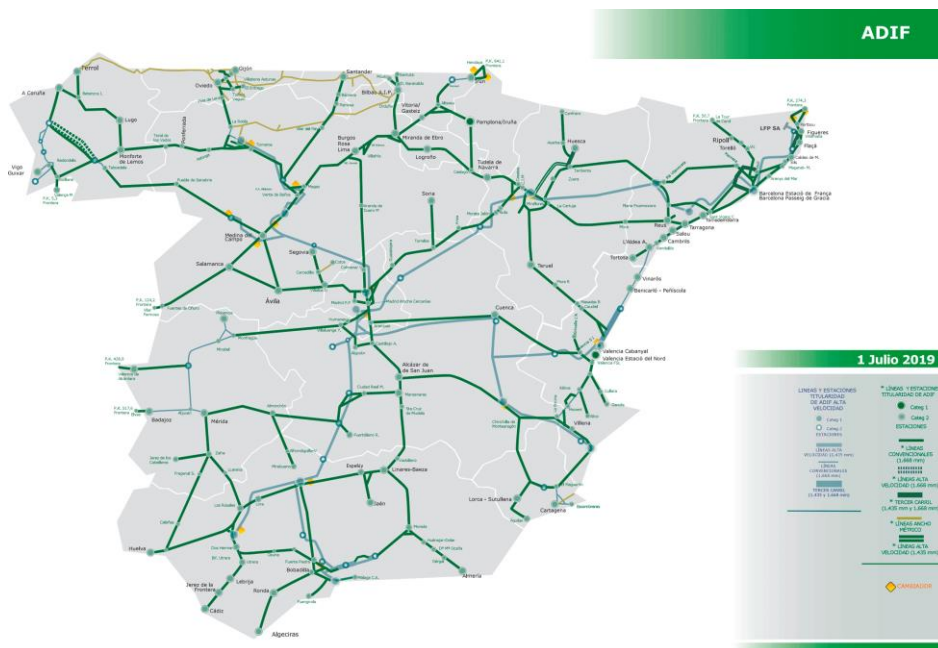
In addition, we will study the benefits of the use of rail transport in domestic and international tourism, as well as its limitations, comparing it with the performance of civil tourism in Spain.

2. High-Speed Rail Transport in Spain

2.1. Railway Network in Spain

In 2019 ("Annual Report of the Railway Sector 2019," 2021), the railway structure in Spain was 15,392 km long, of which 15,372 km belonged to ADIF and ADIF-AV (Railway Infrastructure Administrator). Out of the total kilometers of network managed by ADIF and ADIF-AV, 62.6% is single-track and 36.3% is not electrified. Furthermore, only 19% corresponds to international UIC gauge (2,890 km).

Figure 1. Railway Structure in Spain (ADIF)



73% of the RFIG network (11,272 km) is used by both passenger and freight services. 21% is exclusively used by passenger services (3,299 km), and 2% is dedicated solely to freight services (355 km). 3% of the network does not have any transport service (446 km).

In terms of the relationship between the recorded activity in each corridor and its current capacity, the most jointly used corridors for both passengers and freight are the Madrid-Barcelona, the Madrid-Irún/Hendaya, Madrid-Valencia, Alcázar de San Juan-Cádiz, Zaragoza-Bilbao, and the Venta de Baños-Gijón.

According to ADIF's capacity data from December 2019, these corridors have saturation indices ranging from 27% to 47%. Breaking down the activity by the main lines, the following distribution is obtained:

Table 1. Main Rail Lines in Spain (2019)

<i>Start of line-end of line</i>	<i>Length</i>	<i>Train.km passengers</i>
<i>Madrid-Límite LFP (AV)</i>	752	16.742.047
<i>Madrid-Sevilla (AV)</i>	470	15.766.666
<i>Madrid-Barcelona</i>	700	11.415.705
<i>Madrid-Irún/Hendaya (Francia)</i>	639	10.374.742
<i>Madrid-Valencia</i>	489	9.751.292
<i>Alcázar de San Juan-Cádiz</i>	576	7.538.817
<i>Valencia-Sant Vicenç Calders</i>	285	6.895.159
<i>Bif. Torrejón de Velasco-Valencia (AV)</i>	361	5.979.171
<i>Casetas/Zaragoza-Abando/Bilbao</i>	327	3.416.570
<i>Venta de Baños-Gijón</i>	306	3.481.732
<i>Bifurcación Sagrera-Port Bou</i>	164	4.379.981
<i>Lleida-Barcelona-L'Hospitalet</i>	190	4.444.774
<i>Madrid-Venta de Baños (AV)</i>	216	4.317.187

Data regarding the amount of revenue from passenger services and train-kilometers performed shows a 2.8% increase in passenger services compared to the previous year.

Table 2. Revenue and train-kilometers (2019)

<i>Service</i>	<i>Royalty Income</i>	<i>Train.km</i>	<i>Euro/Train.km (2019)</i>
<i>Passengers</i>	1.109.637.816 €	171.205.866	6,48

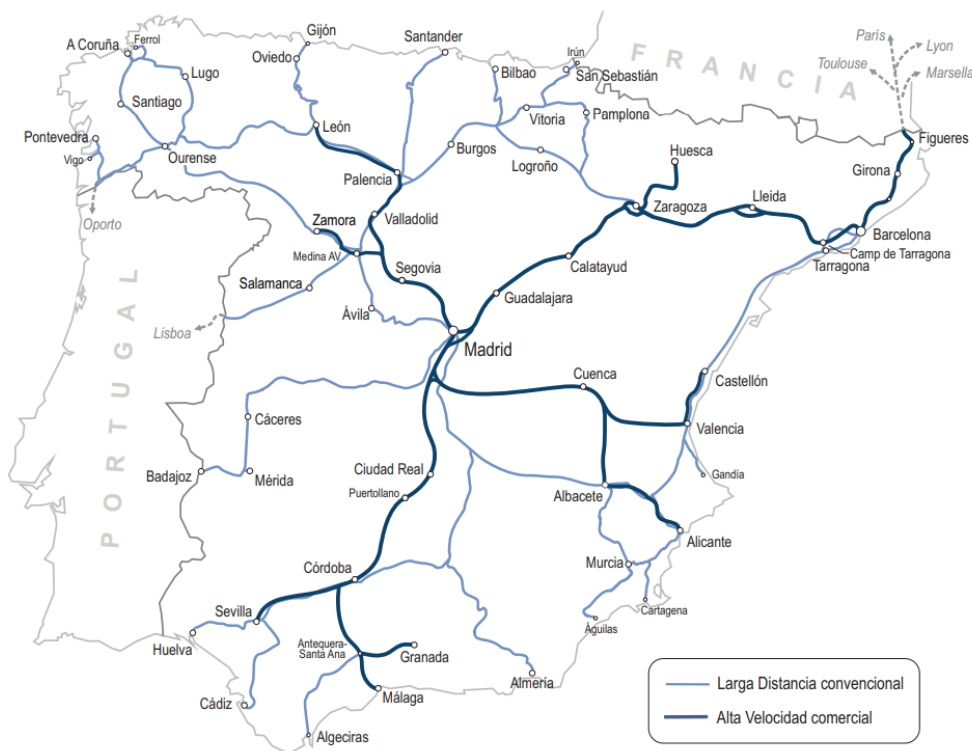
2.1.1. Long-Distance Passenger Transportation

Within this section, a distinction will be made between high-speed transport, where the maximum train speed exceeds 200 km/h, and conventional long-distance transport, where the maximum train speed is equal to or less than 200 km/h ("2019 Report. Railway Observatory in Spain," 2020).

Only Renfe-Viajeros operates long-distance traffic in Spain. The long-distance transport service in Spain operates on a network of 8,438.3 kilometers of track, which represents 59.1% of the Adif network.

This traffic in 2019 takes place in 2019 stations. In the following image obtained from the Government of Spain, we can visualize the lines with commercial services for conventional long-distance and high-speed transport.

Figure 2. Commercial Lines for Long distance and High-Speed Transport (2019)



The total number of passengers transported in long-distance and commercial high-speed services in 2019 was 34.52 million, with a variation of +2.7% compared to 2018. Similarly, passenger-kilometer transport also showed clearly positive figures with 15,674 million.

The five stations with the highest traffic of commercial high-speed and conventional long-distance passengers in 2019 are listed in the following table.

Table 3. Highest Traffic's Stations for High-Speed and Long-Distance (2019)

2019	Passenger
Madrid-P. Atocha	19.863.769
Barcelona-Sants	9.810.950
Madrid-Chamartín	3.976.224
Valencia-J.Sorolla	3.936.910
Sevilla-Santa Justa	3.863.101

The cities that have the highest number of passengers boarding and alighting in 2019 are:

Table 4. Main Cities boarding in 2019

City	Passenger
Madrid	24.320.098

<i>Barcelona</i>	9.840.923
<i>Valencia</i>	4.670.662
<i>Sevilla</i>	3.863.101
<i>Zaragoza</i>	3.174.627

In 2019, the traffic revenue was 1,503.5 million euros. The revenue per passenger was 43.55 euros, and the average price per passenger was 47.91 euros. The total number of commercial train services reached 121,558, covering a total distance of 62.63 million train-kilometers.

Regarding occupancy and utilization, in 2019, the occupancy rate was 89.88%. The average number of passengers per train reflects the average number of passengers who use each train throughout its journey, as not all passengers travel the entire distance by train. In 2019, the average was 250.3 passengers per train.

The most frequented long-distance origin-destination route in 2019 was Madrid - Barcelona, with over 4 million passengers.

Table 5. Most Frequented long-distance routes (2019)

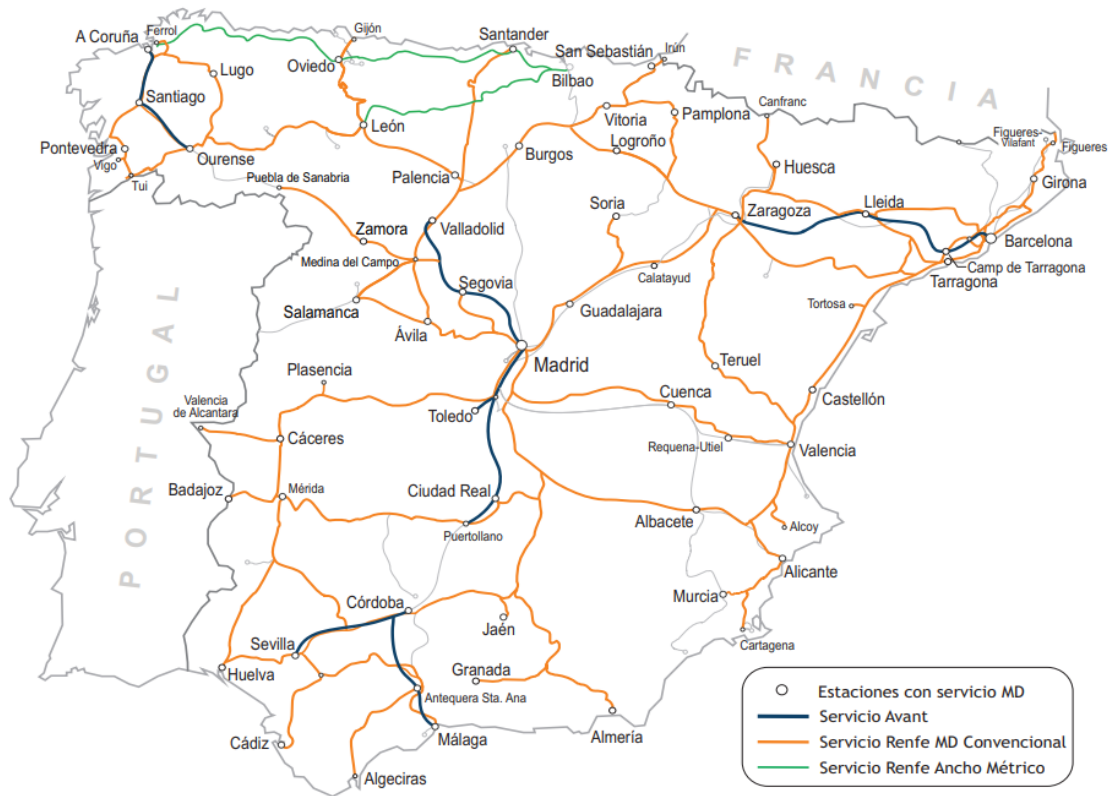
<i>Source</i>	<i>Destination</i>	<i>Passenger</i>
<i>Madrid</i>	<i>Barcelona</i>	4.446.659
<i>Madrid</i>	<i>Sevilla</i>	2.850.540
<i>Madrid</i>	<i>Valencia</i>	2.703.460
<i>Madrid</i>	<i>Málaga</i>	1.991.968
<i>Madrid</i>	<i>Zaragoza</i>	1.548.584

2.1.2. Medium-Distance Passenger Transportation

Medium-distance high-speed services are considered those in which the maximum train speed is equal to or exceeds 200 km/h, while conventional medium-distance services refer to those with a maximum train speed below 200 km/h ("2019 Report. Railway Observatory in Spain," 2020).

At the end of 2019, Renfe's medium-distance passenger service operated on a network of 11,655 kilometers of lines, which represented 75.8% of the total length of the Adif network. In the same year, this traffic served 770 stations. The following map, created by the Government of Spain, shows the lines with medium-distance services in 2019.

Figure 3. Commercial Lines for Medium-Distance (2019)



In 2019, the number of passengers using medium-distance services was 33.1 million, representing an increase of 0.8% compared to 2018. Similarly, the total passenger-kilometers for medium-distance transport amounted to 2,157 million.

Out of the 770 stations that offer medium-distance services in the Adif network, the top 30 stations account for 65.3% of the total passenger traffic for this type of service. The following table lists the top 5 stations with the highest passenger flow.

Table 6. Highest Passenger Flow's Stations (2019)

2019	Passenger
Barcelona-Sants	5.674.805
Girona	3.448.258
Madrid-P. Atocha	2.838.907
Madrid-Chamartín	2.548.717
Sevilla-Santa Justa	2.472.591

In 2019, the five cities that recorded a higher volume of medium-distance traffic are as observed in the table.

Table 7. Higher Volume's Cities for Medium-Distance Traffic (2019)

City	Passenger
Barcelona	7.989.558
Madrid	6.339.588
Girona	3.448.258
Sevilla	3.061.613
Córdoba	3.027.665

The traffic revenue amounted to 271.5 million euros, with an average net commercial revenue per passenger of 8.11 euros.

The overall service capacity for medium-distance services in 2019 was 10,122 million seat-kilometers. The commercial utilization of this type of service was 31.8%.

The medium-distance routes with the highest passenger flow in 2019 (in both directions) are listed in the following table.

Table 8. Medium-Distance Routes (2019)

Routes	2019
Barcelona - Girona	2.055.212
Madrid - Toledo	1.828.514
Madrid - Valladolid	1.527.893
Barcelona - Tarragona	1.244.729
A Coruña - Santiago	1.187.327

2.1.3. Domestic Connections

Based on statistics from Renfe and other partners, Eurail (Spain by Train, n.d.) provides information about the most popular and frequented routes in Spain for both domestic and international passenger tourism.

Table 9. Domestic Connections

Route	Kind of Train	Duration (hours)
Barcelona to Madrid	AVE high-speed train	2,30
Barcelona to Málaga	AVE high-speed train	2,30
Madrid to Granada	Altaia high-speed train	3,30
Madrid to Valencia	AVE high-speed train	1,50
Madrid to Santiago de Compostela	Alvia high-speed train	3,15
Madrid to Seville	AVE high-speed train	2,30
Barcelona to Valencia	Euromed high-speed train	2,50
Madrid to Irun	Alvia high-speed train	5,50

2.1.4. International Connections

Table 10. International Connections

<i>Route</i>	<i>Kind of Train</i>	<i>Duration (hours)</i>
<i>Barcelona to Paris</i>	SNCF	2,30
<i>Vigo to Porto</i>	Celta	2,30
<i>Madrid to Lisbon</i>	IC + RE +IC	3,30
<i>Madrid to Porto (via Badajoz)</i>	IC + RE +IC	1,50
<i>Madrid to Porto (via Vigo)</i>	ALV + RE +IC	3,15

2.1.5. Power Economic

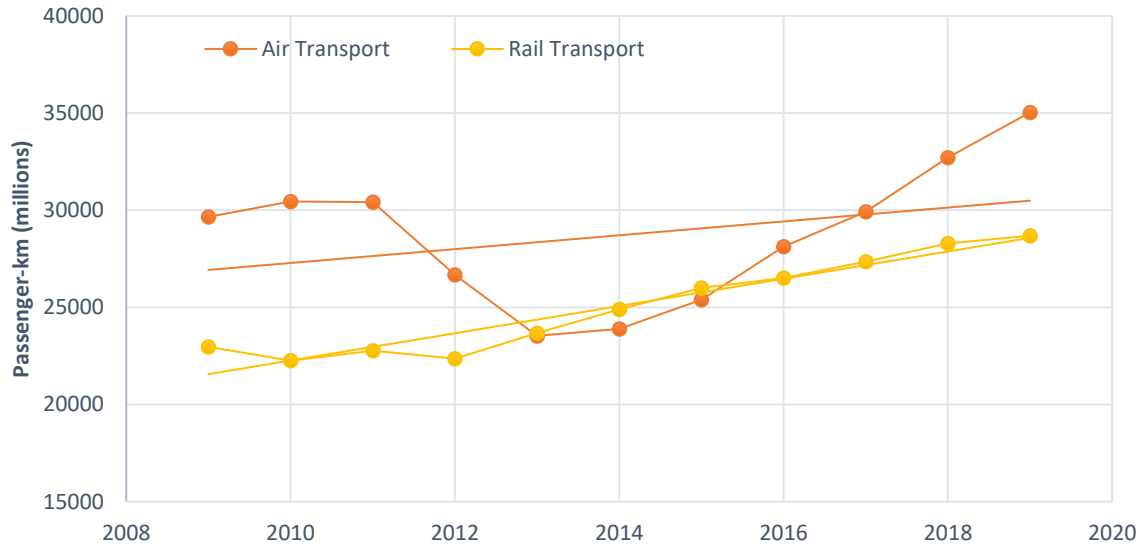
The total revenue in rail transport increased by 80.06 million euros between 2017 and 2018. During the same period, there was a 99.26 million euro increase in revenue for urban passenger transport. As for interurban passenger transport, it exceeded 1,500 million euros.

Data on average expenditure in euros per household for public transport, according to the Family Budget Survey (INE, December 2020), shows an average expenditure of 82.09 euros per household and 32.98 euros per person.

3. Air and Rail Transport Analysis

Both modes of transport, air and rail, have experienced an increase over the past few years (*Consulta BD OTLE: Transporte Interior De Viajeros (Viajeros-kilómetro) Por Modo, n.d.*).

Figure 4. Passenger-km Evolution by mode of Transport



While many nations dismiss the notion of utilizing trains instead of planes for domestic travel, in Spain, opting for trains over planes is a rational decision. Spain has made significant investments in its infrastructure over the last 25 years. This includes the development of a high-speed rail system that links all the prominent cities in the country (Finlay, 2019).

Spain boasts an extensive high-speed rail network known as AVE, comprised of 3,100 kilometers (or 1,926.25 miles) of track with ongoing construction. This system has propelled Spain into a position of global prominence in terms of high-speed track per capita.

It's difficult to fathom that train travel can be faster than air travel between cities until you have experienced the speed of a high-speed bullet train. When you factor in airport transportation and the time spent going through security, the reality of traveling at speeds of 300kph (186.4mph) on trains in Spain is truly remarkable.

Using Barcelona-Madrid route as the example, the time to travel from the city center to the city center by AVE is 2hr 30min, this takes just over an hour. However, when you consider the time required to travel to the airport via train, security, and other aspects, the train is ultimately more advantageous.

Recognizing that the train was detrimental to their business, Spanish airline Iberia has reduced the number of flights in their Madrid-Barcelona-Madrid line by making them more similar to a bus service. Now, you can board the plane immediately upon arriving at the airport.

3.1. Air and Rail Traffic Connections

As far as travel within the peninsula is concerned, stopovers between two cities are often necessary, similar to what happens in air travel (Finlay, 2019).

In the case of traveling from Valencia, in the southeast, to Bilbao, in the north, it will be necessary to transfer in Madrid, which implies a total travel time of eight hours. However, it is possible to fly between the two cities in only one hour and a quarter.

Another case in which the plane outperforms the train is the journey from Alicante to Seville. From the center of Alicante, it takes approximately 20 minutes by bus to reach the airport. The flight to Seville takes one hour and adding another 15 minutes by bus to the city center, the total travel time is one hour and thirty-five minutes. If you add two hours to get to Alicante airport in good time and deal with the corresponding formalities, the total travel time extends to 3 hours and 35 minutes. On the other hand, the same trip by train would take 5 hours and 36 minutes and would involve changing trains in Cuenca.

KLM, the national airline of the Netherlands, has decided to eliminate a flight route and replace it with a train service. In collaboration with railway companies in Belgium, France, and the Netherlands, KLM will transport passengers from Brussels to Amsterdam's Schiphol Airport via train.

Presently, KLM runs a total of five daily flights that connect the Belgian capital to Amsterdam. However, beginning March, this frequency will be decreased to only four, and presumably, it could be entirely eliminated. KLM has labeled this as an initiative that falls under their "Fly Responsibly" campaign, which emphasizes the ecological advantages of opting for train travel over flying. The fact that discontinuing short-haul routes at Schiphol Airport creates additional capacity for long-haul flights is often omitted by critics.

3.2. Economic Determinants

The adoption of sustainable policies and paradigms that encourage the substitution of rail transport with air transport could potentially lead to various economic impacts on Spanish tourism.

In the event that rail transport becomes a more cost-effective and environmentally conscious alternative, there is a likelihood that certain travelers will choose to utilize trains instead of airplanes when traveling within Spain.

In addition, train travel in Spain is becoming less expensive (Finlay, 2019). After studying the business plans of low-cost airlines, Spain's national rail operator, Renfe, introduced what could be called "Ryanair on rails" in 2019.

The trains, called EVA instead of AVE, run between Madrid and Barcelona, and while still as fast as AVE, have more seats and fewer services. Instead of the standard 2-2 seating arrangement, EVA trains feature one additional seat per row in a 3-2 configuration. In addition, the trains will eliminate the bar and cafeteria in favor of vending machines. Tickets for the new EVA trains will cost 25% less than current fares, bringing a one-way ticket between Madrid and Barcelona to €65.

3.3. Train & Fly

"Train and Fly" is a collaboration between the Spanish airline Iberia and the railroad company Renfe (Combina Tren, n.d.), which offers passengers the possibility of combining flights and train travel as part of the same itinerary.

Through this service, passengers can book a single ticket that includes both the Iberia flight and the Renfe train ride, allowing them to travel in an integrated manner and facilitating the connection between the two modes of transport.

The "Train and Fly" option offers connections from 14 domestic Renfe destinations (Zaragoza, Seville, Malaga, Cordoba, Valladolid, Valencia, Alicante, Leon, Palencia, Pamplona, Salamanca, Albacete, Zamora and Ourense) to Iberia's international flight network and its numerous destinations in Europe, Africa, the Middle East and America, via Madrid.

The viability of regional airports is put at risk by this, as the route to Madrid can make up to 73% of their annual traffic, as seen in the case of Pamplona.

Cities near the capital without air connections to Barajas Airport, like Albacete, Zamora, Valladolid, and León, are improving their connectivity, while other cities with direct connections to Madrid, such as Pamplona and Santiago de Compostela, are concerned about losing Iberia flights, as Ourense, Galicia's high-speed train gateway, is not part of this project.

Table 11. Airports Potentially Affected by the Agreement

Airport	Pamplona	Santiago	Sevilla	Valencia	Alicante	Málaga
Total Passengers	243.498	2.904.102	7.519.500	8.539.579	15.948.240	19.858.656
Passengers affected	177.551	722.281	481.424	339.209	299.927	356.867
Percentage of total	72,92%	24,87%	6,40%	3,97%	1,99%	1,8%

There is an argument (Gómez, 2022) that air connections of this type tend to result in economic losses but are still in operation to cater to passengers who need to travel for long-haul flights, especially those bound for Latin America, as it is a natural market for Spain.

4. Environmental Sustainability

The transport sector accounts for 31% of total CO₂ emissions in EU countries (2014). Automobiles and other means of transport accounted for the largest share (73.4%), followed by air transport (12.6%) and sea transport (10.6%). The rail sector accounts for only 1.6% of total transport sector emissions (*A Guide to Sustainable Travel*, n.d.).

In reference to rail transport, diesel consumption in 2019 experienced a decrease of 1.5% compared to 2018. On the other hand, energy consumption for electric traction saw an increase of 1.2%. It is worth noting that passenger transport recorded a growth of 1.05%. Overall, passenger consumption accounted for 9,614.2 TJ (terajoules) in 2019 ("2019 Report. Railway Observatory in Spain," 2020).

Table 12. Power Consumption of Rail Transport

Power consumption	2018	2019
Diesel (TJ)	3.268,10	3.218,40
Electricity (TJ)	9.034,70	9.143,20
Total	12.302,80	12.361,60

The average energy consumption per train-kilometer, seat-kilometer, and passenger-kilometer in passenger transport corresponds to the data in the following table.

Table 13. Average Energy Consumption by Rail Transport

Average Energy Consumption	2018	2019
Consumption per train.km (kWh/train.km)	15,6	15,9
Consumption per seat.km (kWh/100 seat.km)	4,8	4,8
Consumption per passenger.km (kWh/100 passenger.km)	9,8	9,8

Based on the "Fly the Green Deal" report by the European Commission in 2022, the aviation industry is responsible for around 2-3% of all global CO₂ emissions and 4% of CO₂ emissions in Europe. To counter the effects of climate change, efforts are being made to lessen the carbon footprint of air travel through various methods.

These include enhancing the efficiency of flights as well as advocating for cleaner alternatives, wherever possible. With the development of high-speed rail networks in Europe, there is an opportunity to limit short-haul flights through the provision of an equally convenient alternative with door-to-door travel times.

4.1. Shift from air travel to rail as a solution to reduce CO2 Emissions

Commissioned by ACI Europe, A4E, ERA, ASD Europe and CANSO (Vilarasau, 2022), the short-haul flights and sustainable connectivity report examines greenhouse gas emissions from transport, with a focus on commercial aviation. The proposed decarbonization solution is to switch short-haul flights from air to rail by investing in rail infrastructure and limiting short-haul flights.

Although railways emit less CO₂ per passenger kilometer than flights, replacing short-haul flights by railways has limited benefits and comes with additional environmental, social and economic costs. Construction of new rail lines leads to CO₂ emissions from cement and steel production, with significant impacts on biodiversity and wildlife habitat identified.

On many short routes with infrequent flights or at airports without good rail connections, trains may not be economical due to the low-capacity utilization and speed of their business models. Furthermore, there is no guarantee that passengers will transfer from plane to train, which could lead to increased CO₂ emissions if they decide to travel by car.

The report highlights that the deployment of hybrid electric aircraft on regional routes will drive aviation decarbonization by 2030, resulting in a 50% reduction in emissions per flight in the sector. As the rail and aviation sectors continue to decarbonize, the gap between aviation and rail CO₂ emissions will continue to narrow.

It emphasizes the importance of regional airports and airlines to regional economic and social development by providing access to larger economic centers. These airports play a key role in the EU's cohesion policy and in reducing territorial and social inequalities.

4.2. Flygskam and Tagskyrt

Returning to the theme of "flygskam" (Magazine, 2020), let us analyze the case of the Madrid-Barcelona airlift in Spain. Undoubtedly, the case of the Madrid-Barcelona airlift is the best example of the energy and climate incoherence involved in the use of airplanes for short distances in Spain.

According to the Institute for Energy Diversification and Saving (IDAE), traveling by plane between the two cities involves emissions of approximately 192 grams of CO₂ per passenger per kilometer. In contrast, in the high-speed train (AVE) these emissions would be reduced to 23 grams, just over 10%. Despite this, around 2.5 million people uses the Madrid-Barcelona shuttle a year, not counting transit passengers.

Although there are approximately 29 daily trains covering this route, with travel times ranging from two and a half to three hours, the survival of the air bridge can only be understood by the non-existence of air fuel taxes and the aggressive pricing policies of the airlines.

In the midst of the growing awareness of the "Flyskam", there are especially the short trips that could be made in times similar to those of the train, but that in many occasions present deficient connections. This is how, parallel to the "flygskam", the concept of "tagskyrt" arises, which represents the pride of traveling by train and has achieved similar success (BuenaVida & BuenaVida, 2019).

4.3. Regulations: French Law Application

In order to extrapolate these regulations to Spain it is important to know in detail the applicable criteria (Nommon | Blog | Short-haul Flights in Spain: Is High-speed Rail an Alternative?, 2023):

- The rail connection, must be direct, without taking into account transshipments.
- The rail connection must have sufficient frequencies, as well as satisfactory timetables, so that more than 8 hours can be spent at both ends with a round trip within the day.
- If the busier of the two airports has a high-speed rail station, the travel time threshold applies to the connection between that station and the city station served by the other airport.

As mentioned above, Spain is one of the countries with the most extensive rail network, so it would be one of the best prepared countries for the replacement of short-haul flights by high-speed rail connections.

According to Nommon's study, the requirements would only be met for 4 connections in Spain, Madrid with Valencia, Alicante, Seville and Malaga.

Table 14. Summary of the Air Connections that could be replaced by High-Speed Train

Connection	% over total Domestic mainland air operations (2022)	Meet or not French Requirements	Reasons why is not meeting French Requirements
Madrid-Valencia	3,2	Yes	-
Madrid-Alicante	3,1	Yes	-
Madrid-Sevilla	2,1	Yes	-
Madrid-Málaga	3,8	Yes	-
Madrid-Barcelona	9,2	Almost	Travel time 2:30
Barcelona-Valencia	1,3	No	Travel time 2:47
Madrid-Castellón	0,0	No	Travel time 2:55
Madrid-Santiago	2,9	No	Travel time 3:00
Madrid-Pamplona	1,4	No	Travel time 3:05
Madrid-Logroño	0,3	No	Travel time 3:16
Madrid-Granada	1,4	No	Travel time 3:17

In these four cases, flight times are less than 2.5 hours, the schedules offered allow travelers to spend 8 hours at the destination and high frequencies are available. The Madrid-Barcelona connection, responsible for 9.2% of peninsular air operations in 2022, is right at the maximum travel time threshold: direct high-speed rail services offered by Renfe, Ouigo and Iryo take 2.5 hours to complete the journey between the two cities.

It should be noted that connections that do not comply with French law, such as: Madrid and the cities of Castellón, Santiago de Compostela, Pamplona, Logroño and Granada, and Barcelona-Valencia, have pending rail infrastructure improvements that will decrease travel times.

4.4. Sustainability Differences

To better understand the differences between the two modes of transport, a comparison will be made between the main international and domestic routes.

4.4.1. Domestic's Routes Analysis

During the first document, it was found that the two busiest airports in Spain are those of the cities of Barcelona and Madrid. Also, in domestic tourism, the main destination airports of Madrid and Barcelona were studied. Many of the routes cannot be made by rail transport as they are located on the islands.

Table 15. Main Domestic Routes by Airport

	<i>Routes</i>	<i>Can be done by train?</i>	<i>Duration (hours)</i>
<i>Madrid</i>	Ibiza	No	-
<i>Madrid</i>	Tenerife North	No	-
<i>Madrid</i>	Gran Canaria	No	-
<i>Madrid</i>	Palma de Mallorca	No	-
<i>Madrid</i>	Barcelona	Yes	2,30
<i>Barcelona</i>	Málaga	Yes	6,50
<i>Barcelona</i>	Sevilla	Yes	6,15
<i>Barcelona</i>	Ibiza	No	-
<i>Barcelona</i>	Mallorca	No	-
<i>Barcelona</i>	Madrid	Yes	2,30

With these data (Table 15) and those previously studied in Table 14, we will make a comparison between the routes by means of transport: rail and air.

Table 16. Comparison for Domestic Routes

<i>Routes</i>	<i>Duranton</i> <i>[hours]</i>	<i>Daily</i> <i>Availability</i> <i>[days]</i>	<i>Capacity (Per</i> <i>Operation)</i>	<i>Ticket Price</i> <i>[euros]</i>	<i>CO2</i> <i>Emissions</i> <i>Per Person</i> <i>[kg]</i>
<i>Madrid-Valencia</i>					
<i>Air transport</i>	2,49	6	100-187	24-103	81,00
<i>Rail transport</i>	1,55	2	347-720	35-55	9,60
<i>Madrid-Alicante</i>					
<i>Air transport</i>	1,20	6	100-204	23-92	96,00
<i>Rail transport</i>	2,23	4	345-509	45-65	12,50
<i>Madrid-Barcelona</i>					
<i>Air transport</i>	1,25	5	180-333	24-83	62,00
<i>Rail transport</i>	2,30	Hourly	320-347	45-75	17,20
<i>Barcelona-Sevilla</i>					
<i>Air transport</i>	1,45	5	189-218	22-93	71,00
<i>Rail transport</i>	6,15	2	320-347	75-110	18,70
<i>Barcelona-Málaga</i>					
<i>Air transport</i>	1,50	2	182-218	17-72	69,00
<i>Rail transport</i>	6,15	1	320-347	80-120	30,20

As can be seen in Table 16, air transport is more accessible and faster.

Although there is not a great difference in capacity and ticket prices are quite similar, there is a big difference in CO2 emissions per person.

In the first three routes (Madrid-Valencia, Madrid-Alicante, and Madrid-Barcelona) it is more feasible and efficient to choose rail transport, while in the Barcelona-Seville and Barcelona-Malaga routes the journey time when using the train is greatly increased.

4.4.2. International's Routes Analysis

In the same way, the main international routes for Madrid and Barcelona:

Tabla 17. Main International Routes by Airport

<i>Routes</i>	<i>Can be done by train?</i>	<i>How many Trains?</i>	<i>Durantion (hours)</i>	
<i>Madrid</i>	Milán	Yes	4	16,11
<i>Madrid</i>	Lisboa	Yes	3	9,45
<i>Madrid</i>	Roma	Yes	5	17,29
<i>Madrid</i>	Paris	Yes	2	10,15
<i>Madrid</i>	Londres	Yes	3	13,45
<i>Barcelona</i>	Milan	Yes	3	11
<i>Barcelona</i>	Amsterdam	Yes	2 or 3	13,34
<i>Barcelona</i>	Roma	Yes	4	14,3
<i>Barcelona</i>	Paris	Yes	1	4,00
<i>Barcelona</i>	London	Yes	2	10,15

As it can be seen in the Table 17, most international routes require more than one train and too many hours of travel time.

The Barcelona-Paris route can be highlight, which allows a direct route and despite being more than three times longer, the CO2 emissions are much less. Allowing a large flow of tourists between France and Spain.

Tabla 18. Comparasion for International Routes

<i>Routes</i>	<i>Durantion [hours]</i>	<i>Daily Availability [days]</i>	<i>Capacity (Per Operation)</i>	<i>Ticket Price [euros]</i>	<i>CO2 Emissions Per Person [kg]</i>
<i>París-Barcelona</i>					
<i>Air transport</i>	1,3	6	100-187	24-103	81,00
<i>Rail transport</i>	4	2	347-720	35-55	9,60

5. Conclusions

- I. In terms of network use, 73% of the total length of the network, or 11,272 kilometers, was utilized by both passenger and freight transportation services. Passenger services accounted for 21% of the network, or 3,299 kilometers, while freight services exclusively used 2% of the network, which equates to 355 kilometers.
- II. The corridors that saw the highest frequency of use for both passenger and freight transportation were Madrid-Barcelona, Madrid-Irún/Hendaya, Madrid-Valencia, Alcázar de San Juan-Cádiz, Zaragoza-Bilbao, and Venta de Baños-Gijón.
- III. Renfe-Viajeros was responsible for managing long-distance travel across 8,438.3 kilometers of track in Spain. Last year, in 2019, a total of 34.52 million passengers were transported via long-distance and commercial high-speed services, resulting in a 2.7% increase from 2018. The route between Madrid and Barcelona had the highest number of passengers.
- IV. In the year 2019, the revenue generated by rail transport from traffic amounted to 1,503.5 million euros. The average occupancy rate was 89.88%, with each train carrying an average of 250.3 passengers.
- V. In Spain, choosing to travel by train, particularly via high-speed rail, is increasingly being viewed as a cheaper and eco-friendlier alternative to air travel. The establishment of high-speed rail networks has also led to the availability of quicker and more convenient modes of transportation, thereby diminishing the necessity for short-haul flights.
- VI. Programs such as "Train and Fly" allow travelers to seamlessly integrate train travel and flights into a single itinerary, offering smooth and integrated connections between these two modes of transportation.
- VII. Compared to air travel, rail transport is responsible for significantly less CO2 emissions per passenger kilometer. In order to combat the issue of carbon emissions, there are ongoing endeavors to decarbonize both the aviation and rail industries. These efforts include the investment in rail infrastructure and the creation of hybrid electric aircrafts that will be utilized for regional flights.
- VIII. The replacement of brief air travel with rail transportation may have economic consequences for the tourism industry in Spain. Regional airports that rely heavily on flights to Madrid may encounter difficulties, while cities that lack air connections to major airports are enhancing their connectivity through the use of railways.
- IX. One of the most heavily traversed long-distance routes within Spain is the Madrid-Barcelona route, with a staggering 4 million passengers. The AVE high-speed train provides a convenient mode of transportation between Madrid and Barcelona, offering an estimated travel time of around 2.5 hours. In fact, when accounting for travel to and from airports, security measures, and other related factors, the train journey can be just as speedy if not quicker than air travel.

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