UNIVERSIDADE DA BEIRA INTERIOR
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SPANISH AIRPORTS PERFORMANCE AND EFFICIENCY BENCHMARK
A PESA-AGB STUDY

(Versão Corrigida Após Defesa)

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Dedicatory

To my mother and all the people of Guadalix, without their support, love, and encouragement, I would not have been able to finish my studies, and for that, I am very grateful.

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Abstract

Spanish air transportation system is growing annually. In 2018, Spanish Airports belonging to AENA transported 263,753,406 passengers and compared to 2017 increased by 5.8%. For these reasons, it is essential to maintain high levels of quality and improve airports performance and efficiency to address such demand. Through this study, performance and efficiency improvements are sought within several airport key areas such as Core, Safety and Security, Quality Service, Productivity and Effectiveness, Financial, and Environment. This study uses an MCDA tool to analyse and improves Spanish airports performance and efficiency. Thus, a holistic study using MACBETH (with PESA-AGB) is used.

For the choice of airports, we have divided Spain into four quadrants, and for each quadrant, we have selected an airport: Adolfo Suárez Madrid - Barajas, Josep Tarradellas Barcelona - El Prat, Valencia, and Sevilla. The choice of these four airports is because AENA is a centralised organisation and therefore, for our study to be real, there must be large and small airports.

The purpose of this study is to have a vision about the performance and efficiency external (Peer-Benchmarking) and internal (Self-Benchmarking) of these airports, analyse the results and propose improvement measures. As far as is known, this study has never been applied before in Spanish airports.

Keywords: Spanish Airports, Benchmarking, MCDA-MACBETH, Airport Performance, Airport Efficiency.

Resumo

O sistema de transporte aéreo espanhol está crescendo anualmente. Em 2018, os aeroportos espanhóis pertencentes à AENA transportaram 263.753.406 passageiros e, em comparação com 2017, aumentaram 5,8%. Por essa razão, é importante manter altos níveis de qualidade e melhorar o desempenho e eficiência dos aeroportos para atender a essa procura. Por meio deste estudo, são procuradas melhorias de desempenho e eficiência em várias áreas-chave do aeroporto, como "Core", Segurança (Safety e Security), Qualidade de Serviço, Produtividade e Eficiência, Financeira, e Meio Ambiente. Este estudo utiliza a ferramenta MCDA para analisar e melhorar o desempenho e a eficiência dos aeroportos espanhóis. Assim, é usado um estudo holístico recorrendo ao MACBETH (com PESA-AGB).

Para a escolha dos aeroportos, selecionámos dividimos Espanha em 4 quadrantes e em cada quadrante selecionámos um aeroporto: Adolfo Suárez Madrid - Barajas, Josep Tarradellas Barcelona - El Prat, Valência e Sevilha. A escolha destes 4 aeroportos é porque a AENA é uma organização centralizada e, portanto, para que o nosso estudo seja real, deve haver grandes e pequenos aeroportos envolvidos nele.

O objetivo deste estudo é ter uma visão sobre o desempenho e a eficiência externos (Peer-Benchmarking) e internos (Self-Benchmarking) desses aeroportos, observar os resultados e propor medidas de melhoria. Tanto quanto se sabe, este estudo nunca foi aplicado antes em aeroportos espanhóis.

Palavras Chave: Aeroportos Espanhóis, Benchmarking, MCDA-MACBETH, Desempenho do Aeroporto, Eficiência do Aeroporto.

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List of Acronyms

A1 – Airport 1

A2 – Airport 2

A3 – Airport 3

A4 – Airport 4

ACI – Airport Council International

AENA – Aeropuertos Españoles y Navegación Aérea

AHP – Analytic Hierarchy Process

API – Airport Performance Indicator

AVE – Alta Velocidad Española

BCC – Banker, Charnes and Cooper

CCR – Charnes Cooper and Rhodes

DEA – Data Envelopment Analysis

ENAIRE – (public business entity in charge of civil air navigation and civil airports in Spain)

IATA – International Air Transport Association

ICAO – International Civil Aviation Organization

KPA – Key Performance Area

KPI – Key Performance Indicator

LWT – Lost Work Time

MCDA – Multicriteria Decision Analysis

MACBETH – Measuring Attractiveness by a Categorical Based Evaluation Technique

PESA-AGB – Performance and Efficiency Support Analysis for Global Benchmarking

SFA – Stochastic Frontier Analysis

WLU – Work Load Unit

IATA code	HELIPORT
AEI	Algeciras
JCU	Ceuta
IATA CODE	**AIRPORT**
ABC	Albacete
ACE	Lanzarote-César Manrique
AGP	Málaga-Costa del Sol
ALC	Alicante-Elche
BCN	Barcelona-El Prat Josep Tarradellas
BIO	Bilbao
BJZ	Badajoz
EAS	San Sebastián
FUE	Fuerteventura
GMZ	La Gomera
GRO	Girona-Costa Brava
GRX	Granada-Jaén F.G.L.
HSK	Huesca-Pirineos
IBZ	Ibiza
LCG	A Coruña
LECU	Madrid-Cuatro Vientos
LEI	Almería
LEN	León
LESB	Son Bonet
LPA	Gran Canaria
MAD	Madrid-Barajas Adolfo Suárez
MAH	Menorca
MLN	Melilla
ODB	Córdoba
OVD	Asturias
PMI	Palma de Mallorca
PNA	Pamplona
QSA	Sabadell
REU	Reus
RGS	Burgos
RJL	Logroño-Agoncillo
RMU	Murcia Internacional
SCQ	Santiago
SDR	Santander-Seve Ballesteros
SLM	Salamanca
SPC	La Palma
SVQ	Sevilla
TFN	Tenerife Norte
TFS	Tenerife Sur
VDE	El Hierro
VGO	Vigo
VIT	Vitoria
VLC	Valencia
VLL	Valladolid
XRY	Jerez
ZAZ	Zaragoza

Chapter 1 - Introduction

1.1 Motivation

Throughout history, Spain has not been a country that has been noted for its aeronautical advances. However, the use of aircraft within the air transportation of passengers and cargo has been present in the twentieth and twenty-first century. It is possible to observe a change from the decade of the nineties, where various processes were developed such as the liberalisation of air transportation, globalisation, or the emergence of low-cost airlines, which changed several things in the Spanish airport system. Currently, Spanish airports belonging to AENA (Aeropuertos Españoles y Navegación Aérea) transported 263.753.406 passengers in 2018 [1] with an increase compared to 2017 of 5,8%. In 2017, traffic was 249.218.316 people transported and the increase with 2016 was 8,2%, while 2016 was 230.231.359 people and an increase of 11,0% over 2015 [2]. These data enable us to conclude that Spanish air transportation is growing annually and, therefore, the need to improve and assess airports' efficiency and performance is essential to maintain the high levels of quality to address this demand. If we do not improve efficiency and performance, there will be a point where airports will be congested, so two options can be performed: firstly, expand airport facilities and secondly, improve their efficiency and performance using new tools to ameliorate them. This last option is much more economical and maximises the airport infrastructure. Thus, this will increase customer satisfaction and will reduce airport costs. Each time the consumption of the aviation industry increases, it is necessary to study how to improve airport performance and efficiency to its future improvement.

In Spain, the management of airports is centralised; that is, they operate as independent profit centres but are under the control of the central authority AENA. Thus, this study focusses on large airports and leaving small (less than 1 million passengers) behind as they are not considered profitable.

The primary motivation of this work is to use an MCDA (Multi-Criteria Decision Analyses) tool that will suggest how to improve performance and efficiency of Spanish airports, and, a holistic study using a mathematical tool such as MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is used, to do so. As of today, it is unknown if anyone has done this study in Spanish airports. For this purpose, was the MCDA methodology chosen using the PESA–AGB (Performance Efficiency Support Analysis – Airport Global Benchmarking) model.

For these four airports were chosen: Adolfo Suárez Madrid-Barajas (MAD), Josep Tarradellas Barcelona-El Prat (BCN), Sevilla (SVQ) and Valencia (VLC).

Through this study we seek improvement in many aspects of the airport such as core, safety and security issues, having quality service, improving productivity and effectiveness, financial issues and finally, issues related to the environment.

The purpose is to solve this as a holistic problem and thus achieve a global evaluation where measures can be taken to reduce costs and improve customer satisfaction, throughout two benchmarking studies.

1.2 Object and Objectives

The main objective of this study is to assess the performance and efficiency of 4 Spanish airports using MCDA MACBETH with the PESA-AGB model tool, by assessing results, and depicting its representation, and propose improvements. The Benchmarking studies will be conducted both externally and internally.

As specific objectives, we have 3:

First, it is necessary to choose which KPA (Key Performance Area) / KPI (Key Performance Indicator) to use, as there are many, and our data entry program is limited. The selection of these depends on the importance they have at the airport.

Second, to choose the analysis method to use. MACBETH method is the one to be implemented and validate if the obtained results are more realistic ones since this method allows the opinion of experts.

Lastly, perform the airport Benchmarking (self and peer) with the previous relevant data collection, throughout the study of cases.

1.3 Methodology of analysis

In the first place, it is essential to characterise the object of study to be treated. A search for the information and careful reading of 25 articles related to the study keywords were done, where it was possible to learn about the program to be used (MACBETH), Spanish airports, why to use MACBETH and not use other methodologies like DEA, SFA, etc..

For this research, four airports have been chosen from Spain's four quadrants. The airports chosen are Adolfo Suárez Madrid-Barajas, Josep Tarradellas Barcelona-El Prat, Valencia and Sevilla. From these airports, we will obtain the information from 6 areas (KPA): Core, Safety

and Security, Quality, Productivity/Cost Effectiveness, Financial/Commercial, and Environmental. These six areas have been chosen by ACI (Airports Council International) and have 42 indicators (KPI) in total and are the data that must be gathered for each airport in the last five years (2014, 2015, 2016, 2017 and 2018).

A survey to assess the expert's opinion on weights and relevance of KPA/KPI is done. Once we have completed our database, we must allocate all these data in the MACBETH tables.

Afterwards, it is necessary to assess the weights of each KPA/KPI according to an expert data survey. In the weights regarding the airports, a meeting will be held to give the correct weights to the airports in this study.

Once all the weights and data have been entered, it is necessary to analyse and draw conclusions from the outputs of the model and see what the efficiency and performance proposals for the improvement of Spanish airports are, by carrying out internal and external Benchmarking studies. Figure 1.1 depicts the Methodology of Analysis Process.

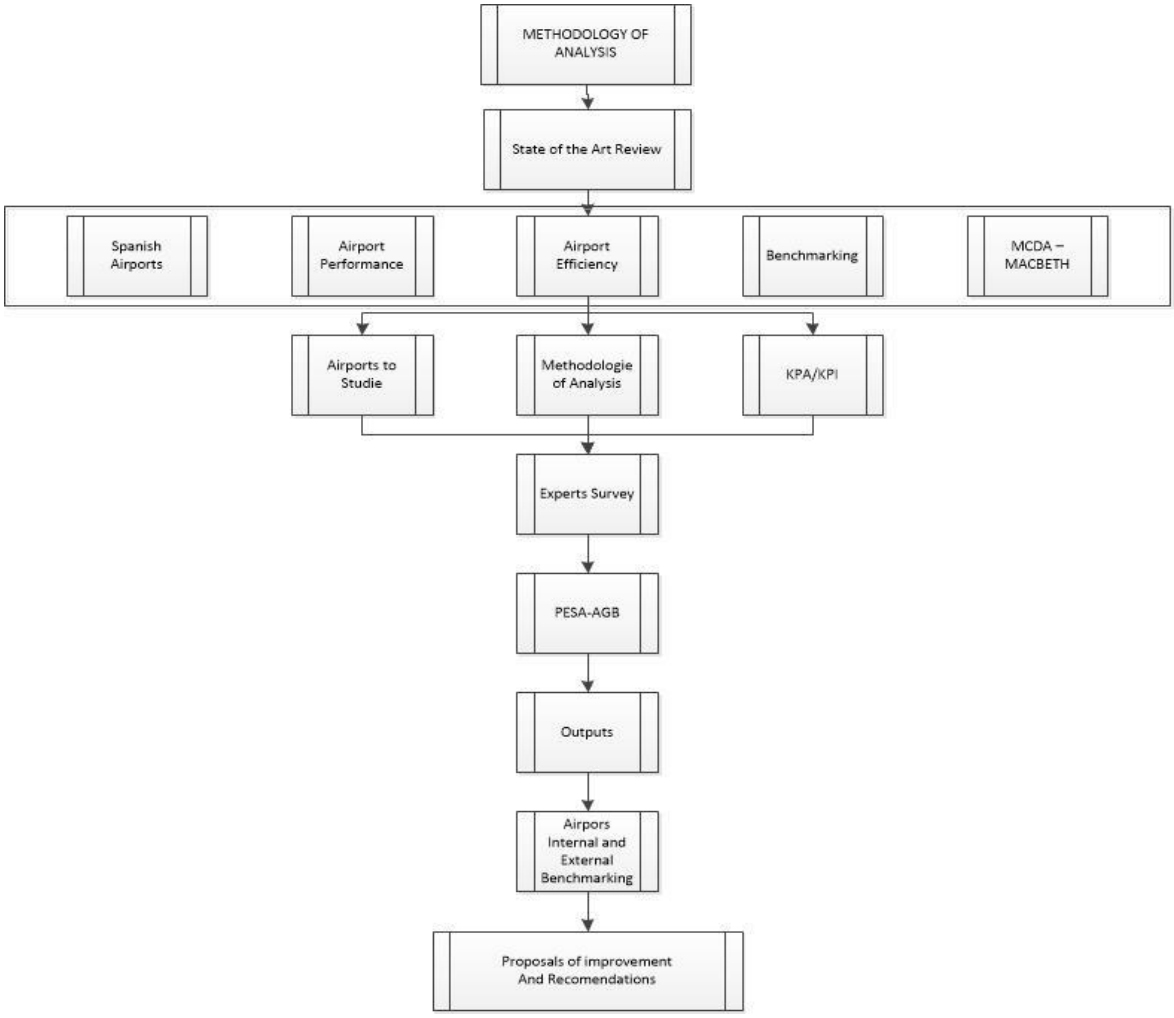

Figure 1.1 - Methodology of Analysis Process

Source: [3]

1.4 Dissertation Structure

This thesis is made up of 4 chapters.

The first chapter is the introduction. It explains why the choice of this topic and its importance in the field of aeronautics. The objectives to be achieved with the completion of this work are also explained.

In chapter two, state of the art is done. In this part of the work, all the keywords related to the work are analysed logically. These keywords are Spanish Airports, where the history of Spanish airports is related to the reason for the choice of airports for this study. Benchmarking is presented too, with the explanation of the two types (self-benchmark and peer-benchmark) since in the case studies both are used. Finally, MACBETH is presented, which is the mathematical tool that we will use to treat data, Airport performance, and Airport efficiency.

In the third chapter, the case studies are made. First, we carry out a self-benchmark, where each airport is worked individually. Moreover, then in Case II, a Peer-Benchmark is carried out, where we work with data from different airports at the same time. Also, in chapter 3, we analyse the obtained results. This analysis is based on the theoretical knowledge acquired thanks to an extensive bibliographic database.

To finish, chapter 4 is the conclusion of the project. In this, a general assessment is made, encompassing all the results obtained, drawing conclusions and possible future situations for research work.

Chapter 2 - Spanish Airports Performance and Efficiency

2.1 Introduction

In this chapter, we will see a review of methodologies usually used by authors to implement the benchmark at airports. For this, we will go into detail with these five keywords: Spanish Airports, where we relate the history of Spanish airports with the choice of our airports for case studies. Benchmarking, done externally (peer-benchmark) and internally (self-benchmark). MCDA - MACBETH, a tool used to treat our data from case studies. Airport Performance and Airport Efficiency, where we delve into theoretical concepts not only at a European level.

2.2 Methodology

First, we perform state of the art. A literature review of 25 articles (Table 2.1) related to our five keywords through which it was possible to understand the global airport studies up to date, as recent papers addressed. Moreover, the term benchmarking is defined, and a few studies are summarised about benchmarking applied to airports. Then, a review is made of the methodologies usually used by other authors to benchmark airport's, including MCDA – MACBETH. Furthermore, airport performance and efficiency issues are addressed and described.

Table 2.1 – Classification of articles related to the study 5 keywords relevance

Source: Own Elaboration

# PAPER	AUTHOR	EFFIC.	PERF.	AIRPORTS	KPA/KPI	METHOD	YEAR	# KEYWORDS
1	José Braz, Emília Baltazar, Jorge Silva, Margarida Vaz [4]	Yes	Yes	54 Iberian airports: 9 Portugal, 44 Spain	ACI: Movements, Passengers, Cargo	MACBETH	2011	5
2	João Jardim [5]	Yes	Yes	Different airports	ACI	DEA/ MACBETH	2012	4
3	Tiago Rosa [6]	Yes	Yes	Companies	ACI	MACBETH/ SPSS	2017	4

# PAPER	AUTHOR	EFFIC.	PERF.	AIRPORTS	KPA/KPI	METHOD	YEAR	# KEYWORDS
4	Miguel Miranda [7]	Yes	Yes	10 companies	ACI	MACBETH	2017	4
5	Duarte Cachola [8]	Yes	Yes	Cargolux and Luftansa	ACI	MACBETH	2017	4
6	Maria Baltazar, João Jardim, Pedro Alves, Jorge Silva [9]	Yes	Yes	3 airports: Lisboa, Ponta Delgada, Barcelona	ACI	MACBETH/DEA	2014	4
7	Miguel Miranda, maria Baltazar, Jorge Silva [10]	Yes	Yes	6 airlines	Transport Business Personnel and Environmental Performance	MACBETH	2016	4
8	Vicente Inglada, Pablo Coto, Lucia Inglada [11]	Yes	Yes	33 Spanish airports	Output: Number of passengers, Quantity of goods, N of movements Input: Cost of work, fixed assets, Rest of operating costs	DEA	2017	4
9	Xavier Fageda, Augusto Voltes [12]	Yes	Yes	44 Spanish airports	Pax, share charter, cargo, pax per square meter, landing charge per tonne, total cost per pax, aeronautical revenues per pax, commercial revenues per pax	DEA	2012	4
10	João Jardim, Maria Emilia Baltazar, Jorge Silva [13]	Yes	Yes	Several world airports	ACI	MACBETH/DEA	2012	4
11	Tiago Rosa, Maria Baltazar, J.Silva [14]	Yes	Yes	3 generic airports	ACI: Core, Safety and Security, Quality, Productivity/Cost Efficiency, Financial/Commercial, Environmental	MACBETH	2018	4
12	Ane Elixabete Ripoll, Cecilio Mar [15]	Yes	No	49 Spanish airports	Inputs: Labour, Operating Cost, Depreciation of Airside Assets Outputs: Passengers, air traffic Movements, Cargo, Commercial Revenues,	DEA	2017	3

# PAPER	AUTHOR	EFFIC.	PERF.	AIRPORTS	KPA/KPI	METHOD	YEAR	# KEYWORDS
					Percentage of Flights on time			
13	Ismael Roldán [16]	Yes	Yes	Sevilla Airport	Economy of the airport, event management, airport commissioner, Future of technology, Airport processes, IATA project processes, Antiterrorism, Serv. fire prevention, networks	-	2017	3
14	Po-Lin Lai, Andrew Potter, Malcom Beynon, Anthoni Beresford [17]	Yes	Yes	24 major international airports	Inputs: number of employees, number of gates, number of runways, size of the terminal area, Length of Runaway, Operational Expenditure Outputs: Aircraft movements, amount of freight and mail, number of passengers, Total revenues	AHP/DEA/DEA-AR	2014	3
15	Maria Emília Baltazar, Tiago Rosa,Jorge Silva [14]	Yes	Yes	3 examples of airports	ACI	DEA/SFA	2017	3
16	David Schaar and Lance Sherry [18]	Yes	Yes	45 airports	-	DEA (CCR, BCC, SBM)	2008	3
17	Phelipe Medeiros, Alexander Pinheiro, Glauco Barbosa, Helder Gomes [19]	-	Yes	15 Brazilian Airports	Access, Check-in, Emigration, Security inspection, Immigration, Customs, Airport facilities, Airport environment	AHP/De Borda	2015	2
18	María Rosa Nieto Delfín [20]	Yes	Yes	Nuevo Aeropuerto Internacional de Ciudad de México.	Inputs: employees / doors, terminals and doors / tracks Outputs: movements and passengers	CCR DEA constant returns of scales)/BCC DEA (variable returns of scales)	2016	2

# PAPER	AUTHOR	EFFIC.	PERF.	AIRPORTS	KPA/KPI	METHOD	YEAR	# KEYWORDS
19	Xosé Luis Fernandez, Pablo Coto, Benito Díaz [21]	Yes	No	35 Spanish airports	Inputs: Capital invested, Labour cost, Size Outputs: Passengers, Cargo, Airport revenue	SFA/DEA	2017	2
20	Tanderss. Granberg, A. Oquillas Muñoz [22]	Yes	Yes	Airports in Sweden and Spain	(5) KPA: operations, economy, environmental issues, safety, and security, customer service	-	2013	2
21	Claudia Giraldo, Amanda Stella, Sandra Zapata [23]	Yes	No	Airports in general	-	DEA	2015	2
22	Graham Francis, Ian Humphreys, Jackie Fry [24]	No	Yes	North American airports.	-	-	2002	2
23	Yuichiro Yoshida, Hiroyoshi Fujimoto [25]	Yes	Yes	67 Japanese airports	-	DEA (VRS, CRS), TFP	2017	2
24	Nicole Adler, Joseph Berechman [26]	Yes	-	Twenty-six airports around the world.	Peak Short, Passenger Terminals, Runways, Distance to City Center, Minimum Connecting times	DEA	2001	1
25	Aghahowa Enoma, Stephen Allen, Anthony Enoma [27]	No	Yes	3 Scottish Airports	KPI for airport safety and security	-	2010	1

After an in-depth analysis of Table 2.1 information, it is possible to conclude: firstly, linking Spanish airports with various types of MCDA studies or related to the efficiency and development of an airport was rare. Secondly, it was visible that except for the work done by UBI researchers, the use of DEA method instead of MACBETH is generalised. In this kind of studies, the results using DEA are acceptable; nevertheless, another way to carry out this research is using a different methodology based on multicriteria decision analysis - MACBETH, thus alloying to input data of world recognised air transportation experts into the performance and efficiency airport assessment. Regarding the KPA and KPI, different types were used, in most articles, the important ones were those that this study would apply, that is, those of ACI. We could also highlight that almost all the documents dealing

with the efficiency of an airport and the development of it were closely linked. The articles that contained four keywords out of 5, usually the missing one is Spanish airports. Moreover, it is the aim of this study to validate the implementation of MACBETH methodology throughout PESA-AGB model to 4 Spanish airports chosen.

After having read these 25 articles, we began with the theoretical analysis of keywords.

2.3 Spanish Airports

The beginning of aeronautics in Spain occurred at the end of the 19th century, where it began to experiment with hot air balloons, which were used in various wars of the early twentieth century in the north of Africa. Later, with the arrival of the aeroplanes, the first aerodrome of Spain was created in Cuatro Vientos, Madrid, in 1911. Here begins the formation of pilots and the use of the aeroplane for military purposes. In 1914 there were more than 100 aerodromes registered in Spain. Spain did not produce aircraft, so with the arrival of the First World War, it entered its first aeronautical crisis because it could not buy any aeroplane from anyone [28].

Later, during the Civil War (1936-1939) both sides received, from their allies, different aeronautical material, and these uses were key to the outcome of the war [29]. After the Civil War, the Air Ministry reconstructed the main airports between 1941 and 1957. In 1958 the National Board of Civil Airports was created, and the first structured airport plan was approved. In 1991, AENA was created and oversees the organisation of Spanish airports until today, although in 2011 became a 51% share of ENAIRE (public). Nowadays in Spain, there are 425 airports and airfields, and of these, 48 airports are managed by AENA.

2.3.1 AENA Airports

Figure 2.1 depicts that a clear majority of airports are in coastal areas. Also, these coastal airports are the ones with the highest traffic and importance, except Madrid, which is the largest and located in the inner central part of Spain. As it was mentioned before the Spanish airport system is centralised, the airports act as independents centres but are under the control of the central authority, AENA. So, the smaller airports, the less profitable ones, are subsidised by the profitable ones.

The 46 AENA airports are:

A Coruña (LCG), Albacete (ABC), Alicante-Elche (ALC), Almería (LEI), Asturias (OVD), Badajoz (BJZ), Barcelona-El Prat Josep Tarradellas (BCN), Bilbao (BIO), Burgos (RGS), Córdoba (ODB), El Hierro (VDE), Fuerteventura (FUE), Girona-Costa Brava (GRO), Gran Canaria (LPA), Granada-Jaén F.G.L. (GRX), Huesca-Pirineos (HSK), Ibiza (IBZ), Jerez (XRY), La Gomera (GMZ), La Palma (SPC), Lanzarote-César Manrique (ACE), León (LEN), Logroño-Agoncillo (RJL), Madrid-Barajas Adolfo Suárez (MAD), Madrid-Cuatro Vientos (LECU), Málaga-Costa del Sol (AGP), Melilla (MLN), Menorca (MAH), Murcia Internacional (RMU), Palma de Mallorca (PMI), Pamplona (PNA), Reus (REU), Sabadell (QSA), Salamanca (SLM), San Sebastián (EAS), Santander-Seve Ballesteros (SDR), Santiago (SCQ), Sevilla (SVQ), Son Bonet (LESB), Tenerife Norte (TFN), Tenerife Sur (TFS), Valencia (VLC), Valladolid (VLL), Vigo (VGO), Vitoria (VIT), Zaragoza (ZAZ).

The 2 AENA heliports are [30]:
Algeciras (AEI), Ceuta (JCU).

Figure 2.1 depicts 48 Spanish airports passengers' traffic in 2018.

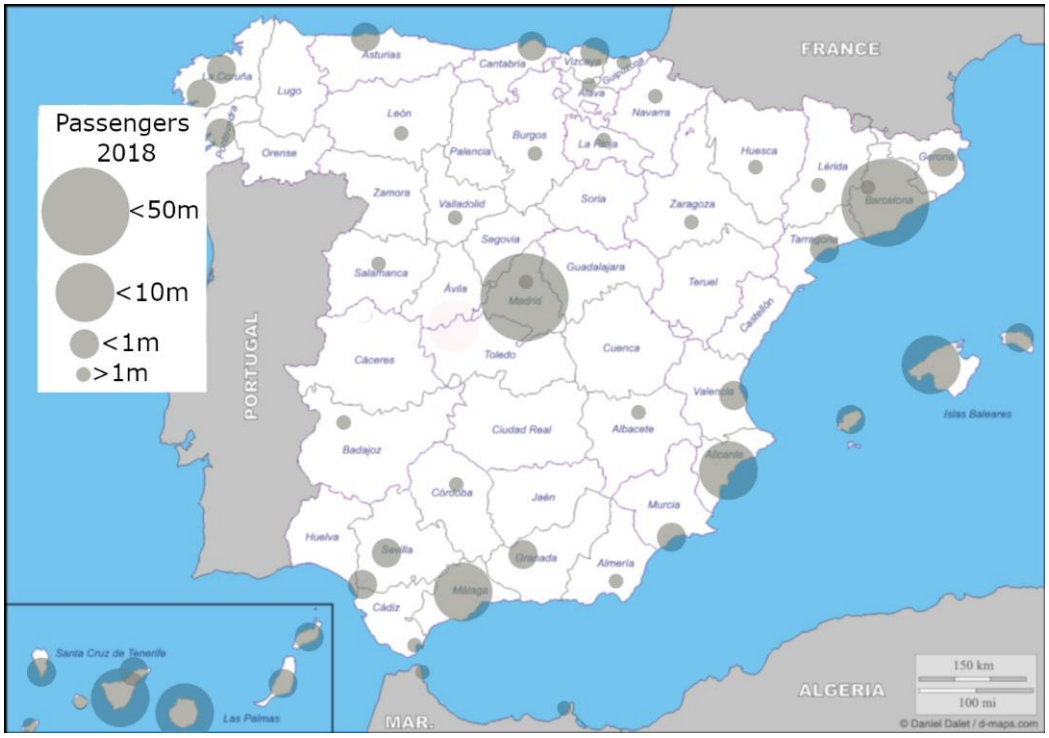

Figure 2.1 - Spanish Airport Passengers 2018
Source: Own Elaboration

2.3.2 Passengers and Tonnes Transported by the Major Spanish Airport

The 9 Spanish airports that transported more passengers in 2018 are depicted in Table 2.2. The volume of passengers travelling in AENA Spanish airports increased by 5.8% compared to 2016.

Table 2.2 – 2018 Spanish Airports Total Transported Passengers

Source: [1]

Airport	Total Passengers
Adolfo Suárez Madrid-Barajas (MAD)	57.891.340
Barcelona-El Prat (BCN)	50.172.457
Palma de Mallorca (PMI)	29.081.787
Málaga-Costa del Sol (AGP)	19.021.704
Alicante-Elche (ALC)	13.981.320
Gran Canaria (LPA)	13.573.242
Tenerife Sur (TFS)	11.042.481
Ibiza (IBZ)	8.104.316
Valencia (VLC)	7.769.867

The 8 Spanish airports that transported more cargo in 2018 are depicted in Table 2.3.

From Table 2.3 it is possible to highlight Zaragoza airport, thus, while is in position 28 with 489.064 transported passengers per year, in the cargo transport is the third place, with 166.833.763 tons per year. Tourism is not an active profile of this airport.

Table 2.3 – 2018 Spanish Airports Total Cargo

Source: [1]

Airport	Total Cargo (Tonnes)
Adolfo Suárez Madrid-Barajas (MAD)	518.858.994
Barcelona-El Prat (BCN)	172.939.998
Zaragoza (ZAZ)	166.833.763
Vitoria (VIT)	62.156.227
Gran Canaria (LPA)	19.166.163
Valencia (VLC)	14.499.793
Tenerife Norte (TFN)	12.669.965
Sevilla (SVQ)	12.561.953

In Figure 2.2, extracted from AENA, it can be depicted that more than 50% of flights departing from Spanish airports are destined for Europe [31]. Among these destinations, the preferred ones are the United Kingdom, Germany, and Italy [1].

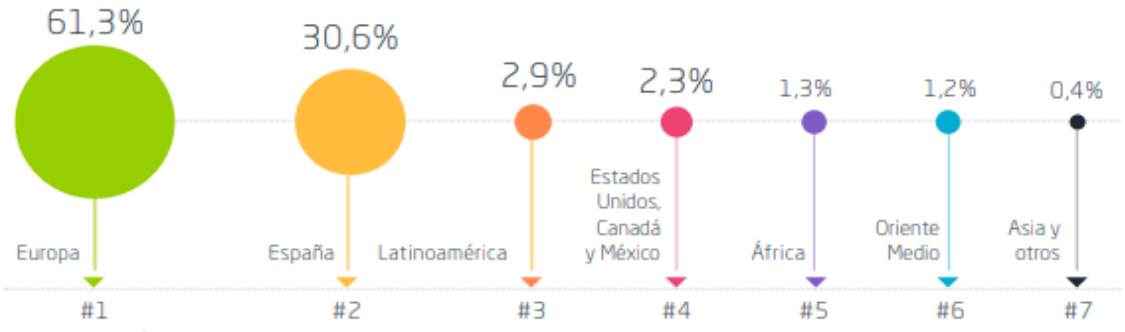

Figure 2.2 – Passengers Distribution by markets

Source: [31]

2.3.3 Spanish Airport by Quadrant

There are many airports located throughout Spain, and each one of the airports serves various cities, regions, and towns across Spain itself.

In this study, the Spanish peninsula was divided into four quadrants, and it was chosen one airport in each quadrant, as in Figure 2.3. The four choices were Josep Tarradellas Barcelona-El Prat (Q1) the biggest in quadrant 1, Adolfo Suárez Madrid-Barajas (Q2) the biggest in quadrant 2, Sevilla (Q3) that is the main airport serving Western Andalusia region and Valencia (Q4) a coastal/touristic airport.

Figure 2.3 – Spanish Peninsula Quadrant Division and Airports

Source: [32]

2.3.3.1. Josep Tarradellas Barcelona-El Prat Airport - 1st Quadrant

Josep Tarradellas Barcelona-El Prat airport, also known as El Prat Airport, is an international airport located 12 km southwest of the centre of Barcelona, located in the municipalities of El Prat de Llobregat, Viladecans, and Sant Boi, in the Autonomous community of Catalonia.

Barcelona El Prat airport is the second largest international airport in Spain. In 2018 it *transported* 50.2 million passengers. It has two runways in parallel and one crossed, 07L / 25R-07R / 25L and 02/20 (Figure 2.4).

Figure 2.4 - Barcelona-El Prat airport aerial photo

Source: [33]

Figure 2.5 depicts the passenger's seasonality of the Barcelona – El Prat in 2018: it has more passengers in Summer than in the Winter. The passengers' monthly range is between 3 million and 5 million.

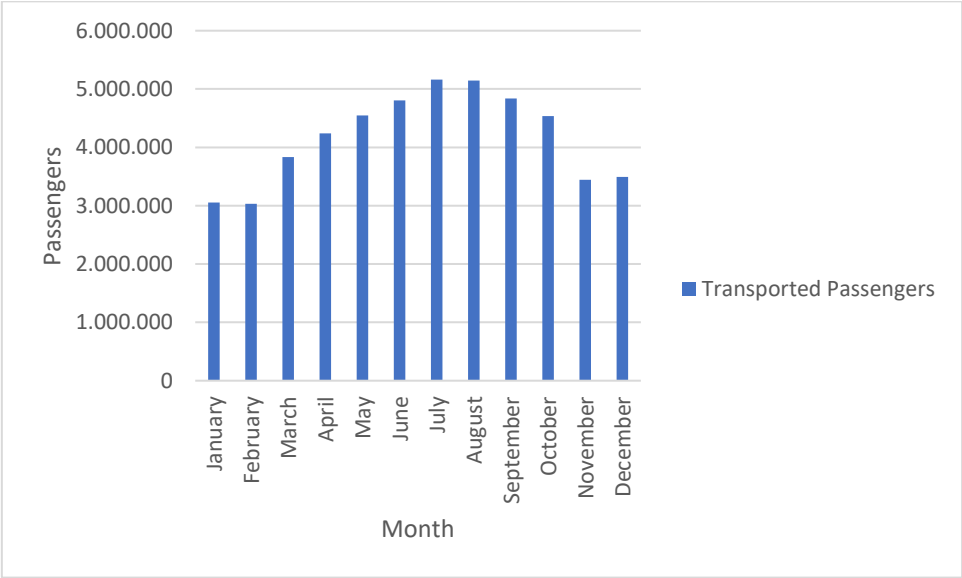

Figure 2.5 – 2018 Barcelona-El Prat Airport Transported Passengers

Source: [2]

Figure 2.6 depicts the passengers' traffic evolutions for the last five years, 2014-2018. It has grown every year, from 37.537.780 in 2014 to 50.127.676 passengers in 2018.

Figure 2.6 - Barcelona-El Prat Airport Transported Passengers 2014-2018
Source: [2]

2.3.3.2. Adolfo Suárez Madrid-Barajas Airport - 2nd Quadrant

The airport, opened in 1928, has grown to be one of the most important aviation centres of Europe. Located within the city limits of Madrid, it is just 9 km from the city's financial district and 13 km northeast of the Puerta del Sol or Plaza Mayor de Madrid, Madrid's historic centre. Consequently, Iberia is responsible for more than 40% of Barajas' traffic.

Madrid–Barajas Airport, is the leading international airport serving Madrid in Spain. It has 3,050 ha in area, and it is the second largest airport in Europe by physical size behind Paris–Charles de Gaulle Airport [34]. In 2018, 57.9 million passengers used Madrid–Barajas, making it the country's largest and busiest airport and Europe's sixth busiest. The airport name derives from the neighbouring district of Barajas, which has its metro station on the same rail line serving the airport.

Madrid–Barajas Airport serves as the gateway to the Iberian Peninsula from the rest of Europe and the world and is a particularly key link between Europe and Latin America.

The airport has five passenger terminals named T1, T2, T3, T4 and T4S, and four runways parallel two to two: 18L / 36R-18R / 36L, 14L / 32R-14R / 32L. Last data of total passengers at

the end of 2018 is 57.891.340 passengers, and the most frequented destination is Lisbon with 1.518.927 passengers.

Figure 2.7 – Madrid-Barajas airport aerial photo
Source: [35]

Figure 2.8 depicts that throughout the year, this airport is used by both tourists and business professionals in all the months. Thus, it is not a seasonal airport, and the passengers' monthly range is between 4 million and 5.5 million.

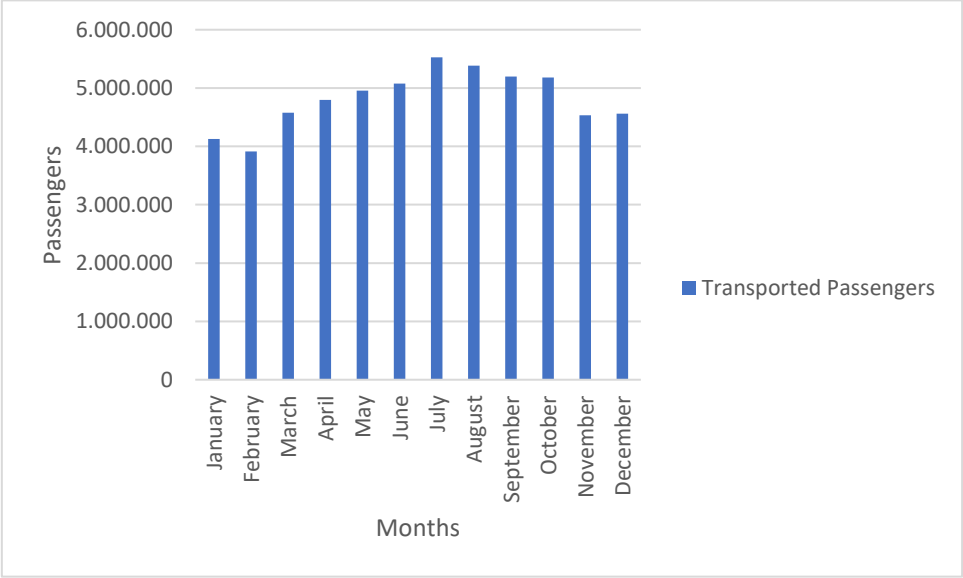

Figure 2.8 – 2018 Madrid-Barajas Airport Transported Passengers
Source: [2]

Figure 2.9 depicts the passengers' traffic evolutions for the last five years, 2014-2018. It has grown every year, from 41.833.686 in 2014 to 57.891.340 passengers in 2018.

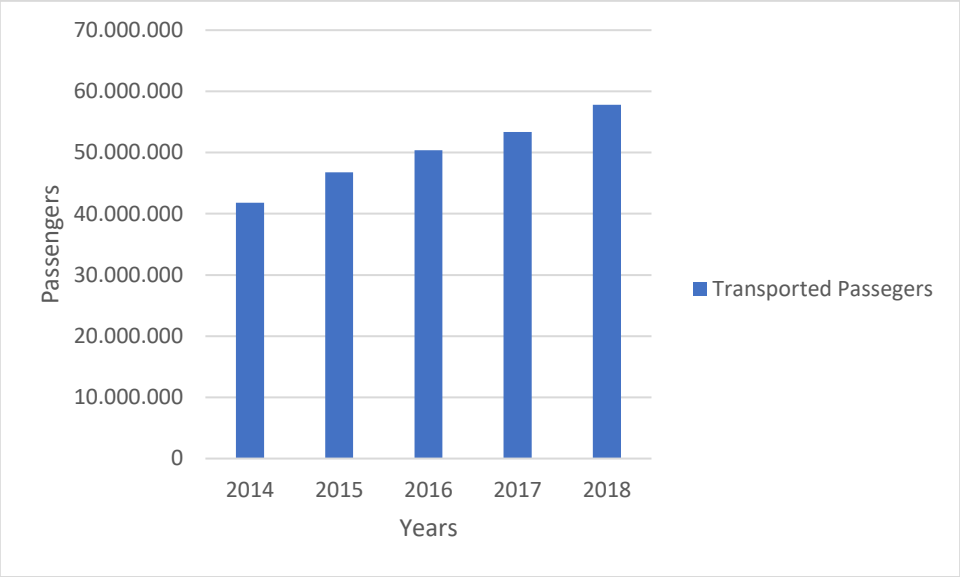

Figure 2.9 – Madrid-Barajas Airport Transported Passengers 2014-2018

Source: [2]

2.3.3.3. Sevilla Airport - 3th Quadrant

Figure 2.10 depicts San Pablo Airport (IATA (International Air Transport Association) : SVQ, ICAO (International Civil Aviation Organization): LEZL) or Sevilla airport; it is in the south of Spain, 10 kilometres north-east of the Sevilla capital. It is the main airport serving Western Andalucia region, being the main base for Vueling and Ryanair, low-cost carriers.
Sevilla airport first flight was in the year 1919, it has a 3.420 m runway, and its orientation is 09-27. The traffic of a great flight as it was Madrid Sevilla has been hugely affected with the implementation of the AVE (Alta Velocidad Española). The month with the most passengers is again that one of August.

Figure 2.10 - Sevilla Airport aerial photo

Source: [36]

Figure 2.11 shows that Sevilla airport is not as seasonal, and its number of passengers ranges between 400.000 and 600.000 passengers.

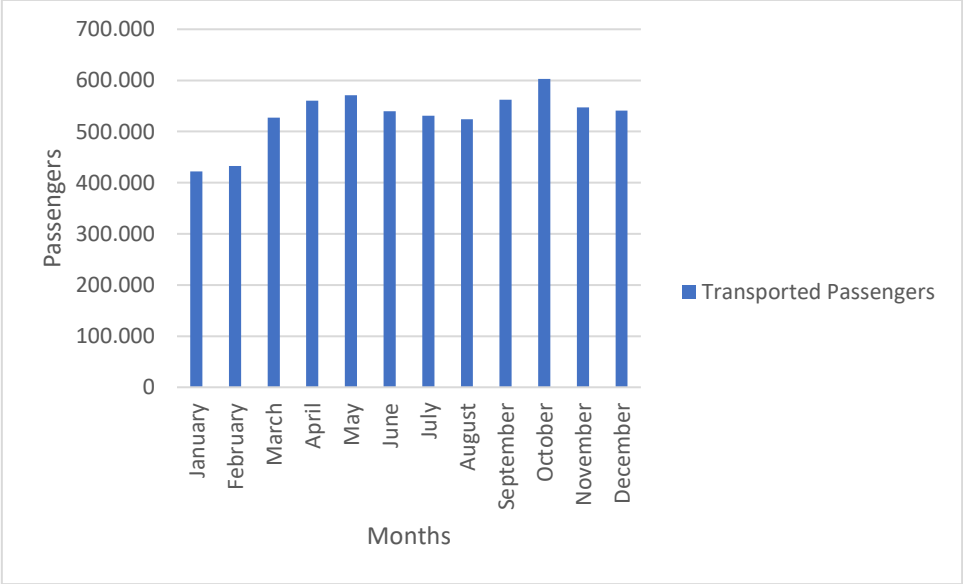

Figure 2.10 – 2018 Sevilla Airport Transported Passengers

Source: [2]

Figure 2.12 depicts the passengers' traffic evolutions for the last five years, 2014-2018. It has grown every year, from 3.866.055 in 2014 to 6.362.000 passengers in 2018.

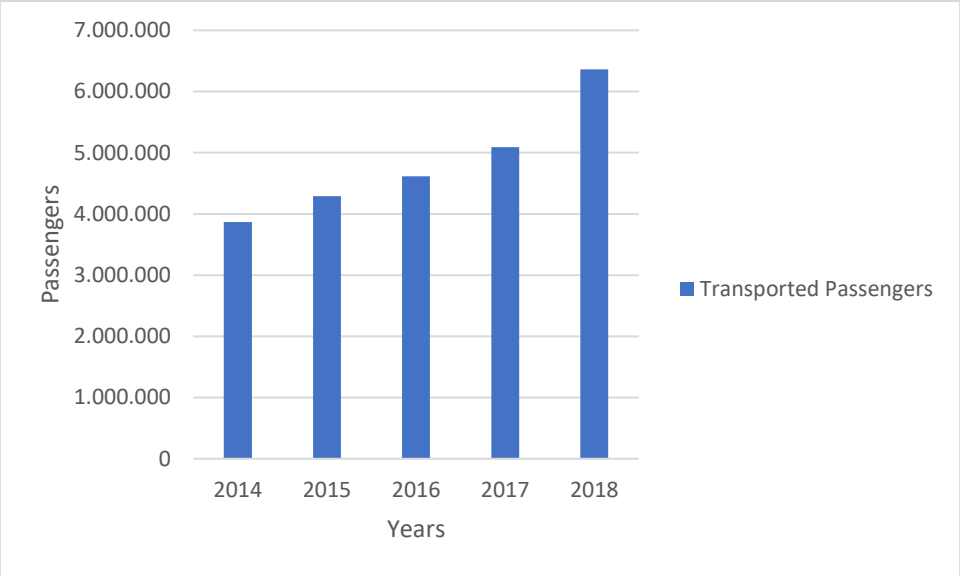

Figure 2.11 – Sevilla Airport Transported Passengers 2014-2018

Source: [2]

2.3.3.4. Valencia Airport - 4th Quadrant

Valencia Airport in Manises (IATA: VLC, ICAO: LEVC), also known as Manises Airport, is the tenth-busiest Spanish airport in terms of passengers [2], and second in the region after Alicante. It is situated 8 km west of the city of Valencia. The airport has flight connections to about 20 European countries, and 5.79 million passengers passed through the airport in 2016 [1].

Valencia airport opened in 1934 where the first flight took place. It has a runway 3.215 m long, 45 m wide and 12-30 orientation. The climate in this region is exceptional, with few spots of rain, few winds, much visibility, and above all this airport is used for touristic purposes.

Figure 2.13 depicts Valencia airport passengers in the year 2018. It can be perceived that in August it exceeded 800.000 transported passengers, and in the winter months, a considerable drop in passengers occurs, noticing the seasonality of this airport.

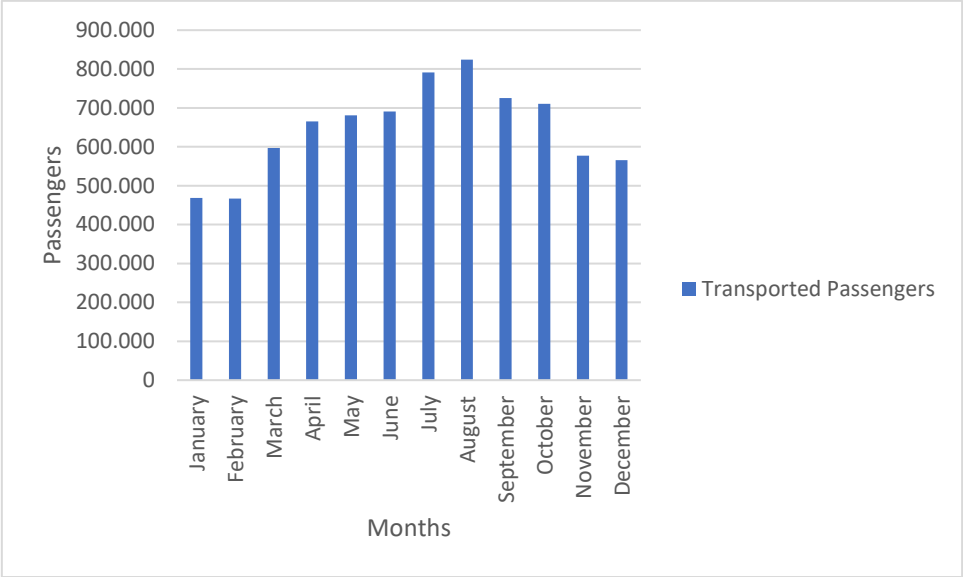

Figure 2.12 - 2018 Valencia Airport Transported Passengers

Source: [2]

Figure 2.14 depicts the evolution of the transported passengers in Valencia for the last five years period (2014-2018).

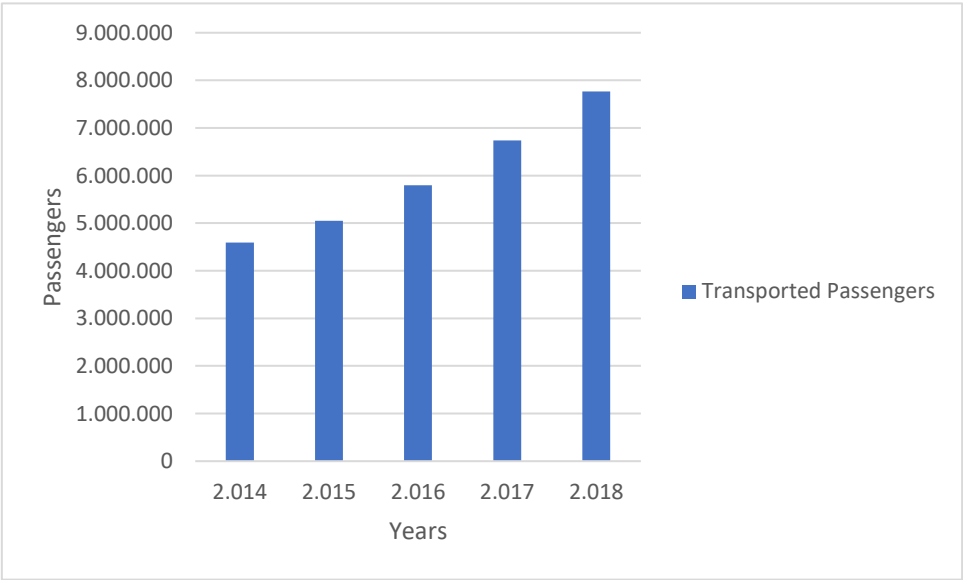

Figure 2.13 - Valencia Airport Transported Passengers 2014-2018

Source: [2]

2.4 Benchmarking

Airports Council International (ACI) defines benchmarking as an economic standard to measure business performance by comparing productivity and efficiency, evaluating specific processes, policies and strategies, and to determine the overall business performance. Thus, this makes the airport benchmarking a component for airports strategic planning process and a tool to monitor and compare airport economic, operational and service performance. Thus, assessing the implementation of the airport's strategic planning, benchmark measures the performance of discrete airport functions, and by identifying and adopting the best practices, the airport can increase its efficiency, quality and customer satisfaction. In other words, airport benchmarking connects day-to-day operations and management strategies with the airports short and long-term actions plans and initiatives [37].

Benchmarking can be divided into two types of evaluation:

- **Internal or Self-Benchmark:** an airport compares its performance with itself over time;
- **External or Peer-Benchmark:** an airport compares its performance with other airports either at a single point of time or during a period.

Several studies suggested four tips to follow so that when applying to benchmark, everything goes accordingly [38]:

1. Many indicators will be useful mainly for internal benchmarking;
2. The internal Benchmarking should not be an end, but a tool that will lead to a series of questions;
3. For benchmarking be significant, should be compared with truly comparable airports;
4. Many activity indicators measure passengers, movements, factors that are out of control of the airport. The description of each PI shows the main evaluation problems to be considered when using.

The careless use of benchmarking can lead us to conclusions that are far from reality. That is mainly because it will be possible to compare airports operating in similar environments such as: passenger volume, capacity limitation, combination of national and international traffic, mix of local and transfer passengers, mix of passenger transport service (charter, low cost …), combination of passengers and cargo activity, range of services provided by the airport, climatic conditions, status of airport development programs, location, urban vs. rural location, access to public transportation, environmental laws, local labour and the property and structure of the government.

2.5 MACBETH

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is an approach designed to build a quantitative model of values, developed in a way that enables facilitators to avoid forcing decision makers to produce direct numerical representations of their preferences. MACBETH employs a non-numerical interactive questioning procedure that compares two stimuli at a time, requesting only a qualitative judgment about their difference of attractiveness [39].

When the judgments of the evaluator are established, their consistency is verified; nevertheless, many corrections may be necessary to avoid unconscious errors [40].

Thus, the main difference between MACBETH and any other type of MCDA method is that MACBETH only needs quantitative judgments, where different criteria and weights are set. A scale of values with ranges must be assigned to each alternative. MACBETH allows assigning ranges to each alternative directly or in pairs by comparing elements according to their relative attractiveness. Given two alternatives, the decision to make is much more attractive [41].

We can divide the process into three distinct phases [42]:

1. **Structuring**:
    a. Criteria: Values of concern and identifying the criteria;
    b. Options: To be evaluated as well as their performances.
2. **Evaluating**:
    a. Scoring: Each option's attractiveness concerning each criterion;
    b. Weighting: Weighting the criteria.
3. **Recommending:**
    a. Analysing Results: Overall attractiveness and exploring the model results;
    b. Sensitivity Analyses: Sensitivity and robustness of the model's results considering several types of data uncertainty.

Before developing any model, it is necessary to make a detailed study and document the subject that is going to be treated. It is essential to finish this first step with a global vision of the subject.

The next step is to create a value tree. In it, there will be nodes that correspond to the KPA and KPI that are going to be considered. In this step, we must bear in mind that MACBETH does not allow the separation of INPUTS and OUTPUTS. In MACBETH, everything goes together.

The next step is to obtain all the necessary data to complete the table of each indicator.

After, the following step is to decide how attractive each indicator is with the previously defined scale. For each node, some decisions must be made individually so that in the end the

model is consistent. After being taken, it will be possible to vary them to give robustness to the system.

2.5.1 MATHEMATICAL PROCESS DEFINED BY BANA e COSTA

The following (described) mathematical process is defined by Bana e Costa [43].

2.5.1.1. ORDINAL VALUE SCALE

Consider X with (X= n≥2) as a finite set of elements (alternatives, choice options) that a group or an individual, J, want to compare their relative attractiveness.

X defines ordinal value scales, which are quantitative representations of preferences, reflecting numerically, the order of attractiveness of the elements of X for J. At this time, J will be able to classify the elements of X in order of attractiveness (it can be in pairs or directly).

Once we have defined the classification, the assignment of a real number v (x) to each element x of X occurs, leaving:

- v(x) = v(y) IF AND ONLY IF J judges equal of attractive to the elements x and y;
- v(x) > v(y) IF AND ONLY IF J judges x more attractive than y.

2.5.1.2. VALUE DIFFERENCE SCALE

Similarly, the program will perform a value difference scale defined in X with the quantitative representation preferences. With this, the program not only wants to reflect the attractive order of the elements of X for J, but also the differences in their relative attractiveness. That is the strength of J's preferences for one element over another. J gives the information of the value of the relative attraction of two elements of x at the same time.

If the two elements are not equally attractive, a qualitative judgment is expressed about the difference in attractiveness between these two elements.

2.5.1.3. THEORETICAL ASPECTS

To facilitate this process of judgment, we can distinguish six categories. MACBETH uses a simple question-answer protocol. The categories of the difference of attractiveness are C6 extreme, C5 very strong, C4 strong, C3 moderate, C2 weak, C1 very weak, C0 null. Weak, strong and extreme were initially called the fundamental categories, but the M-MACBETH software that implements the MACBETH approach does not make this distinction and even allows for group judgments that do not distinguish between several consecutive categories such as strong or very strong.

For a set X of m options, the number of pairwise comparisons can vary from a maximum of m(m-1)/2 judgements. Thus, when all pairwise comparisons are made, to a minimum acceptable number of m-1 judgements, as when comparing only every two consecutive options in the ranking or one option with all of the other m-1 (however, it is recommended to ask for some additional judgments to perform several consistency checks).

As each judgment is entered in the matrix, its consistency with the judgments already inserted is checked, and possible inconsistencies are detected. If an inconsistency is detected, suggestions to overcome it are presented. Technically, this is done by a mathematical programming algorithm.

2.5.1.4. DETERMINATION OF THE WEIGHT

For the use of MACBETH, it is necessary to assign some weights to each indicator. These weights are the reason why we use this process. For that reason, we can count on the opinion of experts in the study.

2.6 Performance and Efficiency Support Analysis for Airport Global Benchmarking (PESA – AGB)

PESA-AGB model is conceived based on PESA-GB (Performance and Efficiency Support Analysis for Global Benchmarking) model [14]. PESA-AGB was built to assess airport performance and efficiency using pre-defined KPAs and KPIs. This model is based on the MACBETH mathematical foundations described in the previous section and supported on the work of Bana e Costa et al. [40].

It is structured in a six steps arrangement (Figure 2.14): Structuring (Step 1); Survey (Step 2); Meeting (Step 3); Evaluation (Step 4); Classification (Step 5); and Outputs (Step 6). Although the sequence of the task is as shown, it is possible to redefine or adjust any task at any time.

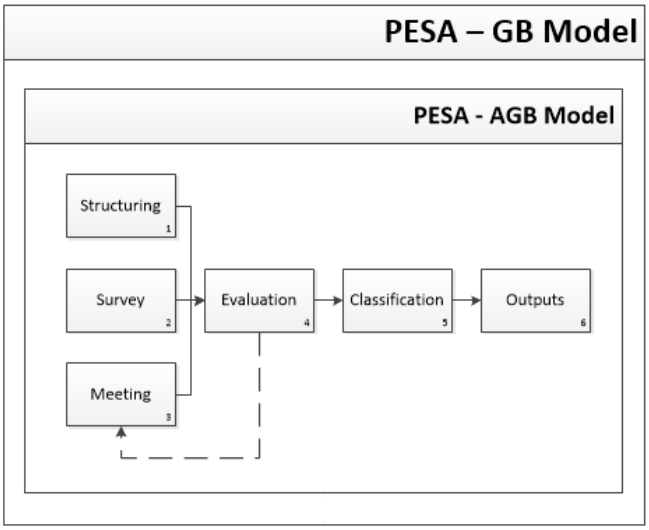

Figure 2.14 - PESA-AGB Model building tasks

Source: [44].

MACBETH mathematical foundations allow the development with a PESA-AGB model incorporating a total of forty-two key performance indicators for a global analysis of airport performance and efficiency, and it is the model that will be used to the 4 Spanish airports case studies.

2.7 AIRPORTS PERFORMANCE

ACI (Airport Council International) divides the airport activity into 6 Key Performance Areas [3], as in Figure 2.16.

Figure 2.15 – ACI Airport Key Performance Areas

Source: [45]

These six key performance areas hold 42 key performance indicators. Different KPIs are used for different airports because some are more relevant or useful in different airports. For example, a private airport focuses on different financial KPIs than airports that are owned by the government. Thus, larger airports will focus on KPI different than the smaller ones. Even in very similar airports, they will have different views on important KPIs. In summary, the importance of the PI depends on each airport and may vary over time.

Next, ACI defines the 6 Key Performance Areas as follows [3]:

- **Core:** basic measures to characterise airports (number of passengers and operations). Although airports may have little control over these (especially in the short term) they are important indicators of airport activity;

- **Safety and Security:** they are the most important at the airport, so they are classified separately;

- **Quality service:** this increasingly important area reflects the evolution of the airport, focusing first on facilities and operations and thus satisfy the customer;

- **Productivity / Efficiency:** measures closely related to those of the airport's performance. Sometimes separate in measures of productivity, in which the output is not based on costs (e.g., passengers per airport, employees or departures per door) and measures of efficiency that is based on costs (e.g., the total cost of an operation per passenger);

- **Financial / Commercial:** these are the measures related to airport charges, the financial strength of the airport and sustainability, and the performance of individual commercial functions;

- **Environmental:** this area is still evolving and is becoming a crucial issue in which we want to minimise the impact on the environment.

Table 2.4, summarises the primary differences between the four ICAO KPAs and the more extensive set of six KPAs used by ACI.

Table 2.4 - ICAO KPAs and ACI Guide to Airport Performance Measures KPAs

Source: [3]

ICAO 4 KPA	ACI 6 KPA	Comments
	Core	Airports may have little control over these core indicators, such as the number of passengers, especially in the short term, but they are important indicators of overall airport activity and drivers and components of other indicators
Safety	Safety and Security	Safety and security are both critical airport functions, which sometimes overlap
Quality of Service	Service Quality	Equivalent KPAs
Productivity	Productivity/Efficiency	Airports often combine Productivity and Cost-Effectiveness in a single KPA. As used by ICAO, productivity refers to the relationship of output to input (e.g., passengers per airport employee), while cost-effectiveness refers to the financial input or cost required to produce a nonfinancial output (e.g., the total cost per passenger)
Cost Effectiveness		
	Financial/Commercial	Financial/commercial may cover a broad range of measures, including those relating to charges, debt, profitability, and commercial revenue
	Environmental	Many airports have developed or are in the process of developing Environmental PIs

In summary, this study will use the 42 indicators provided by ACI - Airports Council International through 2012 "*Guide to airport performance measures*". However, an article of the "First Argentine Congress of Aeronautical Engineering" in La Plata, Argentina, 2008, it was done a compilation of all the indicators reaching 76 ones. In this study, one concludes that a list of standard indicators should be imposed on airport use, facilitating the implementation of comparative studies, thus optimising the operation of each subsystem that makes up the airport system.

Also, a comment on the ACRP Report 19A, Resource Guide to Airport Performance Indicators, refers that it has gathered into one place an extensive and categorised set of airport performance indicators (APIs) from which airports can select specific ones to use in benchmarking, an important component of a successful performance measurement system. These APIs are sorted by functional type and their criticality to the airport strategic plan. Thus, more than 800 performance indicators are presented in three main categories: Core, Key, and Other APIs. Figure 2.16 depicts this data:

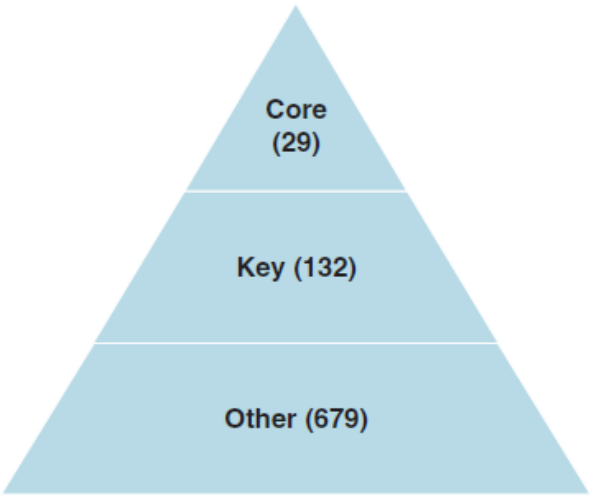

Figure 2.16 - Three Categories of APIs
Source: [46]

- **Core APIs:** Important for overall airport operation or otherwise crucial to the airport executive level (CEO and Aviation Director) and the airport's governing board;

- **Key (Departmental) APIs:** Important for the operations of key airport departments or functions (e.g., Finance and Maintenance);

- **Other APIs**: Not considered as useful for overall airport operation, to the executive level, or key airport departments/functions. However, these APIs can be useful as secondary departmental unit APIs at or below the manager level.

Depending on the circumstances of an airport at a given time, APIs may transition among the categories of Core, Key, and Other.

The comprehensive listing of metrics will be useful as a stand-alone document, especially for airports already experienced in performance measurement; it will also be useful for airports that know something should be measured but have not identified what to measure or how to measure performance [46].

2.8 AIRPORTS EFFICIENCY

Efficiency in airports is a relatively current issue, which has begun to worry airports for a short time. Most efficiency studies related to airports have been carried out since 2000. The reason for this is the considerable increase in the use of air transport and the change in the pace of

life of people in recent decades, which has accelerated thanks to technological improvements and the process of globalisation. People move much more than in the past, which has increased the need to improve efficiency and productivity. In the last decades, the number of aircraft passengers has increased considerably. However, even though the sector does not stop growing, more than half of the airports continue to generate losses.

Table 2.5 – Researches About Airport Efficiency

Source: [47]

Authors	Year	METHODS	INPUTS	OUTPUTS
Gillen and Lall	1997	DEA-BBC model	Terminal Services	
			a) Number of runways b) Number of gates c) Terminal Area	1) Passenger 2) Cargo
			Movement model	
			a) Airport area b) Number of Runaways c) Runway area d) Number of employees	1) Air cargo movements 2) Computes movements
Parker	1999	DEA-BCC and CCR models	a) Number of Employees b) Operating Cost c) Capital Input	1) Passenger 2) Turnover 3) Cargo
Murillo-Melchor	1999	DEA Malmquist Index	a) Number of employees b) Intermediate Expenses c) Accumulated Capital Stock	1) Passenger
Sarkis	2000	DEA-CCR and BCC	a) Number of employees b) Operating cost c) Gates d) Runways	1) Operating Revenues 2) Aircraft movements 3) Passenger 4) Cargo
Fernandes and Pacheco	2002	DEA	a) Terminal size b) Departure Lounge c) Number of Check-in desk d) Number of vehicle parks e) Number of baggage claims	1) Passenger

Authors	Year	METHODS	INPUTS	OUTPUTS
Pels et al.	2003	DEA-BCC model	***Terminal Services***	
			a) Terminal size b) Number of aircraft parks c) Number of runways	1) Aircraft movements
			Movement Model	
			a) Number of check-in desks b) Number of baggage claims	1) Passenger
Pels et al.	2003	SFA	***Terminal Services***	
			a) Terminal size b) Number of aircraft parks	1) Aircraft movement
			Movement Model	
			a) Number of Check-in desks b) Number of baggage claims	1) Passenger
Oum et al.	2003	VFP	a) Labour b) Price of capital	1) Passenger 2) Cargo 3) Aircraft movements 4) Non-Aeronautical services
Barros and Sampaio	2004	DEA	a) Number of employees b) Book value of physical asset c) Price of Capital d) Price of labour	1) Passengers 2) Number of planes 3) Cargo 4) Sales to planes 5) Sales to passengers
Yoshida	2004	Endogenous Method	a) Runway length b) Terminal size	1) Passenger 2) Cargo 3) Aircraft movement
Yoshida and Fujimoto	2004	DEA-CCR and BCC	a) Runway Length b) Terminal size c) Number of employees d) Monetary access cost e) Time access cost	1) Passenger 2) Cargo 3) Aircraft movement

Authors	Year	METHODS	INPUTS	OUTPUTS
Barros and Dieke	2007	DEA	a) Number of employees b) Operational Cost c) Capital invested	1) Passenger 2) Cargo 3) Number of plane 4) Commercial sales 5) Aeronautical sales
Fung et al.	2007	DEA Malmquist Index	a) Runway Length b) Terminal size	1) Passenger 2) Cargo 3) Aircraft movement
Barros	2008	SFA	a) Operating Cost b) Price of capital c) Price of Labour	1) Passenger 2) Sales to planes 3) Non-aeronautical fee
Barros and Weber	2009	DEA Malmquist Index	a) Labour b) Capital c) Other costs	1) Passenger 2) Cargo 3) Aircraft Movements
Hsu-Hao Yang	2010	DEA and SFA	a) Number of employee b) Number of Runway c) Operating Cost	1) Operating Revenues

Table 2.5 depicts the classification of the most important studies on efficiency. We verify that they are practically all from the 21st century and that the most used methods could be classified in two main groups: Parametric, as SFA (Stochastic Frontier Analysis), and non-Parametric, as DEA (Data Envelopment Analysis). We can see in the table that few authors have used the SFA method while the DEA is much more used because it is more suitable to test different aspects of efficiency.

On the other hand, over the years, the various studies combine different types of Inputs such as Price of Capital, Number of Employees, Terminal Size... while in the Outputs, we can observe that they remain constant: Passenger, Cargo, Aircraft Movements…

Some authors, to find more specific efficiencies, within the Inputs differentiate between “Terminal Services” and “Movement Model”.

The key areas to improve the efficiency of an airport are three: Landside, Terminal, and Airside:

- **Landside:** Accessibility to the airport is an example of a variable that the airport must control in order to be efficient. Having proper security measures helps improve efficiency too;

- **Terminal:** there must be a sound communication system between passengers and the airport because if any change occurs, the passenger must be informed in time. It is also important to reduce the queue times as the client does not like them. The good use of the air conditioning of the terminal can make an airport save many expenses;

- **Airside:** it is important to have a good aerial infrastructure, that is, good runways, taxiways, platforms, etc.. It should also be necessary to control the acoustic impact that is not acceptable by the Society in general [48].

Also, these studies which we have been talking about, show that private airports are more efficient than public airports. One option to increase the level of quality and efficiency of an airport seems to be its privatisation.

2.9 Conclusion

In Chapter 2, first, we did a review of 25 articles to get in touch with the keywords. Moreover, then we have been defining them one by one. From keyword Spanish Airports, we have defined the history of Spanish airports, and their current situation; also, we have divided the territory into four quadrants, and we have selected one airport for each quadrant. The airport selected is not in all cases the largest in the quadrant, since, for the study to be valid, there must be a representation of all types of airports.

Afterwards, we have defined Benchmarking, and we have shown the difference between external (Peer) and Internal (Self) processes. Also, we showed the operation of the tool with which we will make the case study, MACBETH. On the other hand, we have defined PESA-AGB Model.

Finally, we have seen many of the features and data of the last two keywords: Airports Performance and Airports Efficiency.

Chapter 3 – Case Studies

3.1 Introduction

In this chapter, we are going to do two types of practical cases using MACBETH and PESA-AGB Model. Once we have entered all the data in MACBETH, we begin to run the studies. First, the CASE I consists of making a Self-Benchmarking (analyse each airport separately from 2014 to 2018). The reason for taking five years into account is because the official aeronautical studies usually go in multiples of 5 years (5, 10, 15...). Then we will do CASE II, a Peer-Benchmarking (we use the data of all the airports together, to compare them).

3.2 Method of carrying out the study

In this section, we will explain step by step how these practical cases have been carried out in a general way.

3.2.1 Obtaining data

The first step of the case study is the collection of data. The thesis was designed to make a study of 4 Spanish airports in order to get a global result of the development and efficiency of them. When extracting the data for this study, we found several difficulties related to AENA. What we did was using data from American airports in the KPIs where we did not have any data yet, and using the trend line for KPI where several data was already available, we fulfil our tables.

Concerning the American airports, they were the only source of finding the KPIs where we still had no data available. We meticulously choose American airports that had concrete characteristics equal or very similar to ours, so that it could reflect reality accurately. The airports chosen were: San Francisco International Airport (SFO) for A.S. Madrid-Barajas (MAD), Orlando International Airport (MCO) for J.T Barcelona-El Prat (BCN), Bradley International Airport (BDL) for Valencia (VLC), and Hollywood Burbank Airport (BUR) for Sevilla (SVQ), (Tables 3.1 to 3.4).

Table 3.1 - Comparison A.S. Madrid-Barajas - A.I. San Francisco

Source: [49]

	A.S. Madrid-Barajas	A.I. San Francisco
Passengers	57.891.340	57.793.313
Movements	409.832	470.164
Tracks	4	4
Terminals	5	4
Gates	228	215
Public/Private	Public	Public

Table 3.2 - Comparison J.T. Barcelona-El Prat - A.I. Orlando

Source: [50]

	J.T. Barcelona-El Prat	A.I. Orlando
Passengers	50.172.457	47.696.627
Movements	335.651	347.672
Tracks	3	4
Terminals	2	2
Gates	162	129
Public/Private	Public	Public

Table 3.3 - Comparison Valencia - Bradley I.A.

Source: [51]

	Valencia	Bradley I.A.
Passengers	7.769.867	6.668.198
Tracks	2	3
Terminals	2	1 (with 2 parts)
Gates	22	23
Public/Private	Public	Public

Table 3.4 - Comparison Sevilla - Hollywood Burbank Airport

Source: [52]

	Sevilla	Bob Hope Airport
Passengers	6.380.465	5.263.972
Tracks	1	2
Terminals	1	1 building - 2 terminals
Gates	14	14
Public/Private	Public	Public

In America, all these data are available to anyone and having practically the same characteristics as needed, the results will not be drastically altered by this *small* approach.

On the other hand, we also applied trend lines only in KPIs that were missing data for a specific year.

For all these reasons, the study data is the following:

- **SECURITY:** AENA has refused to give us any information of this type. So, about runway accidents, we did a literature review of various newspapers and the only occurred accident from 2014 to 2018 happened in Sevilla in 2015. runway incursions, bird strikes, public injuries, occupational injuries, LWT (Lost Work Time) employee accidents and injuries, all these data were obtained from the American airports previously mentioned;
- **CORE**: the number of passengers, number of movements, etc.. all airports data was obtained from AENA website. The origin and destination number of passengers, and routes, data was obtained thanks to airlinebox@aena.es too. They sent us the 2014-2018 reports of the 4 airports and so we were able to extract these data;

- **PRODUCTIVITY / COST EFFECTIVENESS**: the number of gates was obtained from the specific reports of each airport already mentioned above. The number of workers was obtained from their respective American airports and the remaining data - Total Cost, Operating Cost, and WLU (Work Load Unit)- was obtained from the annual economic report of AENA. These reports contain data from AENA in general, but also there are percentages of the shares of each airport on those data. What we did was to apply to each data set its respective percentage (different for each year for the same airport);
- **SERVICE QUALITY:** the practical hourly capacity of the 4 airports was obtained thanks to the annual reports sent to us by airlinebox@aena.es too. All other data were obtained from similar American airports except for one indicator: customer satisfaction, in 2014. To get this data from the 4 airports, what we did was to insert a trend line within the other 4 years data and get the latter one;

- **FINANCIAL / COMMERCIAL:** all the data has been extracted from the AENA Economic Report of the year in which they were involved. The percentage that AENA manifests in the same report has been applied to all the related data;

- **ENVIRONMENT:** we obtained the environmental reports from Madrid (2015-2017) and Barcelona (2013-2015). Thanks to those reports, and the trend line (again) when

necessary, we obtained the required data. On the other hand, Valencia and Sevilla's data were taken entirely from their American analogous.

Due to all these inconveniences, we cannot say that the studies are integrally from the 4 Spanish airports because there is some data that doesn't belong to them. So, instead of calling them by their real name, we will assign each one an airport number, as shown in Table 3.5.

Table 3.5 - Airports: Real vs Thesis Names
Source: Own Elaboration

Name of Real Airports	Name of Thesis Airports
A.S. Madrid-Barajas	Airport 1
J.T. Barcelona-El Prat	Airport 2
Valencia	Airport 3
Sevilla	Airport 4

3.2.2 MACBETH Self-Benchmarking

Before starting, we must clarify that in the studies of Case I, we will do Self-Benchmarking, that is, a study of 1 airport in particular during 5 years where we will analyze their KPIs and their KPAs, as we see in Figure 3.1 – Triangle of KPIs, KPAs, and Airports.Figure 3.1.

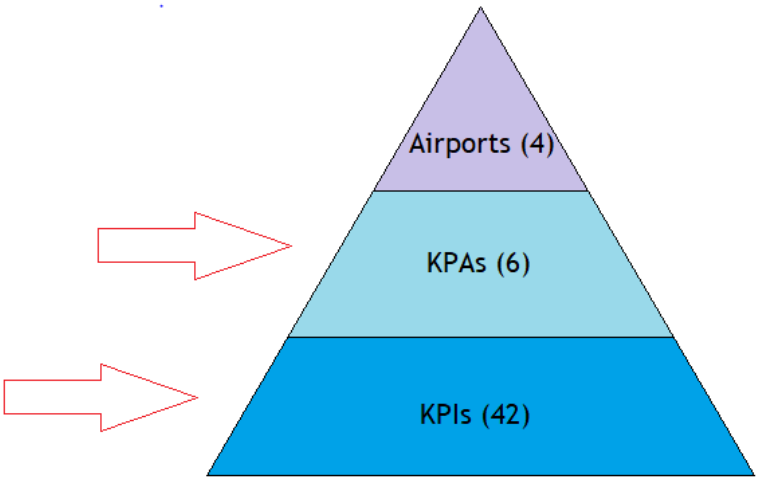

Figure 3.1 - Triangle of KPIs, KPAs, and Airports.
Source: Own Elaboration

We are emphasizing this because the opinion of the specialists is applied in these two areas (KPI and KPA) by means of matrices of judgments and by means of the weights. Having said that, we started with the process.

Once we have all the data, we start with MACBETH. First, we create a decision tree, with the airport as the main node. There are 6 more nodes (KPA) from this node. All the nodes named so far are non-criteria. We can see how it looks in Figure 3.2.

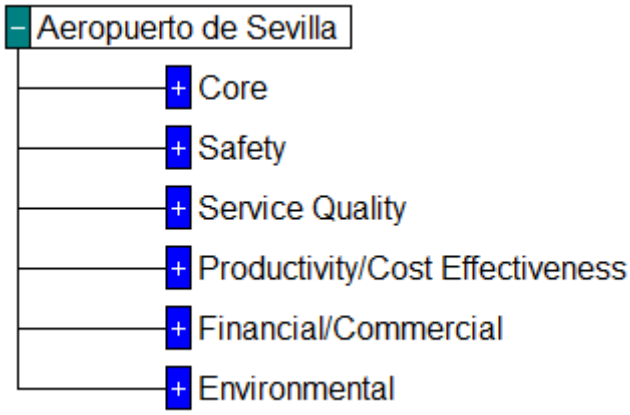

Figure 3.2 - KPAs MACBETH
Source: Own Elaboration

Next, we proceed to the creation of the KPI nodes as shown in Figure 3.3. In that image, we see only the KPIs of the KPAs Core, and Safety and Security because it is an example. In MACBETH there are 4 missing KPAs with their respective KPIs (42 in total).

Regarding safety, the ACI calls this KPA Safety and Security, but in reality, it is only Safety because no airport wants to provide data on Security. For specialists, it is the KPA that has more weight.

Figure 3.3 - KPIs MACBETH
Source: Own Elaboration

The KPI nodes are criterion ones and belong to the quantitative level as shown in Figure 3.4.

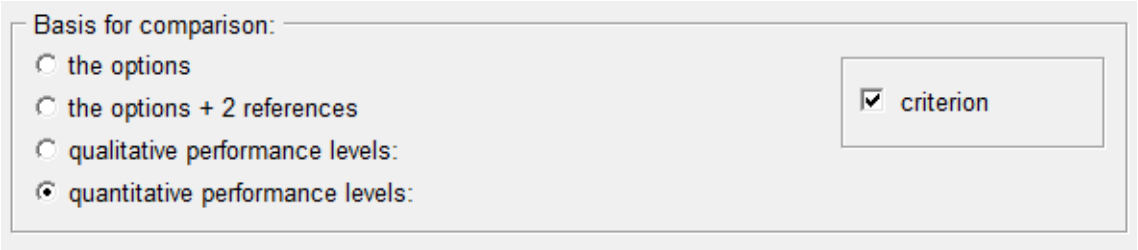

Figure 3.4 - Menu Comparison MACBETH
Source: Own Elaboration

Once the decision tree is finished, we begin with the manual introduction of data for each year and its related (appropriate) KPI (Figure 3.5). In Figure 3.5 we only see the Core KPIs because it is an example. The Table of Performances contains the 42 KPIs.

Table of performances

Options	PAx	AM	OD	Cargo	Destinations
2014	3885434	42379	3691162.3	5667.539	45
2015	4308845	46086	4093402.75	6007.279	47
2016	4625314	45840	4394048.3	6626.457	46
2017	5108817	48661	4853376.015	10715.97	65
2018	6380465	57909	6061441.75	12561.95	76

Figure 3.5 – Table of Performance MACBETH

Source: Own Elaboration

When we have entered all the data we have to mark the performance levels. To obtain these it will be necessary to take from each KPI the biggest and smallest data of the 5 years period. The biggest one will be the upper reference (marked in green in Figure 3.6) and the smallest one the lower reference (marked in blue in Figure 3.6) The two central data are 1/3 and 2/3 of the distance between the reference upper and lower. Figure 3.6 is an example for the KPI Passengers of Airport 4. For all other KPIs, it is done identically.

Performance levels:

	Quantitative level
1	6380465
2	5548788
3	4717111
4	3885434

Figure 3.6 – Performance Levels MACBETH

Source: Own Elaboration

With the levels of development already marked we proceed to insert the judgments. Judgments are one of the reasons why we have chosen M-MACBETH. In this part of the practice, the opinion of the specialists is incorporated, which makes our study more realistic. We see in Figure 3.7 how the table incorporates the judgments of the specialists that are separated between the different levels of performance.

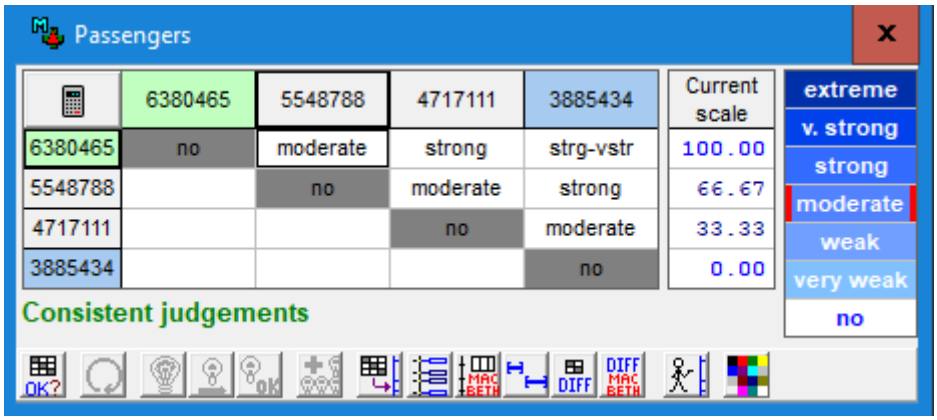

Figure 3.7 - Matrix of Judgements

Source: Own Elaboration

Figure 3.7 is an example for the KPI Passengers of Airport 4. Each KPI of the study is given its own matrix that has been made by the specialists.

We verify that the judgments are consistent and we scale them from 0 to 100 as seen in the graphic of Figure 3.8. All Matrix of Judgements can be found in Annex I.

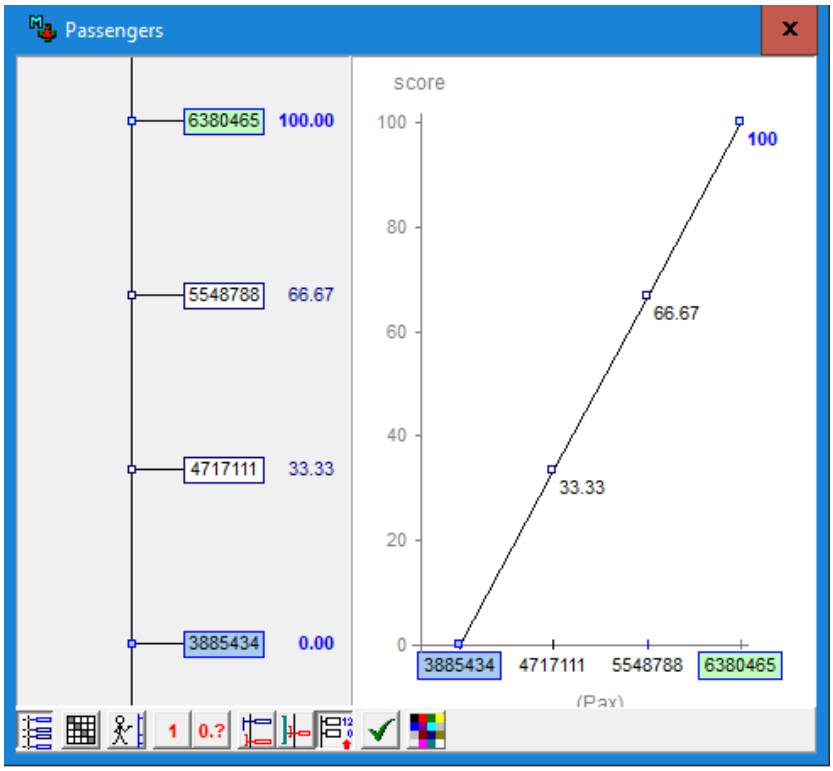

Figure 3.8 - New Scale

Source: Own Elaboration

Again, Figure 3.8 is an example of KPI Passengers of Airport 4. For each KPI of the study, we make a new scale.

With this what we have achieved is to pass all the data to a level of punctuation from 0 to 100 with which we will work from this step.

Now we are ready to apply the weights. Here we apply the opinion of the specialists again. The sum of all the weights is 100 and the result is that of Table 3.6.

Table 3.6 - Weights of KPIs
Source: Specialists

KPA	KPI	Value %
CORE	Passengers	5.02
	Aircraft Movements	4.46
	OD	3.90
	Freight and Mail Loaded Unlodaded	3.34
	Destination-Nonstop	2.79
SAFETY	Runway Accidents	4.73
	Runway Incursions	4.30
	Bird Strikes	3.87
	Public Injuries	3.44
	Occupational injuries	3.01
	Lost Work Time form Employee Accidents and Injuries	2.58
SERVICE QUALITY	Customer Satisfaction	2.32
	Gate departure Delay	2.14
	Baggage Delivery Time	1.96
	Taxi Departure Delay	1.78
	Security Clearing Time	1.78
	Border Control Clearing Time	1.61
	Check-in to Gate Time	1.61
	Practical Hourly Capacity	1.43
	Total Cost per Passenger	2.44
	Total Cost per Movement	2.27
	Operating Cost per Movement	2.09
	Aircraft Movement per Gate	1.92

KPA	KPI	Value %
PRODUCTIVITY-COST EFFECTIVENESS	Total Cost WLU	1.92
	Operating Cost per Passenger	1.74
	Operating Cost per WLU	1.74
	Passengers per Employee	1.57
	Aircraft movement per Employee	1.39
FINANCIAL-COMMERCIAL	Aeronautical Revenue per Passenger	2.35
	Aeronautical Revenue per Movements	2.17
	Non-Aeronautical Operating Revenue per Passenger	1.99
	EBITDA per Passenger	1.99
	Non-Aeronautical Operating Revenue as Percentage of Total Operating Revenue	1.81
	Debt to EBITDA Ratio	1.63
	Debt Service as Percentage of Operating Revenue	1.45
	Long-Term Debt per Passenger	1.26
ENVIRONMENTAL	Carbon Footprint	2.59
	Waste Recycling	2.22
	Renewable Energy Purchased by the Airport	2.22
	Waste Reduction Percentage	1.85
	Energy per Square Meter of Terminal	1.85
	Water Consumption per Passenger	1.48

Once the weights are applied, the punctuation table remains as in Figure 3.9. We can see below all the weights that are going to be applied. On the left the years as options and the average of the scores (between 0 and 100) per year of the 42 KPIs. In the center-right of the image, we observed the scores of PAX, AM, and OD already scaled. Figure 3.9 is an example of Airport 4 and in the image are missing 39 KPIs. And the Overall is the Airport 4 efficiency for 5 years. For the other airports, it is done identically but with other data.

Table of scores

Options	Overall	PAx	AM	OD
2014	32.58	0.00	0.00	0.00
2015	41.60	16.97	23.87	16.97
2016	42.55	29.65	22.28	29.65
2017	59.41	49.03	40.45	49.03
2018	69.38	100.00	100.00	100.00
Bom	100.00	100.00	100.00	100.00
Neutro	0.00	0.00	0.00	0.00
Weights :		0.0502	0.0446	0.0390

Figure 3.9 - Table of Scores MACBETH

Source: Own Elaboration

Now, with all the data collected and inserted into M-MACBETH, we can start the study. For aesthetic reasons, the graphics will be extracted through Excel and not from MACBETH.

3.2.3 MACBETH Peer-Benchmarking

Before starting, it is necessary to clarify that in the studies of Case II we will perform Peer-Benchmarking, that is, the study of the 6 KPAs of 4 airports related to each other during 5 years (2014-2018), as depicted in Figure 3.10.

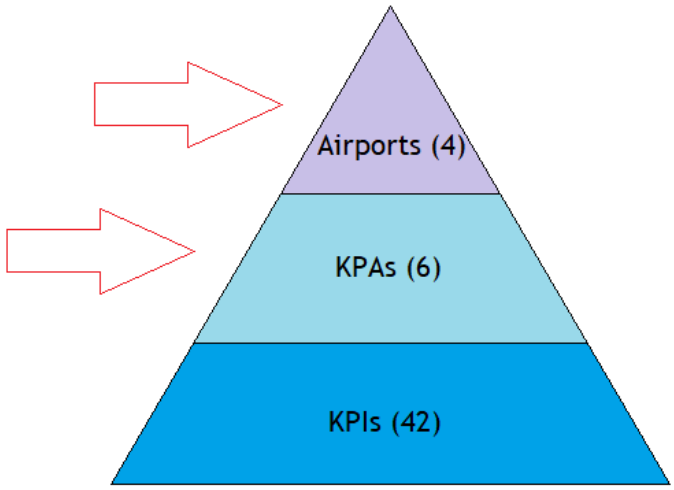

Figure 3.10 - Triangle of KPAs, KPIs, and Airports

Source: Own Elaboration

We emphasize this because the opinion of the specialists is applied in these two areas (Airports and KPAs) by means of matrices of judgments and by means of weights. Having said that, we start with the process.

First, we proceed to the creation of the decision tree, taking out 4 non-criteria nodes that will be the 4 Airports of the study (Figure 3.11).

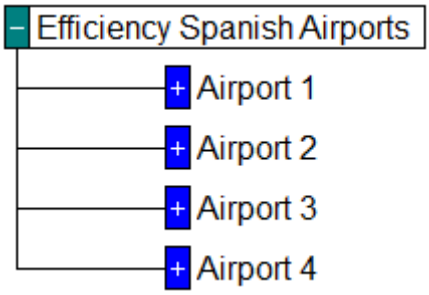

Figure 3.11 – Tree Nodes non-criteria Peer-Benchmarking
Source: Own Elaboration

Within each Airport, we find all 6 KPAs as nodes, as they are our criteria.

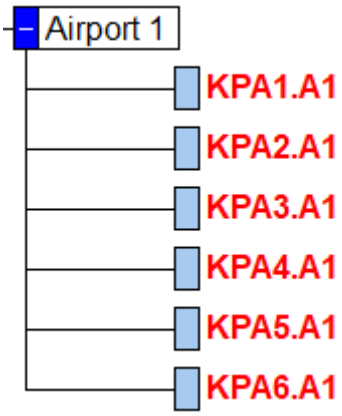

Figure 3.12 – Nodes criteria Peer-Benchmarking
Source: Own Elaboration

Each Airport is a non-criterion node, which in its interior has 6 criterion nodes. In all places/nodes, we have a KPA followed by A1, A2, A3 or A4 that designed which airport is, as can be depicted from Figure 3.12. This image is an example of Airport 1 and for the other airports is done identically.

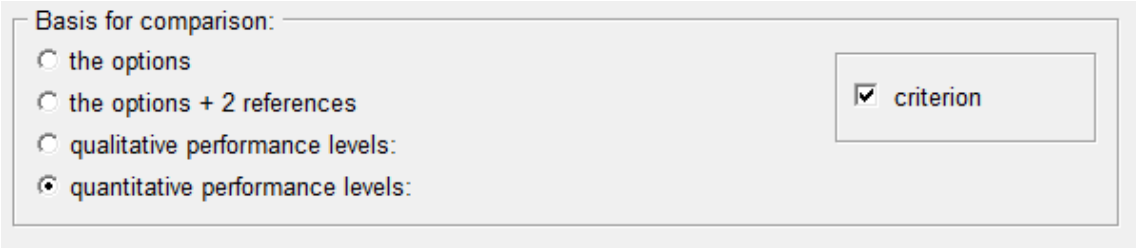

Figure 3.13 - Basis for Comparison Peer-Benchmarking
Source: Own Elaboration

In the nodes of the KPAs, we assign the Quantitative Performance Levels mode as shown in Figure 3.13.

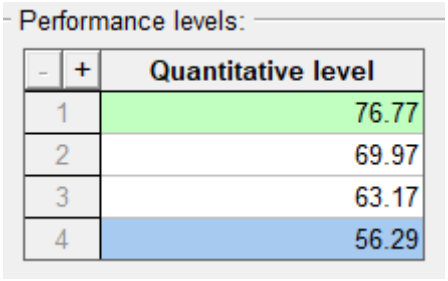

Figure 3.14 - Performance Levels Peer-Benchmarking
Source: Own Elaboration

The data of the KPAs are taken from the study of Case I; we inserted in the performance level table (Figure 3.14). The biggest one will be the upper reference (marked in green in Figure 3.14) and the smallest one the lower reference (marked in blue in Figure 3.14) The two central data are 1/3 and 2/3 of the distance between the reference upper and lower. These data will be used below in the matrix of judgments. Figure 3.14 is an example where we use the data of KPA 1 of Airport 1. For the other KPAs of the other airports we do it identical, but with their own data

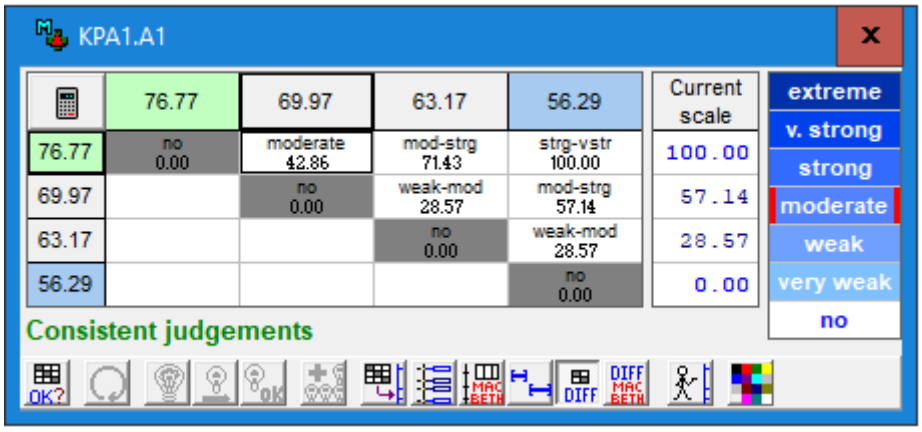

Figure 3.15 – Matrix of Judgements Peer-Benchmarking

Source: Own Elaboration

The matrix of judgments that we see in Figure 3.15 is that of the corresponding KPA. It is an example of KPA 1 of Airport 1, and we apply to each KPA its own matrix. These are made with the opinion of specialists and it originates the Current Scale seen as in Figure 3.16 and Figure 3.17. We underline that these scales take into account the opinion of specialists. All matrix of judgments can be found in Annex I.

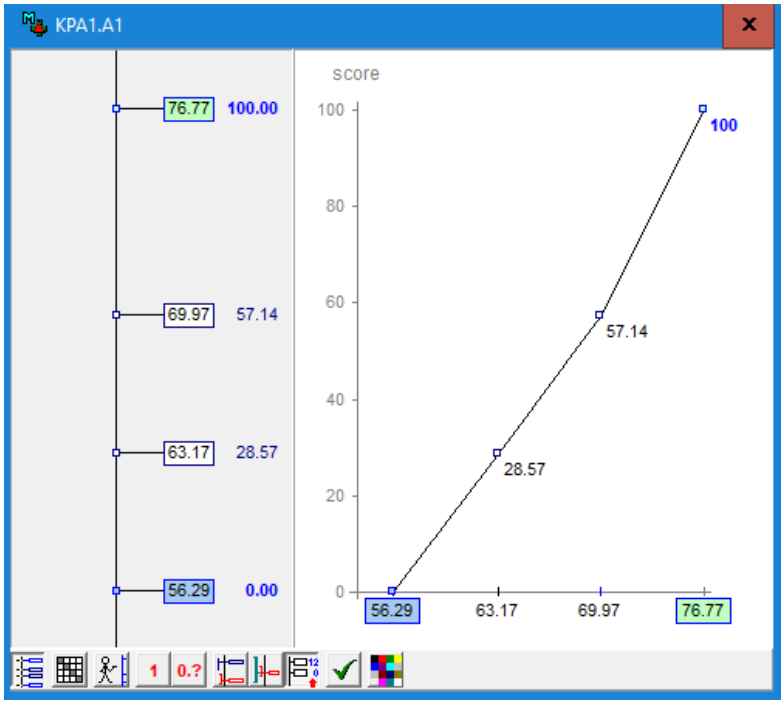

Figure 3.16 – New Scale graph Peer-Benchmarking

Source: Own Elaboration

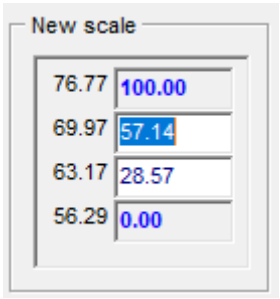

Figure 3.17 - New Scale Peer-Benchmarking
Source: Own Elaboration

Figure 3.16 and Figure 3.17 are an example of KPA 1 of Airport 1, and for the other KPAs, we do exactly the same.

After this, the data of the various KPAs are inserted into a table like the one in Figure 3.18. This figure is an example and only shows the KPAs of Airport 1. The KPAs of all the airports must be introduced in an identical way to the example.

Options	KPA1.A1	KPA2.A1	KPA3.A1	KPA4.A1	KPA5.A1	KPA6.A1
2014	76.77	0	34.3	61.88	11.02	17.82
2015	57.3	26.09	9.68	80.29	70.58	45.18
2016	56.29	45.62	47.18	45.17	56.37	76.76
2017	65.38	68.51	85.87	39.41	60.75	42.87
2018	69.27	100	82.57	42.86	75.99	74.38

Figure 3.18 - Table of performances Peer-Benchmarking
Source: Own Elaboration

Finally, what is done is to enter the weights of the airports accordingly the specialist's opinion, which we have done directly with Excel from where we took the graphs for aesthetic reasons. These weights can be seen in Table 3.7.

Table 3.7 - Weights of Airports Peer-Benchmarking
Source: Own Elaboration

Airports	Weights (%)
Airport 1	38,75
Airport 2	30,00
Airport 3	17,00
Airport 4	14,25

On the other hand, Table 3.8 depicts the weights of the KPAs.

Table 3.8 - Weights of KPAs

Source: Own Elaboration

KPA	Weights (%)
KPA 1 – Safety and Security	22,00
KPA 2 - Core	20,00
KPA 3 – Productivity / Cost Effectiveness	17,00
KPA 4 – Service Quality	15,00
KPA 5 – Financial / Commercial	15,00
KPA 6 - Environmental	12,00

When choosing weights, specialists were encouraged to take into account the following factors ordered from most to least important:

- Impact of the airport in GDP;
- Impact of the airport on the Tourism;
- Number of movements and passengers;
- What would be the impact to the country if the airport disappeared;
- If there are close and real transport infrastructures alternatives to the airport.

3.3 CASE I – Spanish Airports Self-Benchmarking Study

3.3.1 Airport 1 - Adolfo Suárez Madrid (Barajas). Partial Data Analysis

Then we will perform an internal analysis of the Airport 1. We will analyse the different KPIs of the 6 KPAs and we will finish with the analysis of all the KPAs together. The order that we follow is that of the weights of KPAs, that is, the KPA that weighs the most for specialists goes first, then the second that weighs the most... And within each KPA, each KPI is also ordered according to its weight from highest to lowest.

Table 3.9 - KPIs Safety and Security Airport 1

Source: Own Elaboration

Safety and Security	2014	2015	2016	2017	2018	Weight (%)
Runway Accidents	100	100	100	100	100	21,57
Runway Incursions	80	26,66	53,33	100	43,33	19,61

Safety and Security	2014	2015	2016	2017	2018	Weight (%)
Bird Strikes	100	95	98,33	8,89	-1,11	17,65
Public Injuries	38,93	47,85	-2,45	50,35	95,71	15,69
Occupational Injuries and Accidents	28,89	45,42	-1,11	68,75	99,17	13,73
Lost Work Time from Employee Accidents and injuries	100,26	-0,11	63,32	44,97	91,57	11,76

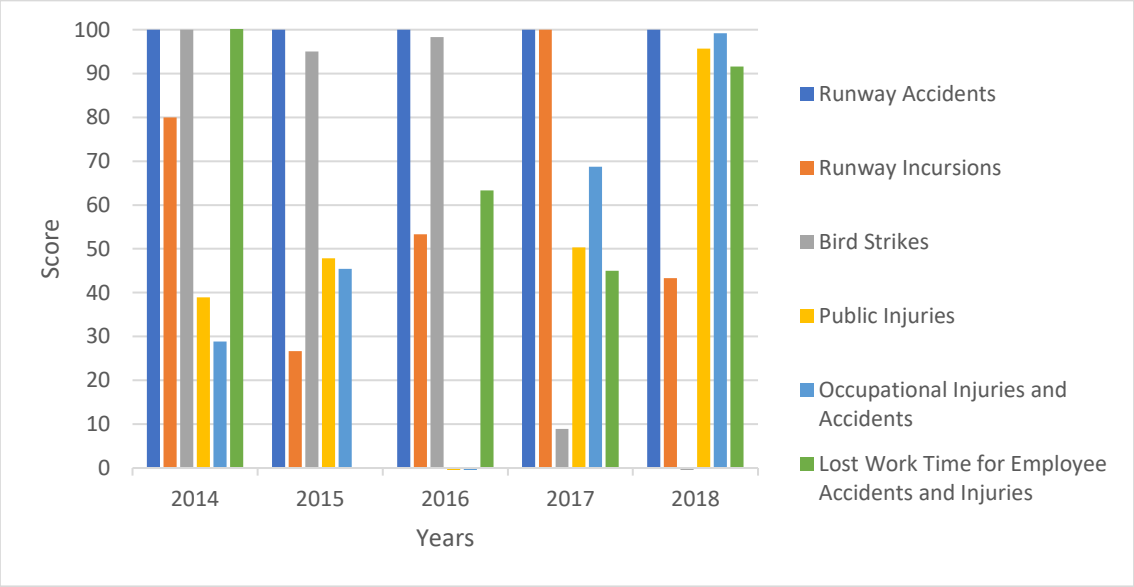

Figure 3.19 - KPIs Safety and Security Airport 1

Source: Own Elaboration

In Table 3.9 and Figure 3.19 we can observe the 6 KPIs of Safety and Security. Predictably, the values of Runway Accidents are at 100 since there have been no accident in the last 5 years at the airport. On the other hand, in the KPI of Runway Incursions, we can see how it is quite irregular over the years. It has an ascending character between 2015 and 2017 (during those years the number of Runway Incursions decreased), but decreasing in 2018 (increase the number of Runway Incursions). On the other hand, we can clearly observe the increase in the number of Bird Strikes over the years. We recall that Figure 3.19 shows the reality under the MACBETH scale, that is, the more points we see in the graph, the fewer values of Bird Strikes there are in reality. In the 3 remaining KPIs, which are Public Injuries, Occupational Injuries and Accidents, and LWT for Employee and Accident Injuries, we see how in Figure 3.19 they have a positive trend, leading to the reduction of these 3 KPIs in the reality of 2018 to 188 Public Injuries, 792 Occupational Injuries and Accidents, and 3801,6 hours by LWT from Employee and Accident Injuries. The complete table of these data is found in Annex II.

Table 3.10 - KPA 1 - Safety and Security

Source: Own Elaboration

KPA 1	2014	2015	2016	2017	2018
Safety and Security	76,77	57,30	56.29	65,38	69,27

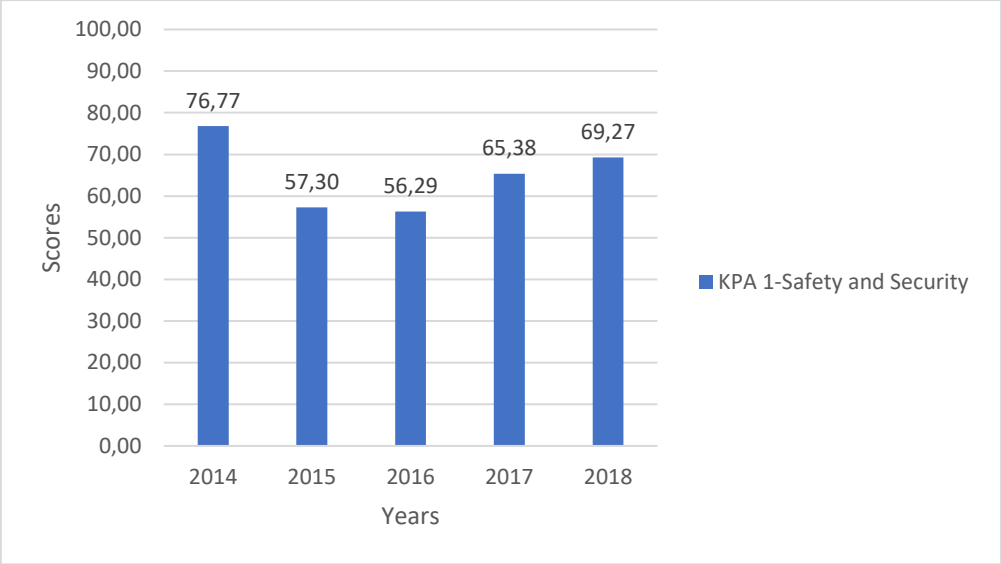

Figure 3.20 - KPA 1 - Safety and Security

Source: Own Elaboration

We can see in Table 3.10 and then graphically in Figure 3.20 as the maximum of Safety and Security was achieved in 2014, in 2015 it decreased 17,47. In 2018 they managed to recover by staying at 69,27, which is the second-best brand of the last 5 years.

Table 3.11 - KPIs Core Airport 1

Source: Own Elaboration

Core	2014	2015	2016	2017	2018	Weight (%)
Passengers	0	31,08	53,47	72,04	100	25,71
Aircraft Movements	0	35,7	52,88	66,89	100	22,86
Origin and Destination Passengers	0	32,7	40,29	67,55	100	20,00
Freight and Mail Loaded Unloaded	0	8,24	27,85	60,54	100	17,14
Destinations - Nonstop	0	13,9	48,64	75,67	100	14,29

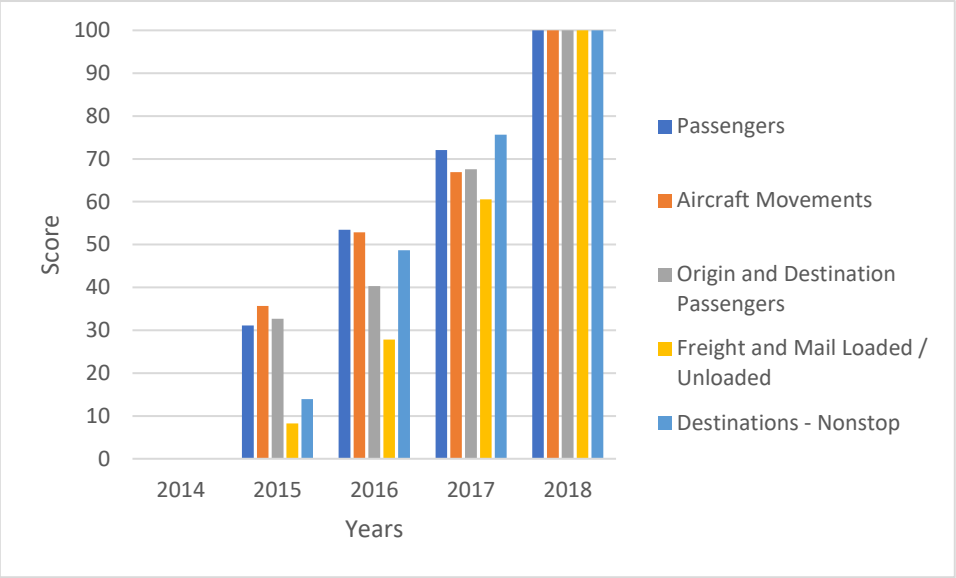

Figure 3.21 - KPIs Core Airport 1

Source: Own Elaboration

We proceed now to analyze the KPA 2 of Airport 2: Core. In Table 3.11 and Figure 3.21 the results of this KPA are very clear. The 5 KPIs are always ascending, having all 0 points in 2014 and ending 2018 all with 100 points. In Table 3.12 shown below, we can see the real data of this KPA and appreciate its differences between 2014 and 2018.

Table 3.12 - Real Data Core Airport 1

Source: Own Elaboration

	Passengers	Origination and Destination P.	Aircraft Movements	Freight and Mail Loaded / Unloaded	Destinations-Nonstop
2014	41.833.686	28.195.904	342.604	366.994	181
2018	57.891.340	37.050.457	409.832	518.859	218
Difference	16 Million	9 Million	66.396	315.135	37

Table 3.13 - KPA 2 - Core

Source: Own Elaboration

KPA 2	2014	2015	2016	2017	2018
Core	0,00	26,09	45,62	68,51	100,00

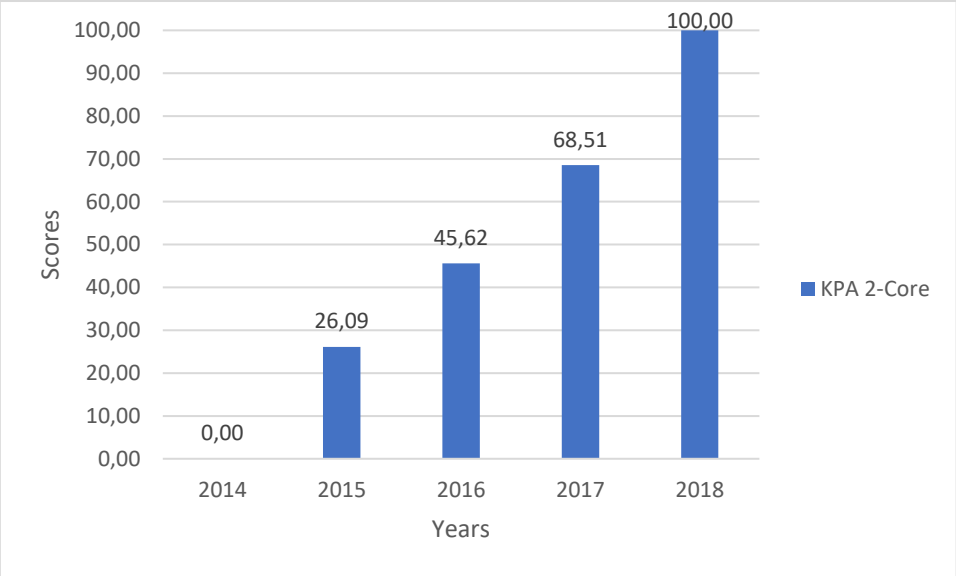

Figure 3.22 - KPA 2 - Core

Source: Own Elaboration

In Table 3.13 and Figure 3.22, we can see what we have already said, that KPA 2 at Airport 1 is totally positive and improves over the years with a very positive vision for the coming years.

Table 3.14 - KPIs Productivity / Cost Effectiveness Airport 1

Source: Own Elaboration

Productivity / Cost Effectiveness	2014	2015	2016	2017	2018	Weight (%)
Total Cost per Passenger	7,27	-0,3	55,3	100,12	95,01	14,29
Total Cost per Movement	63,32	-0,03	51,18	100	63,41	13,27
Operating Cost per Movement	100	0	22,97	61,29	17,85	12,24
Aircraft Movement per Gate	-0,14	35,68	52,93	66,97	99,83	11,22
Total Cost per WLU	31,03	-1,89	41,08	96,11	97,07	11,22
Operating Cost per WLU	53,5	1,67	40,75	98,93	100,4	10,20
Operating Cost per Passenger	24,96	0,04	54,94	99,96	94,57	10,20
Passengers per Employee	0,07	26,63	54,49	76,06	99,95	9,18
Aircraft Movement per Employee	14	40,67	53,5	63,97	88,7	8,16

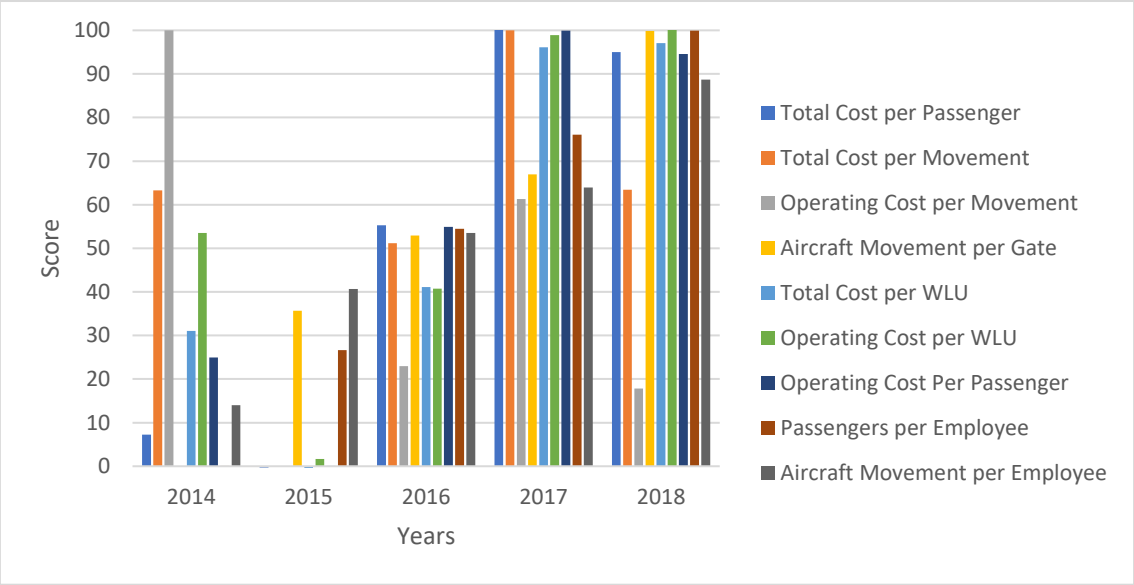

Figure 3.23 - KPIs Productivity / Cost Effectiveness Airport 1

Source: Own Elaboration

We have now the third KPA: Productivity / Cost Effectiveness. In Table 3.14 and Figure 3.23 we can differentiate 3 important years. First 2015, it is by far the worst year with KPIs as Total Cost per Passenger, Total Cost per Movement, and Operating Cost per Movement at 0. These three KPIs, that 2015 has at 0, are the three most important for specialists, that is to say, those who have more weight in this KPA. On the other hand, we have the years 2017 and 2018, with maximums in many of their KPIs. Except for the KPI Operating Cost per Movement that, as shown in Figure 3.23, is quite irregular, we could say that the others rise from 2015 to 2017, and from 2017 to 2018 they remain constant with small movements.

Table 3.15 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

KPA 3	2014	2015	2016	2017	2018
Productivity / Cost Effectiveness	34,30	9,68	47,18	85,87	82,57

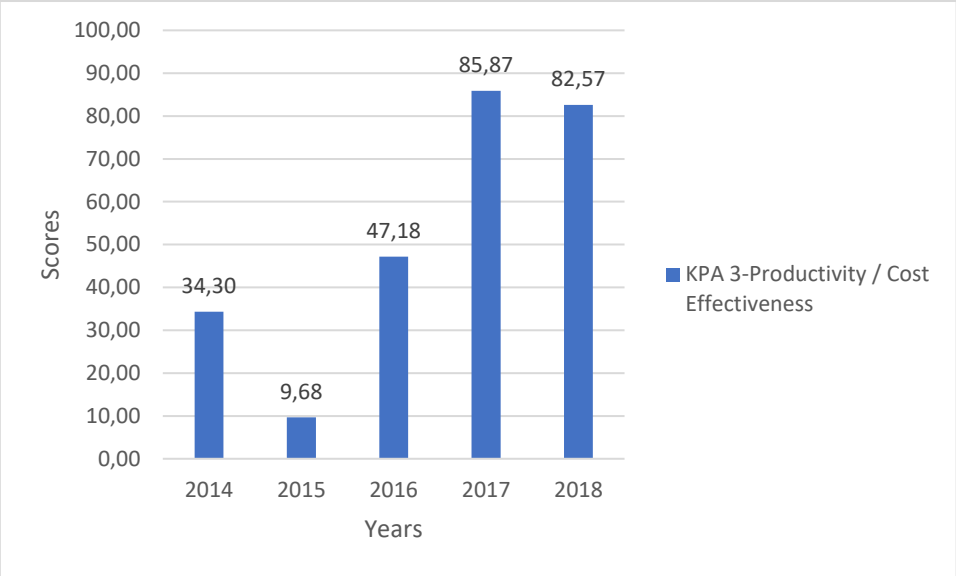

Figure 3.24 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

As expected after having seen Table 3.15 and Figure 3.24, when applying the weights of the specialists to the eight KPIs, the KPA 3 of Airport 1 reaches its maximum in 2017 and in 2018 it has a drop of 3,3 points. Despite having dropped some points, the future of this KPA at this airport is quite promising as it is currently very positive.

Table 3.16 - KPIs Service Quality Airport 1

Source: Own Elaboration

Service Quality	2014	2015	2016	2017	2018	Weight (%)
Customer Satisfaction	0	41,07	7,14	83,93	100	15,85
Gate Departure Delay	76	89,5	100	0	8	14,63
Baggage Delivery Time	76,2	60,44	0	63,73	100	13,41
Taxi Departure Delay	86,39	100	65,98	8,93	0	12,20
Security Clearing Time	29,66	100	24,39	18,47	-0,06	12,20
Border Control Clearing Time	51,43	100	78,57	23,81	0	10,98
Check-in to Gate Time	100	67,79	0	16,77	24,39	10,98
Practical Hourly Capacity	100	100	100	100	100	9,76

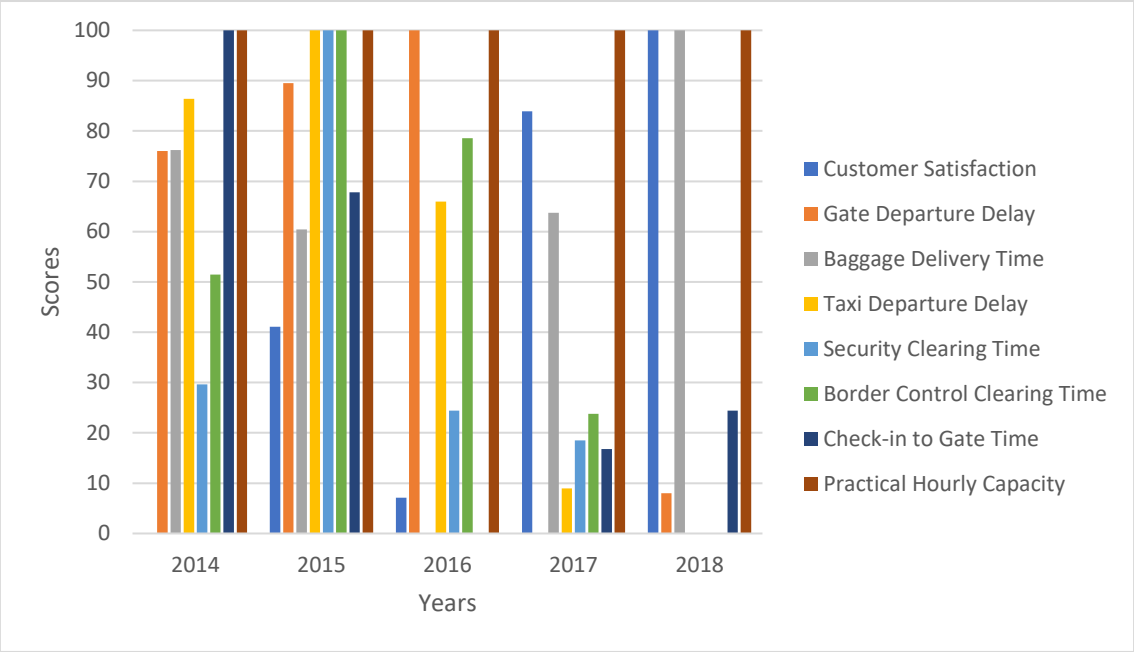

Figure 3.25 - KPIs Service Quality Airport 1

Source: Own Elaboration

This is the turn to analyse the KPA 4 of Airport 1, Service Quality (Table 3.16 and Figure 3.25). Regarding the most important KPI, Customer Satisfaction, we see that it rises from 2014 to 2015, decreases in 2016, and then rises to its maximum value of 2018. Gate Departure Delay surprises in its behaviour since in the first years it undergoes improvements until in 2017 it falls and stays down. Baggage Delivery Time, Taxi Departure Delay, Security Clearing Time, and Border Control Clearing Time are characterized by their randomness since each one takes different routes but maintaining an element in common: in 2015 all have good values. Finally, we must highlight the KPI Practical Hourly Capacity, which according to AENA reports has been maintained for 48 the last 5 years, so in Table 3.16 and Figure 3.25, it appears in all the years with 100 points.

Table 3.17- KPA 4 - Service Quality

Source: Own Elaboration

KPA 4	2014	2015	2016	2017	2018
Service Quality	61.88	80.29	45.17	39.41	42.86

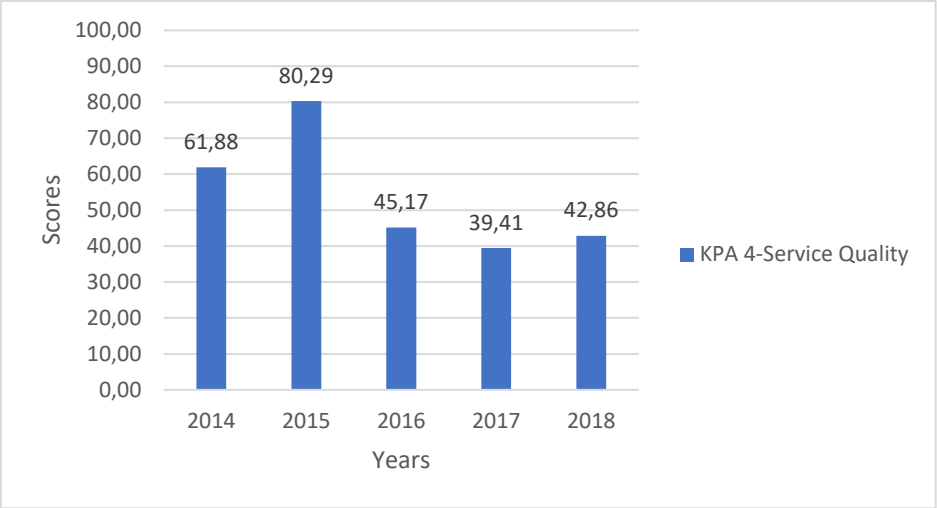

Figure 3.26 - KPA 4 - Service Quality

Source: Own Elaboration

It does not strike us to see the results of Table 3.17 and Figure 3.26 after analysing the KPIs individually. By far the best year of Service Quality is 2015, and the years 2016, 2017 and 2018 are penalized by the increase of the average waiting times. We want to comment on something that stands out: why if 2015 has such a good result in KPA 4 it has the 3rd place in the KPI Customer Satisfaction? Well, because the KPI Customer Satisfaction report raises many more questions related to comfort and customer satisfaction such as WI-FI, etc., besides the waiting times, which is what this KPA focuses on.

Table 3.18 - KPIs Financial / Commercial Airport 1

Source: Own Elaboration

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Aeronautical Revenue per Passenger	6,07	100	29,28	0	24,16	16,05
Aeronautical Revenue per Movement	-0,02	57,82	62,68	74,47	100,01	14,81
Non-Aeronautical Operating Revenue per Passenger	0,35	83,24	66,51	70,56	100,09	13,58
EBITDA per Passenger	0,48	99,26	68,98	92,22	85,19	13,58
Non-Aeronautical Revenue as Percentage of Total Operating Ratio	0	52,69	52,58	65,79	100,08	12,35
Debt to EBITDA Ratio	0	38,23	65,82	88,61	99,87	11,11
Debt Service as Percentage of Operational Revenue	100,57	81,81	55,19	24,43	0,43	9,88
Long-Term Debt Passenger	-0,01	27,18	54,69	83,7	100,02	8,64

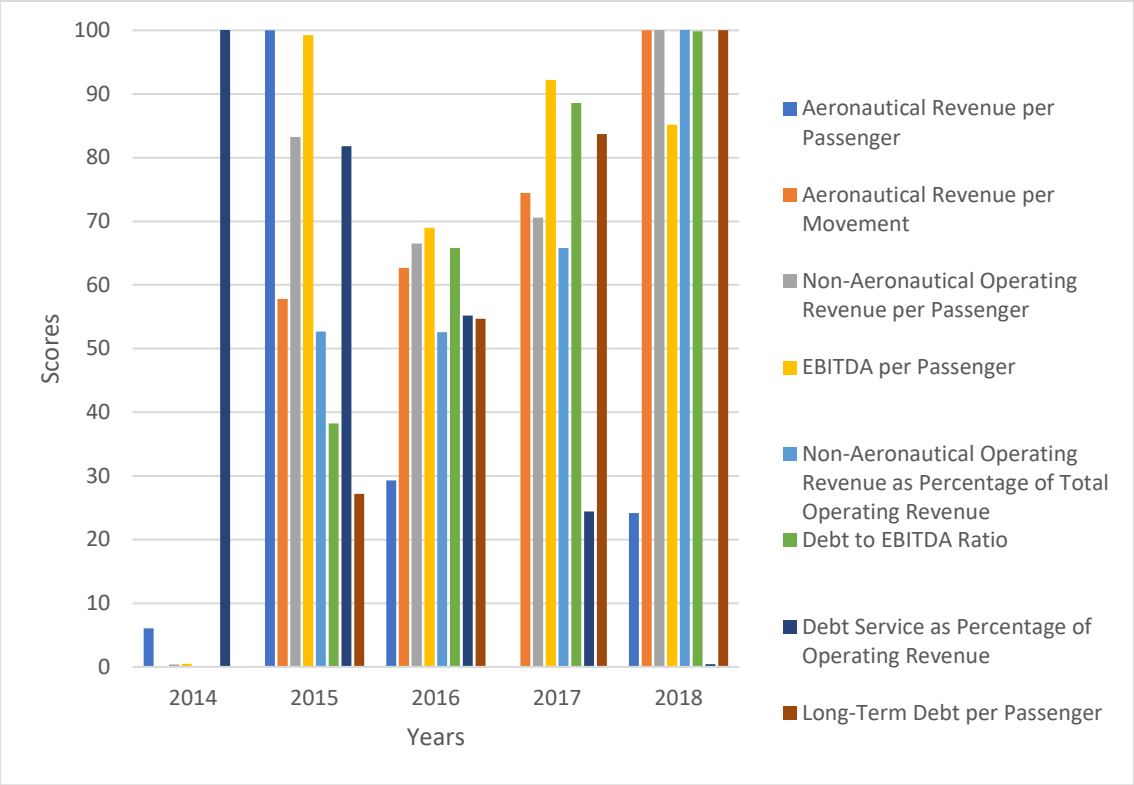

Figure 3.27 - KPIs Financial / Commercial Airport 1

Source: Own Elaboration

Now it's the turn of the KPA Financial / Commercial of Airport 1 (Table 3.18 and Figure 3.27). Most KPIs have very few points in 2014 except for Debt Service as Percentage of Operating Revenue, which has maximum value in 2014 and decreases until 2018. This KPI is the second least important according to specialists, so this will barely affect positively in the final assessment of this KPA in 2014. The year with the highest Aeronautical Revenue per Passenger is 2015 by far, followed by 2016 and 2018. In contrast, we can see how the KPIs Aeronautical Revenue per Movement, Non-Aeronautical Operating Revenue as Percentage of Total, Operating Revenue, Debt to EBITDA Ratio, and Long-Term Debt per Passenger have an upward trajectory from 2014 to 2018. And finally, a comment for Non-Aeronautical Operating Revenue per Passenger KPI that has a high value in 2015, decreases in 2016 and 2017, but in 2018 it reaches its maximum value of 100 points.

Table 3.19 - KPA 5 - Financial / Commercial

Source: Own Elaboration

KPA 5	2014	2015	2016	2017	2018
Financial / Commercial	11,02	70,58	56,37	60,75	75,99

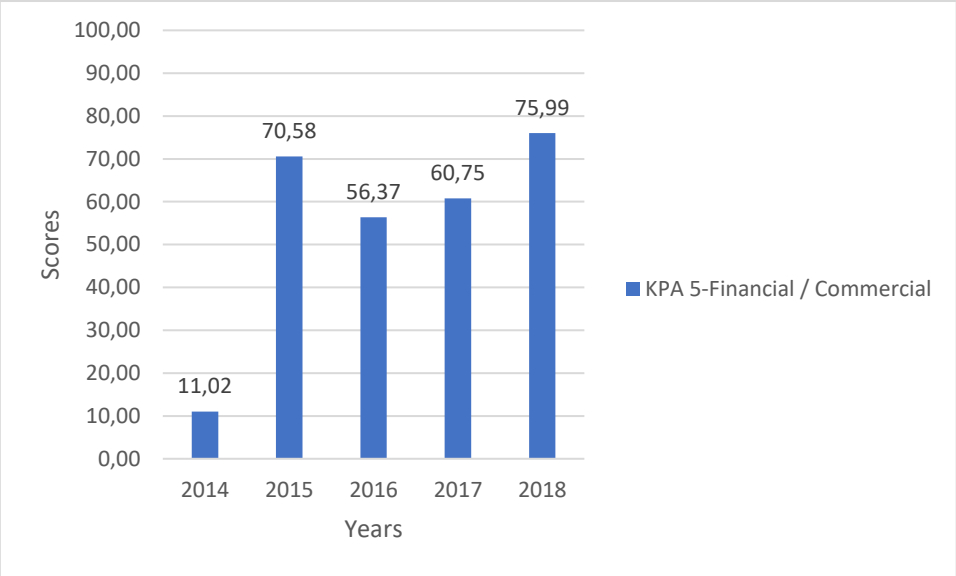

Figure 3.28 - KPA 5 - Financial / Commercial

Source: Own Elaboration

In Table 3.19 and Figure 3.28, we can see how bad 2014 is concerning the financial and commercial field. In 2015 there is a very sharp change for the better, increasing 59,56 points, this being the second-best mark of the study. In 2016 and 2017 there is a decline that is not very noticeable and in 2018 the maximum score is reached with a score of 75,99 for this KPA. It is positive for the future to see how the airport has improved positively in the KPA Financial / Commercial for the last three years.

Table 3.20 - KPIs Environmental Airport 1

Source: Own Elaboration

Environmental	2014	2015	2016	2017	2018	Weight (%)
Carbon Footprint	0	16,67	100	66,67	100	21,21
Waste Recycling	0	52,28	97,08	46,7	100	18,18
Renewable Energy Purchased by the Airport (%)	14,67	0,25	100,27	26,74	69,59	18,18
Waste Reduction (%)	0	100	71,85	1,18	67,46	15,15
Energy Usage per Square Meter of Terminal	100	95,24	6,35	33,48	0	15,15
Water Consumption per Passenger	0	20,73	64,55	83,53	100	12,12

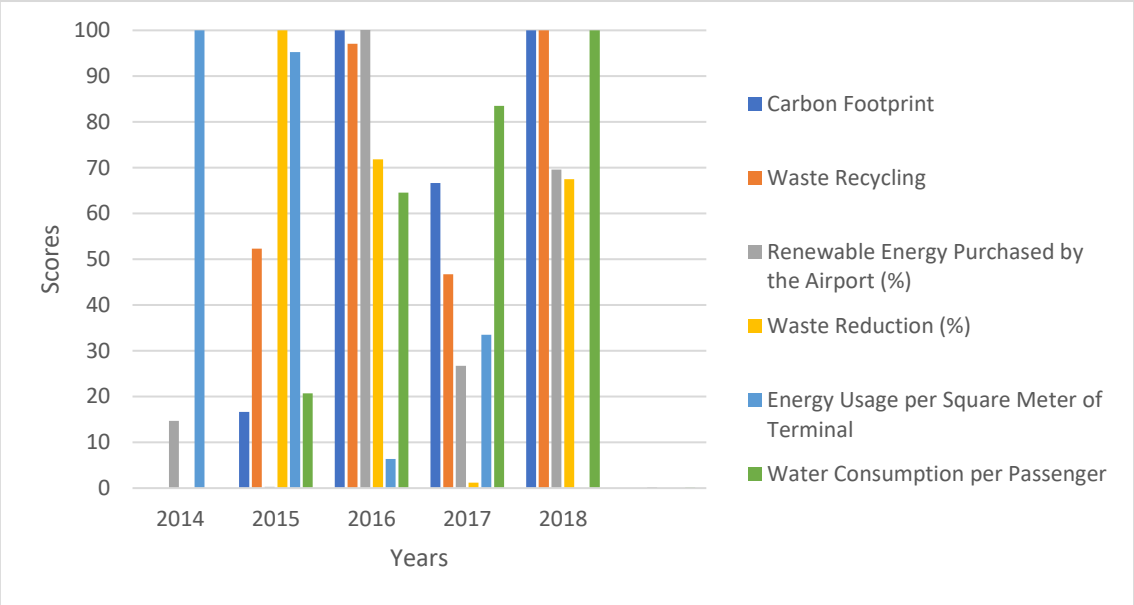

Figure 3.29 - KPIs Environmental Airport 1

Source: Own Elaboration

We have reached the last KPA to analyze from Airport 1, Environmental. First, a comment for the values of the KPIs that do not seem to follow any kind of order except the Water Consumption per Passenger KPI, which we depict in Table 3.20 and Figure 3.29, as it increases over the years until reaching 100 points in 2018. Again, this means that the water consumption per passenger decreases from 2014 to 2018, specifically from 25.28 lit/pax to 20.11 lit/pax. We can see the improvement of the last few years of Carbon Footprint, which has two maximums in 2016 and 2018. This is reflected by AENA in the airport report showing that it has received Level 2 certified by ACI Europe's Airport Carbon Accreditation Program for its reduced carbon footprint. The levels of Renewable Energy Purchased by the Airport reach a maximum in 2016 and the second highest is in 2018. The levels of use of renewable energy purchased by the airport are very low for such a large air infrastructure.

It can be understood the decrease in Energy Usage Score per Square Meter of terminal that is observed in Figure 3.29 because the dimensions of the terminals have not changed (940.000 m^2) and the number of passengers has increased, so also much more energy is consumed. Waste Recycling KPI has a positive tendency to increase more and more. And finally, the KPI Waste Reduction is the only one that has a random trend. It depends a lot on the year and has the maximum in 2015 and the minimum in 2014.

Table 3.21 - KPA 6 - Environmental

Source: Own Elaboration

KPA 6	2014	2015	2016	2017	2018
Environmental	17,82	45,18	76,76	42,87	74,38

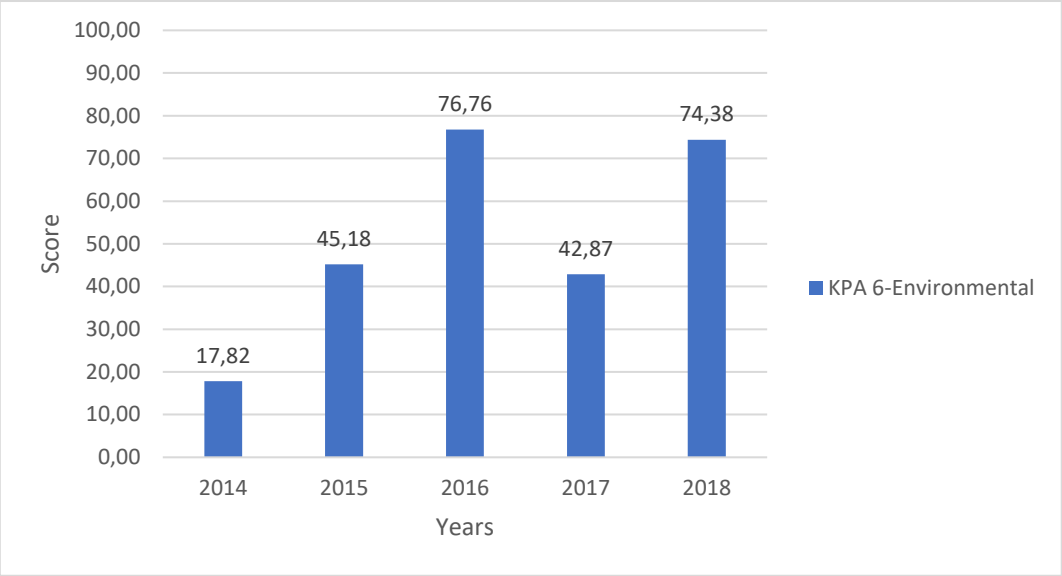

Figure 3.30 - KPA 6 - Environmental

Source: Own Elaboration

The KPA 6, Environmental, is the one that has less weight for the analysis of the efficiency of an airport according to the specialists with 12%. We can see in Table 3.21 and Figure 3.30 how we have two very good years, 2016 and 2018, two mediocre years, 2015 and 2017, and a relatively bad one, 2014. Little by little this KPA is becoming more important in airports since it was the last one to join.

Table 3.22 - KPAs Airport 1

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018	Weight (%)
Safety and Security	76,77	57,30	56,29	65,38	69,27	0,22
Core	0,00	26,09	45,62	68,51	100,00	0,20
Productivity / Effectiveness	34,30	9,68	47,18	85,87	82,57	0,17
Service Quality	61,88	80,29	45,17	39,41	42,86	0,15
Financial / Commercial	11,02	70,58	56,37	60,75	75,99	0,15
Environmental	17,82	45,18	76,76	42,87	74,38	0,12

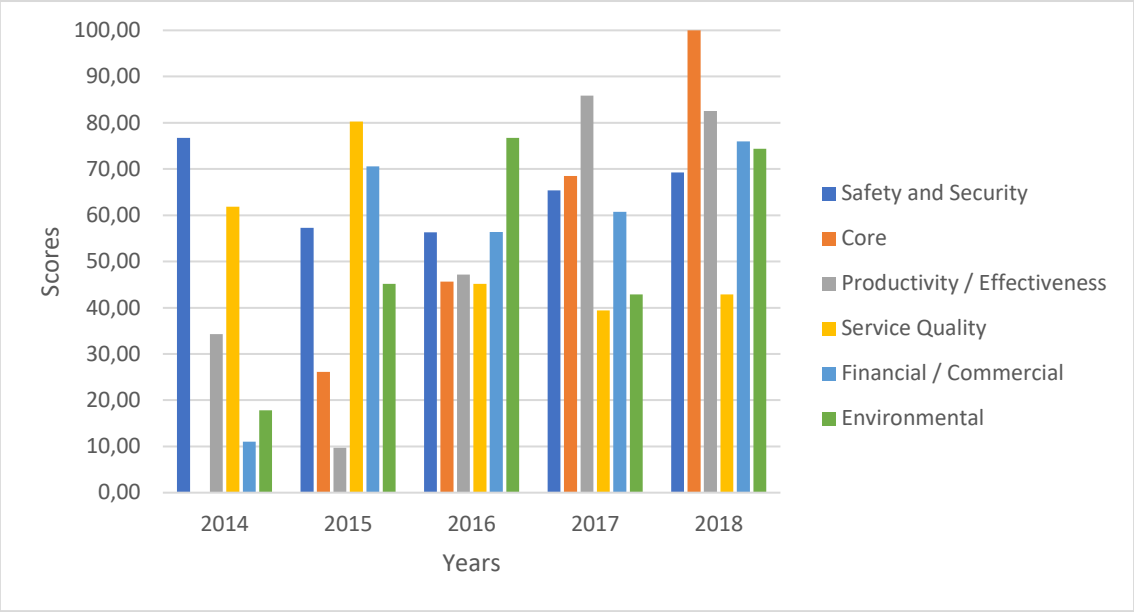

Figure 3.31 - KPAs A1

Source: Own Elaboration

It is curious to analyse Table 3.22 and Figure 3.31 because each year has a different maximum KPI. First, 2014 has the best results from KPA 1 - Safety and Security. Afterward, 2015 has the best results of KPA 4 - Service Quality. 2016 has the best results from KPA 6 - Environmental. On the other hand, 2017 has the best results of KPA 3 - Productivity / Effectiveness. Finally, 2018 has the best results from KPA 2 – Core, and KPA 5 - Financial / Commercial.

Table 3.23 - % Efficiency A1

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018
% EFFICIENCY	35,55	46,90	53,53	62,26	75,27

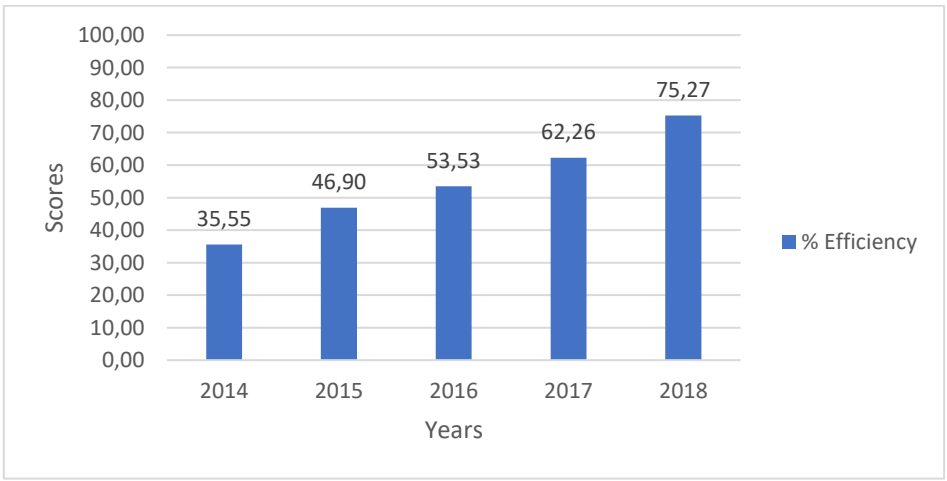

Figure 3.32 - % Efficiency Airport 1

Source: Own Elaboration

In Table 3.23 and Figure 3.32 we can see the final results of the Airport 1 study. To the data of Table 3.22, we applied the weights of the specialists and the result is very positive towards the future. We can see how the airport has been improving year after year and it seems that the same behaviour will continue to improve towards the future. The final efficiency of the airport after this study is 75,27% and the increase per year is about 10%. As a proposal to the airport, it should focus on improving its KPAs that fail the most, which are: KPA 1 - Safety and Security and KPA 4 - Service Quality.

3.3.2 Airport 2 - Josep Tarradellas Barcelona (El Prat). Partial Data Analysis

Now is the time to analyze the Airport 2. Let's first see the 6 KPAs by weight order of the specialists and within each KPA all their KPIs also sorted by weight. In the end, we will make a joint analysis of all the KPAs in order to obtain the efficiency percentage per year of this airport.

Table 3.24 - KPIs Safety and Security Airport 2
Source: Own Elaboration

Safety and Security	2014	2015	2016	2017	2018	Weight (%)
Runway Accidents	100	100	100	100	100	21,57
Runway Incursions	30	93,33	6,67	-16,67	20	19,61
Bird Strikes	0	75,56	77,78	92,22	76,67	17,65
Public Injuries	0	8	38,57	96,79	72,14	15,69
Occupational Injuries and Accidents	52,67	-0,56	36	95	34,66	13,73
Lost Work Time from Employee Accidents and injuries	52,96	0,03	41,78	99,95	87,25	11,76

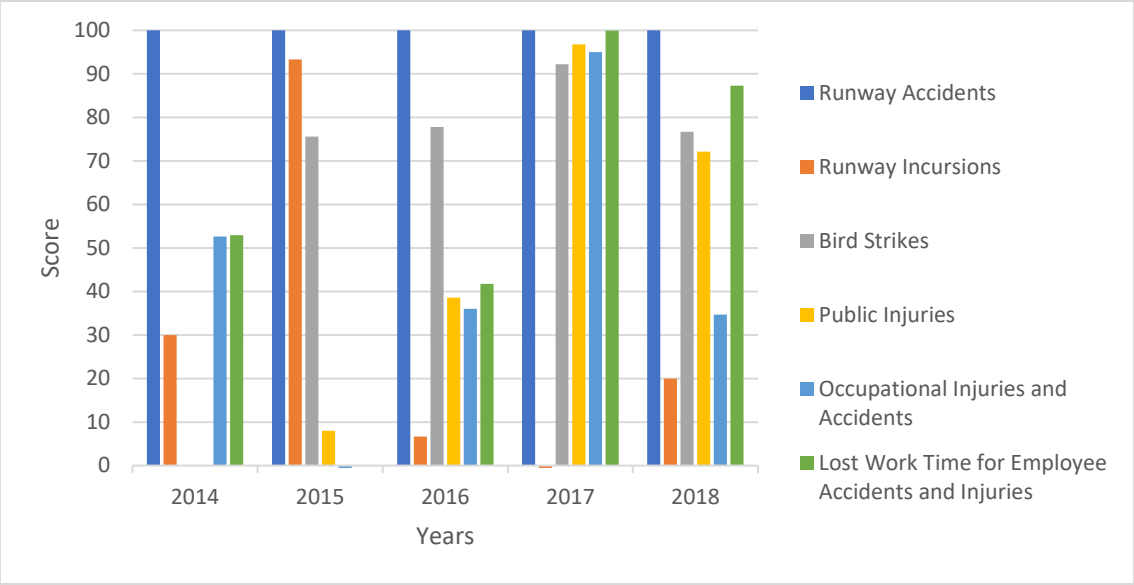

Figure 3.33 - KPIs Safety and Security Airport 2

Source: Own Elaboration

Firstly, we will analyze the airport's Safety and Security KPIs, since its weight according to specialists is 22%. When looking at Table 3.24 and Figure 3.33, they stand out among the rest of KPIs Runway Accidents. In the 5 years, this KPI has a score of 100 points since there have been no accidents.

The year with the best results is 2017, which has a very good score in Bird Strikes. We can see from the graph that this KPI through the time is reducing its number of incidents as well as Public Injuries. Also, note from 2017 the good results of the KPI Occupational Injuries and Accidents and therefore, logically, as the number of accidents is reduced; the KPI LWT for Employee Accidents and Injuries is also reduced. Finally, we must highlight the KPI Runway Incursions, which unlike all others, have its maximum score in 2015 and unlike the others in 2017, where the other KPIs had their maximum, it has a minimum.

Table 3.25 - KPA 1 - Safety and Security

Source: Own Elaboration

KPA 1	2014	2015	2016	2017	2018
Safety and Security	40,91	54,39	52,51	74,56	65,36

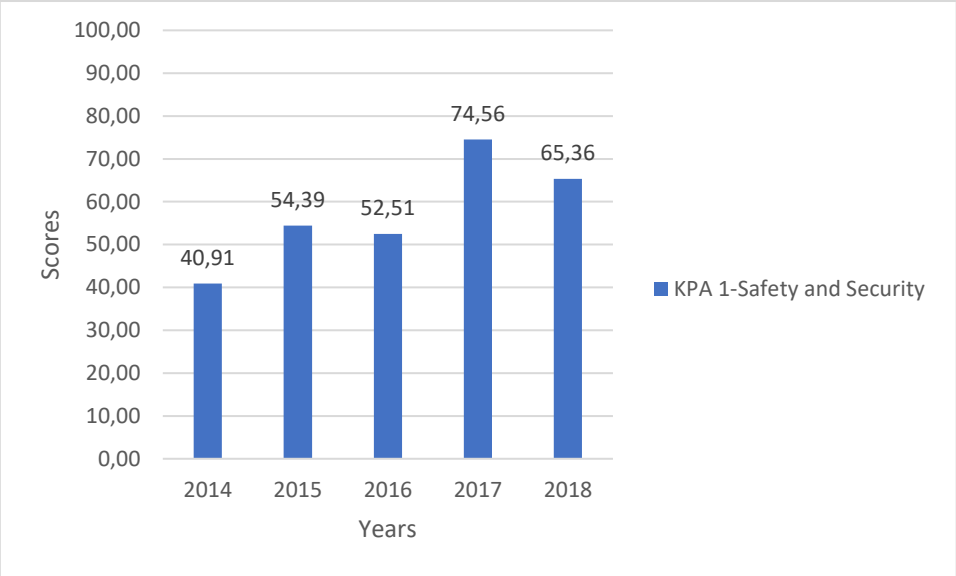

Figure 3.34 - KPA 1 - Safety and Security

Source: Own Elaboration

Looking at Table 3.25 and Figure 3.34, we visualize the maximum in 2017 followed by a difference of 9,2 points by 2018. Despite this drop in 2018, when looking at the graph of KPA 1 - Safety and Security, we can see how there is a growing trend, which shows that the airport is taking measures to improve safety, and we foresee that over the years the score of this KPA will improve while measures to improve it are promoted.

Table 3.26 - KPIs Core Airport 2

Source: Own Elaboration

Core	2014	2015	2016	2017	2018	Weight (%)
Passengers	0	17,06	52,29	77,11	100	25,71
Aircraft Movements	0	9,71	46,35	76,61	100	22,86
Origin and Destination Passengers	0	17,07	43,46	70,42	100	20,00
Freight and Mail Loaded Unloaded	0	17,71	40,41	69,18	100	17,14
Destinations - Nonstop	34,28	0	17,13	47,14	100	14,29

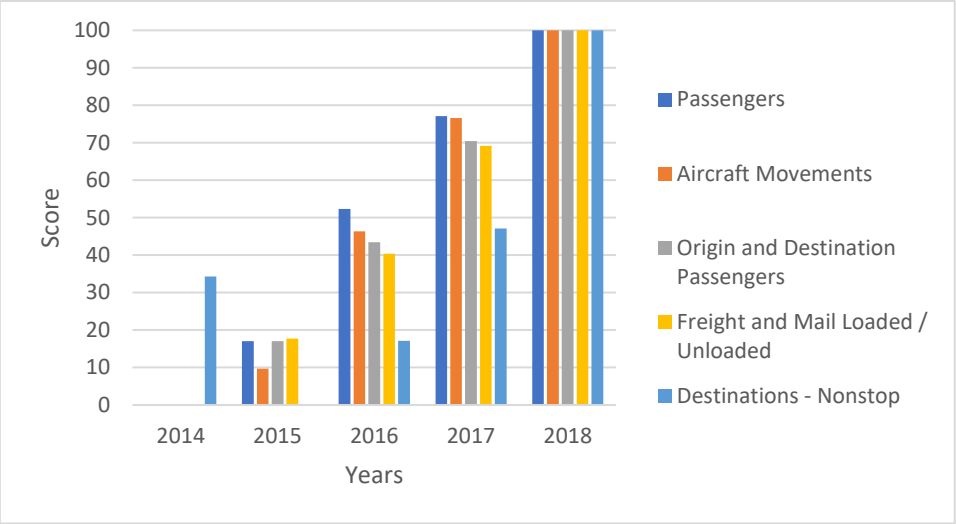

Figure 3.35 - KPIs Core Airport 2

Source: Own Elaboration

Now we are going to carry out the study at the 5 KPIs of KPA 2 - Core of Airport 2 (Table 3.26 and Figure 3.35). At first glance, we see that it is a totally growing graph with some exceptions. We see how the values of all the KPIs in 2018 are 100 points. This is a very good sign of the airport's progress and to see more clearly the improvement from 2014 to 2018 it is convenient to observe Table 3.27, which shows the differences between 2014 and 2018 of the airport's actual data.

Table 3.27 - Real data Core Airport 2

Source: Own Elaboration

	Passengers	Origination and Destination P.	Aircraft Movements	Freight and Mail Loaded / Unloaded	Destinations-Nonstop
2014	37.558.981	35.981.503	283.851	102.706	207
2018	50.172.457	46.660.385	335.651	172.940	219
Difference	12,5 million	10,5 million	51.800	70.234	12

Returning to Figure 3.35, we must highlight the KPI Destinations - Nonstop. Since in 2014 the score is higher than in 2015 and 2016. This was due to a drastic reduction in routes that companies did not consider to be profitable. In 2014, the airport had 207 destinations and in 2015, 199; in 2017, it has recovered the 2014 figures (Table 3.27).

Table 3.28 - KPA 2 - Core

Source: Own Elaboration

KPA 2	2014	2015	2016	2017	2018
Core	4,90	13,06	42,11	70,02	100,00

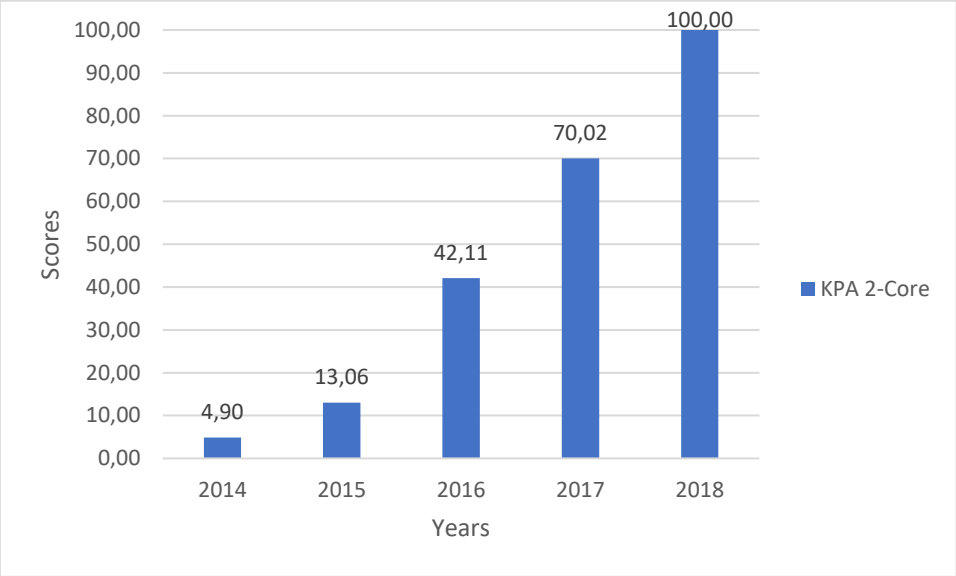

Figure 3.36 - KPA 2 - Core

Source: Own Elaboration

After having seen Table 3.28 and Figure 3.36, the results of the KPA 2 - Core of Airport 1 were expected. We can see how this KPA is growing over the years and has good prospects for the future.

Table 3.29 - KPIs Productivity / Cost Effectiveness Airport 2

Source: Own Elaboration

Productivity / Cost Effectiveness	2014	2015	2016	2017	2018	Weight (%)
Total Cost per Passenger	6,17	0	54,32	100	95,43	14,29
Total Cost per Movement	48,54	0	42,91	100	70,64	13,27
Operating Cost per Movement	100	0	21,63	84,12	37,78	12,24
Aircraft Movement per Gate	0,02	9,72	46,34	76,57	99,94	11,22
Total Cost per WLU	0	16,05	53,85	92,31	99,62	11,22
Operating Cost per WLU	0,67	10,76	48,36	91,44	100,85	10,20
Operating Cost per Passenger	24,17	0	54,95	100	95,87	10,20
Passengers per Employee	0	14,63	53,06	80,4	99,95	9,18
Aircraft Movement per Employee	6,42	14,8	46,44	72,57	92,67	8,16

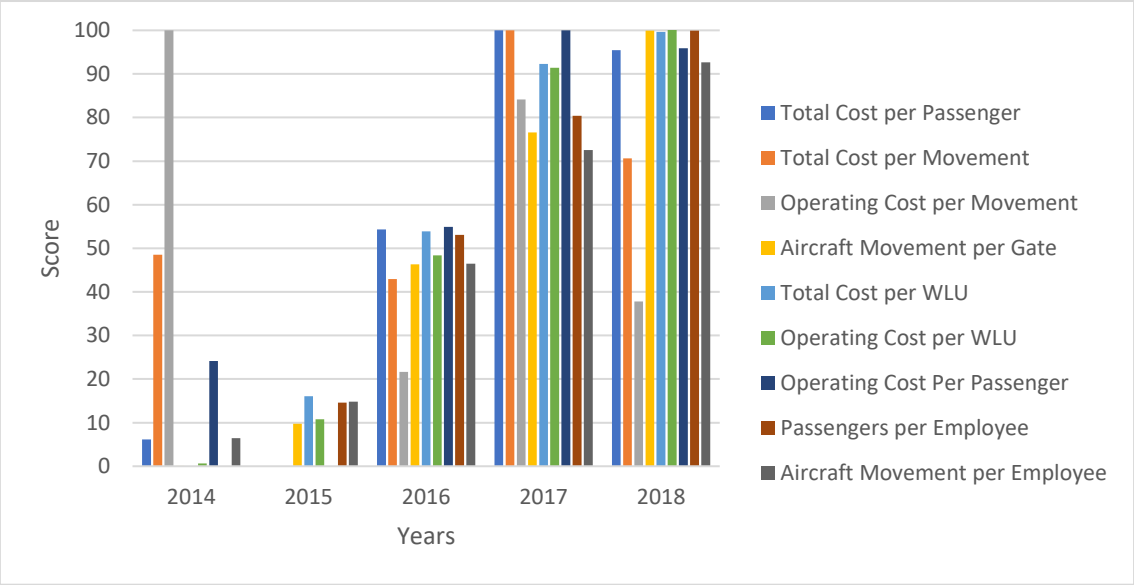

Figure 3.37 - KPIs Productivity / Cost Effectiveness Airport 2

Source: Own Elaboration

Let's now proceed to the analysis of the KPIs of KPA 3 - Productivity / Cost Effectiveness of Airport 2 (Table 3.29 and Figure 3.37). We can see how the KPIs Aircraft Movement per employer, Passengers per employee, Operation Cost per WLU, Total Cost per WLU, and Aircraft Movement per Gate have increased from 2014 to 2018. On the other hand, we have the KPIs Total Cost per Passenger, Total Cost per Movement, and Operating Cost per Passenger which are also increasing but have the maximum in 2017 instead of 2018. And finally, a comment on the KPI Operating Cost per Movement, which has its highest score in 2014 and its minimum in the following year, 2015. This KPI in 2018 has a score of 37,78, which makes it the worst KPI score of 2018.

Table 3.30 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

KPA 3	2014	2015	2016	2017	2018
Productivity / Cost Effectiveness	22,62	6,54	46,54	89,63	86,83

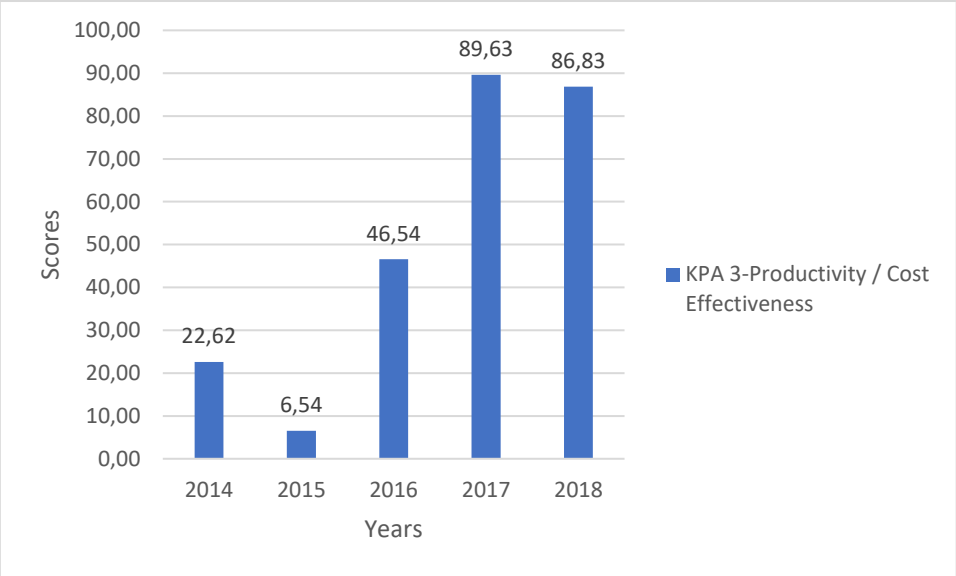

Figure 3.38 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

In Table 3.30 and Figure 3.38, which represents KPA 4 - Productivity / Effectiveness, we clearly see two parts. One of the lowest values belongs to the years 2014 and 2015 where the worst year is 2015 with a score of 6,54. And the part of 2017 and 2018, which has very high values, specifically 2017, with the maximum of this KPA being 89,63. We can say that the graph is growing and if one continues to promote this KPA it will have good prospects for the future.

Table 3.31 - KPIs Service Quality Airport 2

Source: Own Elaboration

Service Quality	2014	2015	2016	2017	2018	Weight (%)
Customer Satisfaction	0	12,5	0	88,75	100	15,85
Gate Departure Delay	0	43,75	100	59,38	46,88	14,63
Baggage Delivery Time	9,52	53,97	100	0	3,17	13,41
Taxi Departure Delay	46,33	100	30,89	0	54,05	12,20
Security Clearing Time	53,23	100,15	41,61	16,12	0,1	12,20
Border Control Clearing Time	100	47,62	10,71	0	41,27	10,98
Check-in to Gate Time	10,94	100	3,13	32,03	0	10,98
Practical Hourly Capacity	100	100	100	100	100	9,76

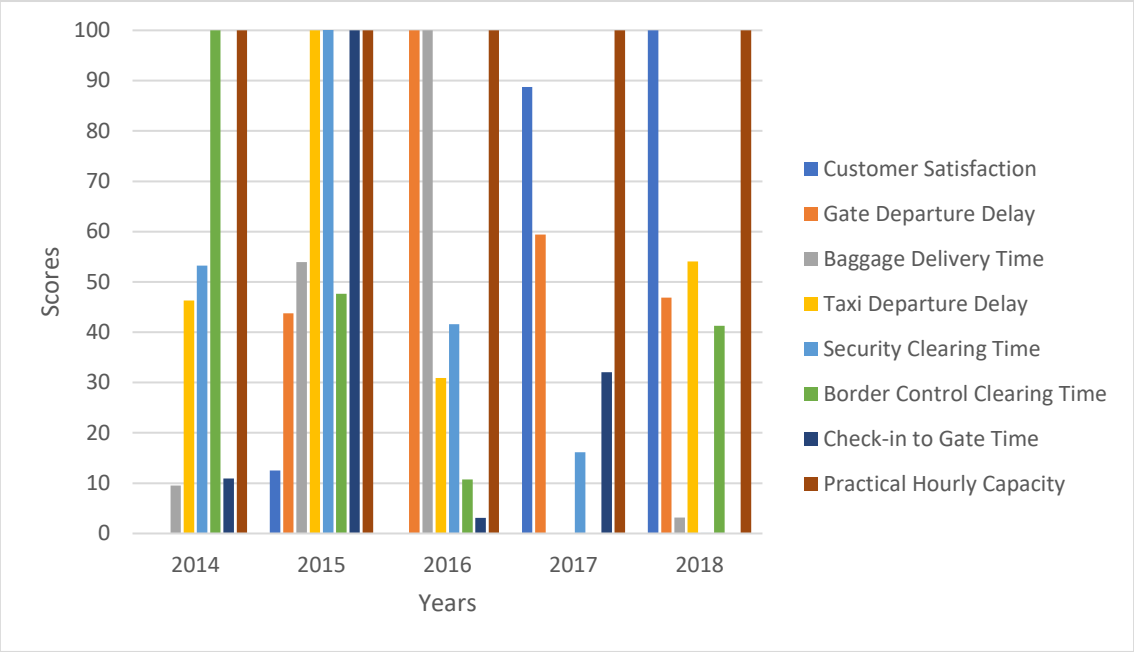

Figure 3.39 - KPIs Service Quality Airport 2

Source: Own Elaboration

We now proceed to study the KPIs of KPA 4 - Service Quality of Airport 2. Table 3.31 and Figure 3.39 draws attention for its randomness since we can see that in each year there is at least one KPI with maximum score. Before starting to analyze year after year, we see how the KPI Practical Hourly Capacity is at 100 points every year. This is because they have maintained the data of 48 flights per hour during the 5 years at this airport. We see now 2014, where we find the maximum score of the KPI Border Control Clearing Time, which decreases slowly until 2017 where its score is minimal, and it goes back in 2018. On the other hand, we have 2015, which is the year where we have more KPIs with a maximum score like the KPI Taxi Departure Delay that decreases until 2017 and goes back in 2018. The KPI Security Clearing Time also has its maximum in 2015 and that decreases until it reaches its minimum in 2018. The best data of 2015 is from the KPI Check-in to Gate Time, since it is much higher than the rest of the 4 years, although this value is the second most important of this KPA for specialists. In 2016 we found the maximum in Gate Departure Delay. This KPI will decrease until 2018; even so, the value of 2018 is higher than that of 2014 and 2015. Finally, a comment on the maximum of 2018 that belongs to KPI Customer Satisfaction. In this KPI there is a big difference between very low values from 2014 to 2016 and very high values from 2017 to 2018.

Table 3.32 - KPA 4 - Service Quality

Source: Own Elaboration

KPA 4	2014	2015	2016	2017	2018
Service Quality	35,36	66,01	48,16	38,00	44,03

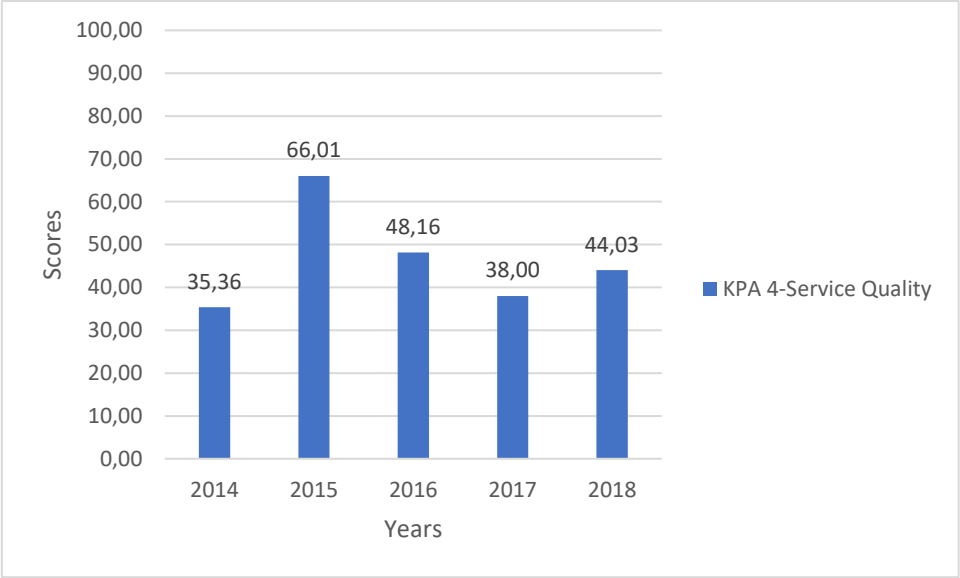

Figure 3.40 - KPA 4 - Service Quality

Source: Own Elaboration

After the randomness of the values in Table 3.31 and Figure 3.39, applying the weights we obtain Table 3.32 and Figure 3.40, where we observe that there is a year that exceeds the normality of the rest. That year is 2015. 2018 is in third place and 2017 fourth. Being such a large airport, it is understandable that waiting times are increasingly higher when the number of passengers increases and not the facilities as is the case. That is why the airport should suggest measures or reforms to improve this KPA and not stagnate in the mediocrity of the last 3 years.

Table 3.33 - KPIs Financial / Commercial Airport 2

Source: Own Elaboration

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Aeronautical Revenue per Passenger	-0,13	100,13	29,86	0,53	24	16,05
Aeronautical Revenue per Movement	-0,01	60,78	69,54	73,68	100	14,81
Non-Aeronautical Operating Revenue per Passenger	0	81,59	66,67	71,67	100	13,58
EBITDA per Passenger	0	94,45	72,23	99,26	88,89	13,58
Non-Aeronautical Revenue as Percentage of Total Operating Ratio	0	52,2	52,2	60,44	93,41	12,35
Debt to EBITDA Ratio	-0,13	38,27	66,05	88,49	99,7	11,11
Debt Service as Percentage of Operational Revenue	100,57	81,81	55,19	24,43	0,43	9,88

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Long-Term Debt Passenger	0,03	27,6	54,57	83,42	100	8,64

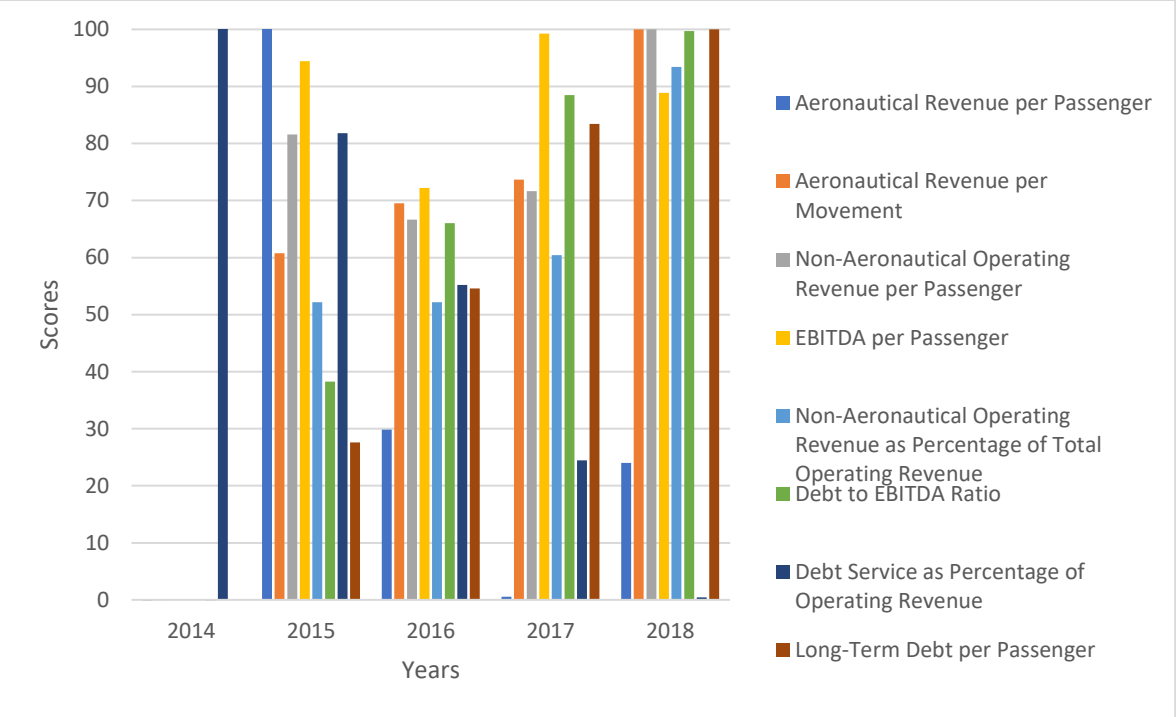

Figure 3.41 - KPIs Financial / Commercial Airport 2

Source: Own Elaboration

Now is the time to comment on the KPIs of KPA 5 - Financial / Commercial (Table 3.33 and Figure 3.41). We see how 2014 is the worst year by far except for the KPI Debt Service as Percentage of Operating Revenue that has the maximum. This KPI is decreasing until reaching 0 in 2018. From 2014 to 2018 we can see several KPIs that are ascending and have their maximum value in 2018 such as Aeronautical Revenue per Movement, Non-Aeronautical Operating Revenue as Percentage of Total Operating Revenue, Debt to EBITDA, and Long-Term Debt per Passenger. We also have the KPI EBITDA per Passenger which is irregular with very similar values between 2015 and 2018, and which has its maximum in 2017. And finally, a comment on the KPI Non-Aeronautical Operating Revenue per Passenger. This KPI has a high value in 2015 but suffers a large decline in 2016, from here it changes its direction reaching its maximum in 2018.

Table 3.34 - KPA 5 - Financial / Commercial

Source: Own Elaboration

KPA 5	2014	2015	2016	2017	2018
Financial / Commercial	9,90	70,14	57,91	61,13	75,61

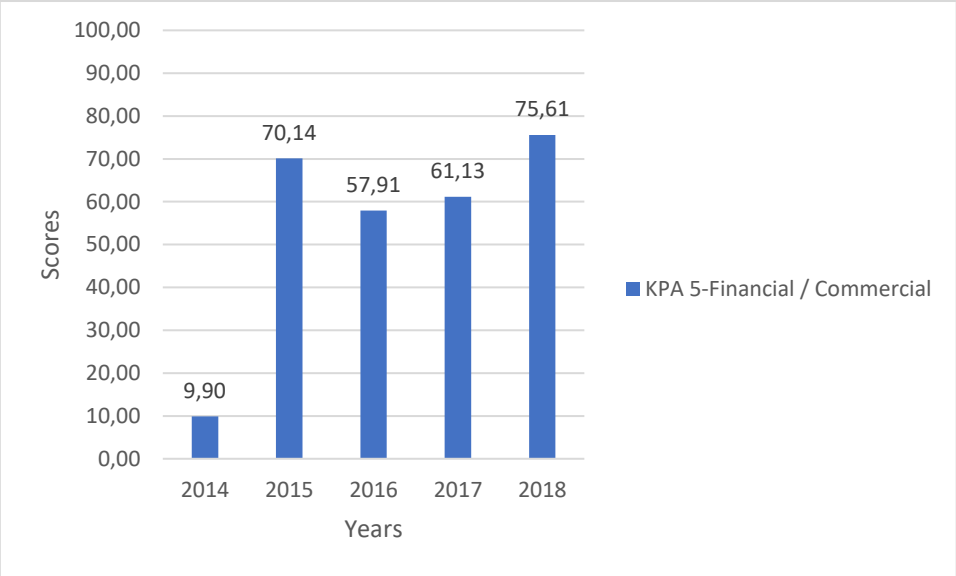

Figure 3.42 - KPA 5 - Financial / Commercial

Source: Own Elaboration

Table 3.34 and Figure 3.42 shows the KPA 5 - Financial / Commercial for the last 5 years. The highest value is that of 2018 and we see how the scores between 2015 and 2018 are in a range of 17,7 points. Which indicates that a good level has been maintained. The forecast for this KPA is good in the near future and although this KPA for specialists is only worth 15%, the financial and commercial issue is very important too in Spanish airports, since AENA is public by 51% but 49% is private. And what is sought from the private sector is to maximize revenues.

Table 3.35 - KPIs Environmental Airport 2

Source: Own Elaboration

Environmental	2014	2015	2016	2017	2018	Weight (%)
Carbon Footprint	50	0	50	50	100	21,21
Waste Recycling	80	0	100	40,22	42,35	18,18
Renewable Energy Purchased by the Airport (%)	0,08	43,1	68,33	86,18	100,02	18,18
Waste Reduction (%)	67,64	83,81	0	100	66,9	15,15
Energy Usage per Square Meter of Terminal	100	42,78	17,8	87,08	0	15,15
Water Consumption per Passenger	46,31	-0,05	71,8	53,94	100	12,12

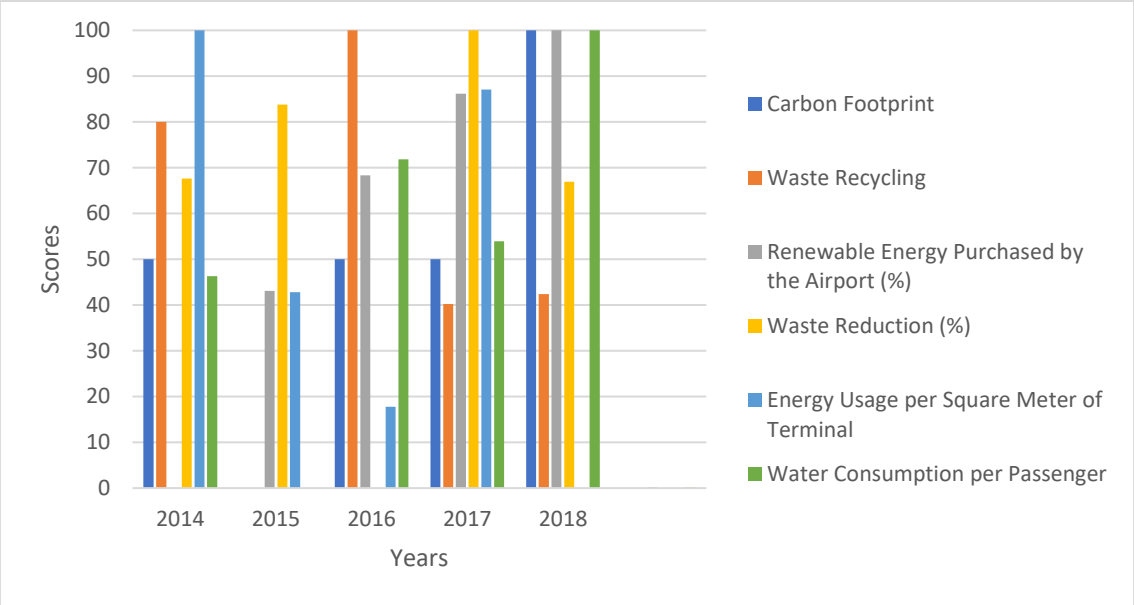

Figure 3.43 - KPIs Environmental Airport 2

Source: Own Elaboration

Next, we will comment on Table 3.35 and Figure 3.43 that represent the KPIs of KPA 6 - Environmental of Airport 2. First, a comment on the randomness of the values that make the analysis a complex task. We see that the only value that improves year by year is that of the KPI Renewable Energy Purchased by the Airport that reaches its maximum in 2018. On the other hand, we have the most important KPI for the specialists of this KPA, which is Carbon Footprint. Except for the year 2015 that has a minimum, the rest is on the rise and reached its maximum in 2018.

The results of Waste Recycling and Waste Reduction are quite random: the first has the maximum in 2016 and the minimum in 2015, and the second we see how the maximum is in 2017 and the minimum in 2016. Let's focus now on the KPI Energy Usage per Square Meter of Terminal, where we see a reduction of the score between 2014 and 2016, an improvement in 2017 and a decrease with the worst value of all in 2018. As a justification for the result of 2018, we could argue that it exists in such a large airport as the Airport 2 a terminal of 670000 m^2 that is not wide, and every time there are many more passengers so that more Energy is spent. The airport must implement new systems of air conditioning, lighting, etc. in which much less energy is consumed and so the improvement of the aforementioned KPI Renewable Energy Purchased by the Airport, which, as we see depict in Figure 3.43, each year improves. Finally, commenting on the evolution of the KPI Water Consumption per Passenger that has a minimum in 2015 and a maximum in 2018, which shows that the measures adopted by the airport in water saving are working.

Table 3.36 - KPA 6 - Environmental

Source: Own Elaboration

KPA 6	2014	2015	2016	2017	2018
Environmental	56,17	27,01	52,61	68,46	69,35

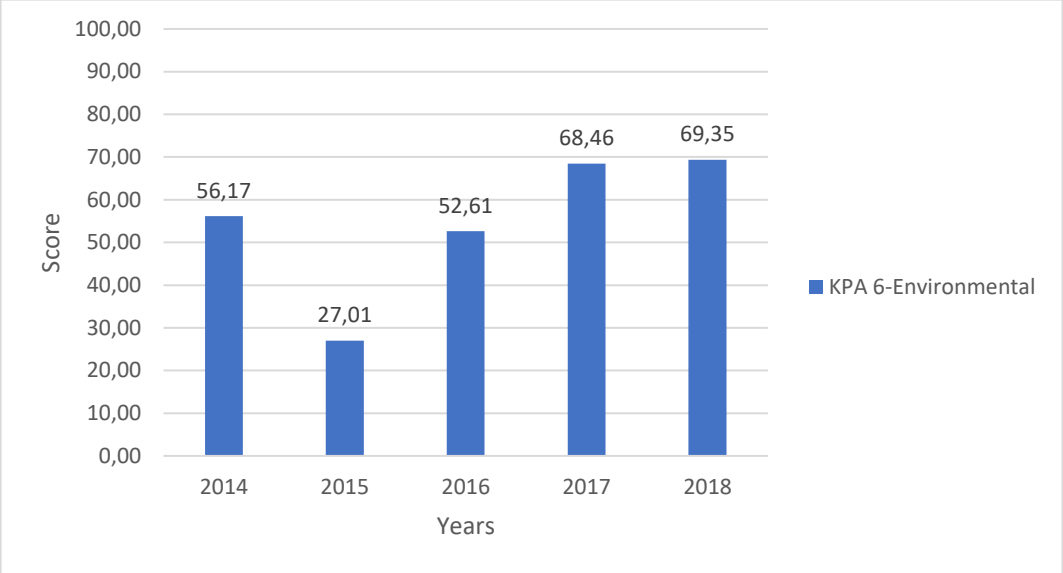

Figure 3.44 - KPA 6 - Environmental

Source: Own Elaboration

In Table 3.36 and Figure 3.44 we observe the evolution of KPA 6 - Environmental. With a minimum in 2015 and a maximum in 2018 reaching the 70 points. The evolution is positive and little by little the measures that are applied by airports in the environmental field are being noticed.

Table 3.37 - KPAs Airport 2

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018	Weight (%)
Safety and Security	40,91	54,39	52,51	74,56	65,36	22,00
Core	4,90	13,06	42,11	70,02	100,00	20,00
Productivity / Effectiveness	22,62	6,54	46,54	89,63	86,83	17,00
Service Quality	35,36	66,01	48,16	38,00	44,03	15,00
Financial / Commercial	9,90	70,14	57,91	61,13	75,61	15,00
Environmental	56,17	27,01	52,61	68,46	69,35	12,00

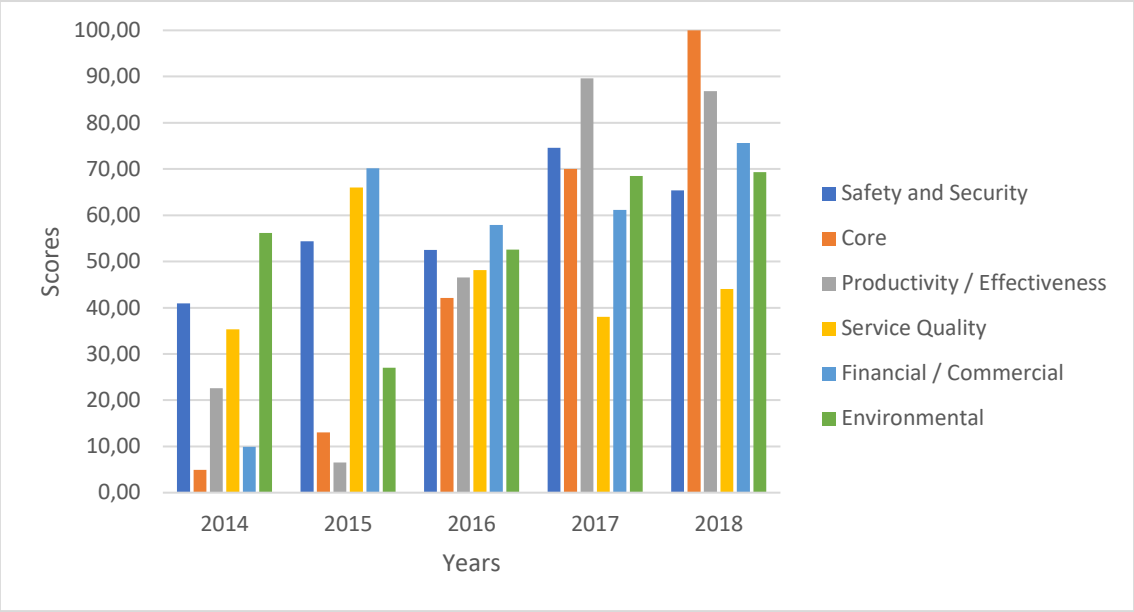

Figure 3.45 - KPAs Airport 2

Source: Own Elaboration

In Table 3.37 and Figure 3.45 we can see the KPAs of the different years of Airport 2. It is a fairly ordered graph where, over the years, the KPAs' score is generally increasing. In 2018 we can see the maximum of three KPAs: Core, Financial / Commercial, and Environmental. In 2017 we can see the maximum of KPAs: Safety and Security, and Productivity / Effectiveness. And finally, we depict 2015 with a maximum in Service Quality KPA.

Table 3.38 - KPAs % Efficiency

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018
TOTAL	27,27	38,82	49,62	68,18	74,64

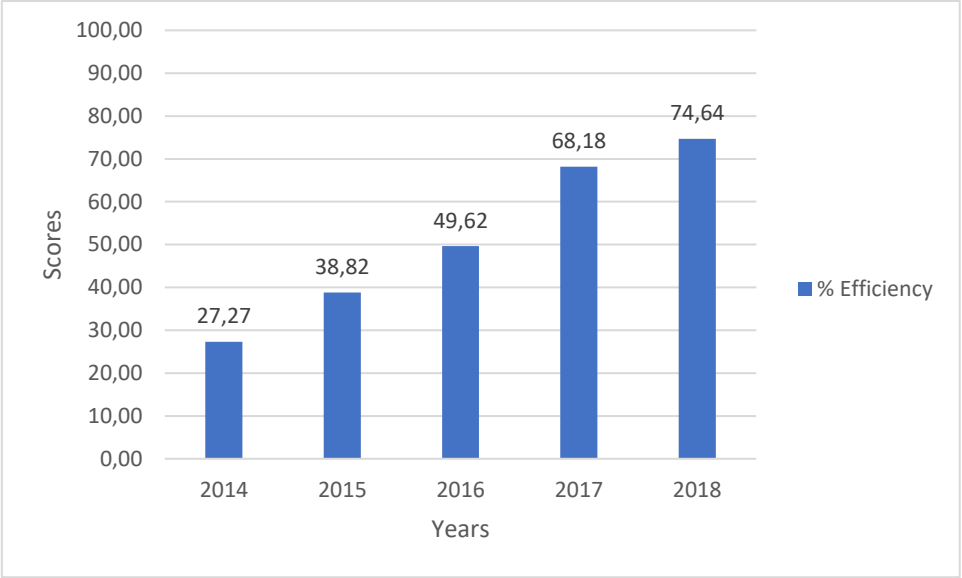

Figure 3.46 - % Efficiency Airport 2

Source: Own Elaboration

In Table 3.38 and Figure 3.46 we can find the results of our airport 2 efficiency analysis. 2018 has the highest score of all years and since 2014 it is a growth chart. This graph shows the good functioning of the airport and the good long-term future that can be seen as positive. The airport must not forget to continue taking measures and reforms to maintain this direction and improve it. Above all, they should focus on improving the three weakest KPAs. As in the case of Service Quality, it is necessary try to reduce times to improve the quality of the passenger with a better organization, increase of employees and machinery or increase the square meters of terminals and thus add boarding gates... The second KPA with the lowest score is that of Safety and Security. In this KPA the measures applied for the reduction of the Bird Strikes are already being noticed, but it has much to improve with the reduction of the Runway Incursions and with Occupational employee accident and injuries. And finally, it should be noted that KPA 6 - Environmental should also be improved. Despite being one of the most advanced airports regarding renewable energies, it must continue applying measures to maintain and improve this area.

3.3.3 Airport 3 – Valencia. Partial Data Analysis

Now we will perform the study of the efficiency of Airport 3. We will analyze the 6 KPAs of the airport in order of weight according to the specialists. The order of the KPIs within the KPAs are also according to the weight assigned to them by the specialists.

Table 3.39 - KPIs Safety and Security Airport 3

Source: Own Elaboration

Safety and Security	2014	2015	2016	2017	2018	Weight (%)
Runway Accidents	100	100	100	100	100	21,57
Runway Incursions	73,34	13,33	93,33	76,67	53,33	19,61
Bird Strikes	40,74	0	100	66,67	59,26	17,65
Public Injuries	20,95	2,86	88,57	34,28	70	15,69
Occupational Injuries and Accidents	-1,67	61,11	93,33	58,89	34,44	13,73
Lost Work Time from Employee Accidents and injuries	0,12	74,79	2,46	100,19	42,23	11,76

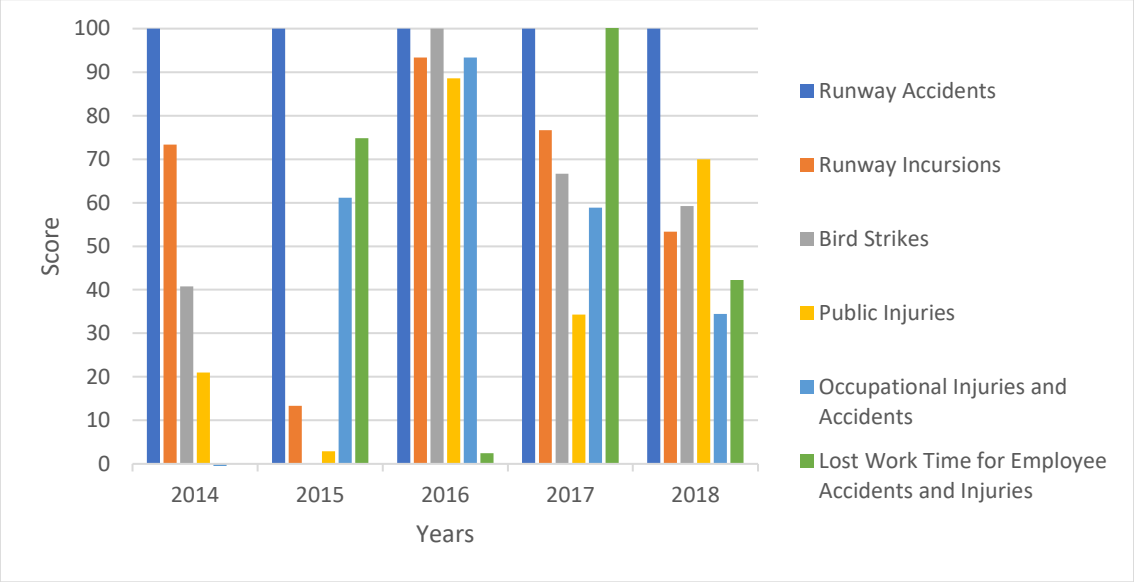

Figure 3.47 - KPIs Safety and Security Airport 3

Source: Own Elaboration

In Table 3.39 and Figure 3.47 we can see the KPIs of KPA 1 - Safety and Security of Airport 3. We can see how the KPI Runway Accidents is at 100 points every year since no accident has occurred in the last 5 years. We can also see how 2016 is a year with many high values. We see how the KPIs of Runway Incursions, Bird Strikes, Public Injuries, and Occupational Injuries and Accidents reach their maximum levels in 2016 and these KPIs gradually decrease until 2018. It is striking that 2016, despite being the year with the lowest Occupational Injuries and Accidents, has one of the lowest values in LWT for Employee Accidents and Injuries, which has its maximum in 2017.

Table 3.40 - KPA 1 - Safety and Security

Source: Own Elaboration

KPA 1	2014	2015	2016	2017	2018
Safety and Security	46,21	41,82	84,52	73,62	63,17

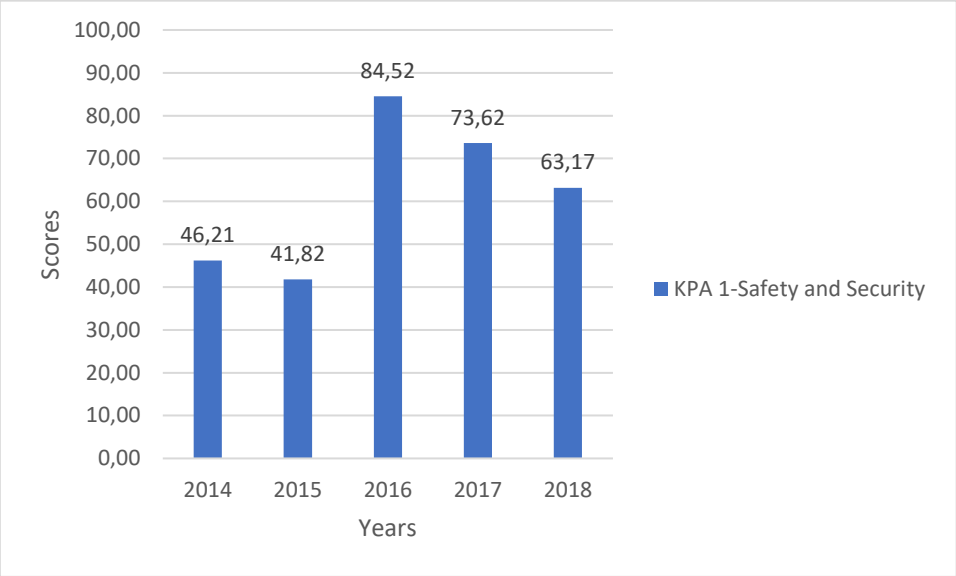

Figure 3.48 - KPA 1 - Safety and Security

Source: Own Elaboration

In Table 3.40 and Figure 3.48 we can see KPA 1 - Safety and Security of Airport 3. As expected, the year with the best results is 2016. After 2016, the results decrease to 21,35 points in 2018. On the other hand, the years with the lowest values are 2014 and 2015. The latter one has the minimum, with a difference to 2016 of 42,7 points.

Table 3.41 - KPIs Core Airport 3

Source: Own Elaboration

Core	2014	2015	2016	2017	2018	Weight (%)
Passengers	0	14,43	37,87	67,71	100	25,71
Aircraft Movements	0	13,24	32,82	59,83	100	22,86
Origin and Destination Passengers	0	14,43	37,87	67,71	100	20,00
Freight and Mail Loaded Unloaded	2,63	42,82	0	24,32	100	17,14
Destinations - Nonstop	0	3,3	26,39	90,15	100	14,29

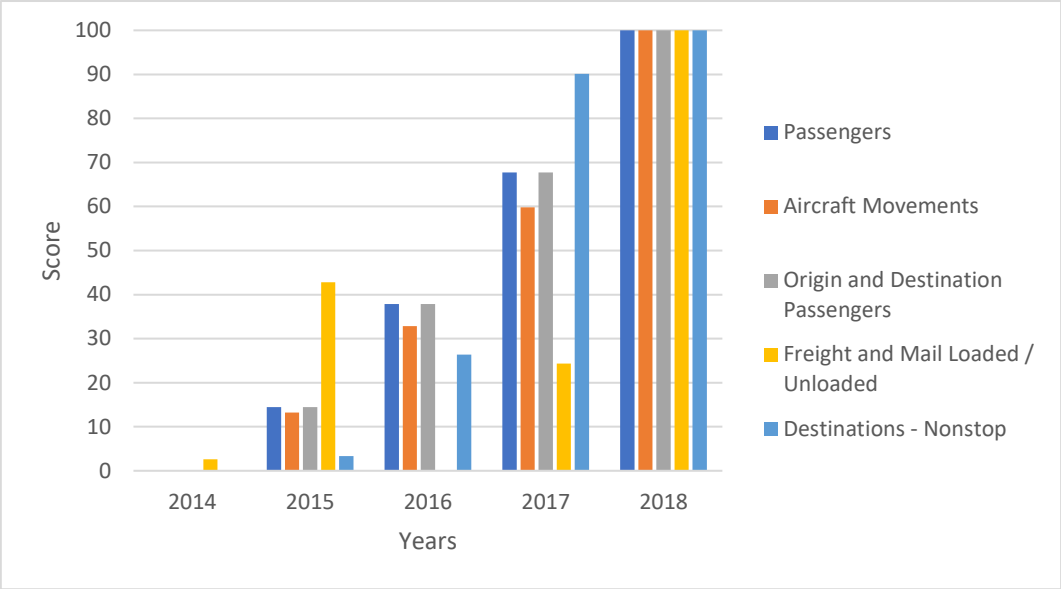

Figure 3.49 - KPIs Core Airport 3

Source: Own Elaboration

Next, we are going to analyze KPIs from KPA 2 - Core of Airport 3 (Table 3.41 and Figure 3.49). It should be noted that all KPIs have their maximum in 2018 and they are all increasing except for Freight and Mail Loaded / Unloaded. This KPI increases from 2014 to 2015, from 2015 to 2016 it decreases, and from 2016 to 2017 it increases, but it is lower than the value of 2015. Next, we show Table 3.42 that depicts the real values from 2014 to 2018.

Table 3.42 - Real Data Core Airport 3

Source: Own Elaboration

	Passengers	Origination and Destination P.	Aircraft Movements	Freight and Mail Loaded / Unloaded	Destinations-Nonstop
2014	4.597.095	4.137.386	56.438	12.640	59
2018	7.769.867	6.992.880	75.834	14.499	85
Difference	3 million	2,8 million	19.396	1.859	26

Table 3.43 - KPA 2 - Core

Source: Own Elaboration

KPA 2	2014	2015	2016	2017	2018
Core	0,45	17,43	28,58	61,68	100,00

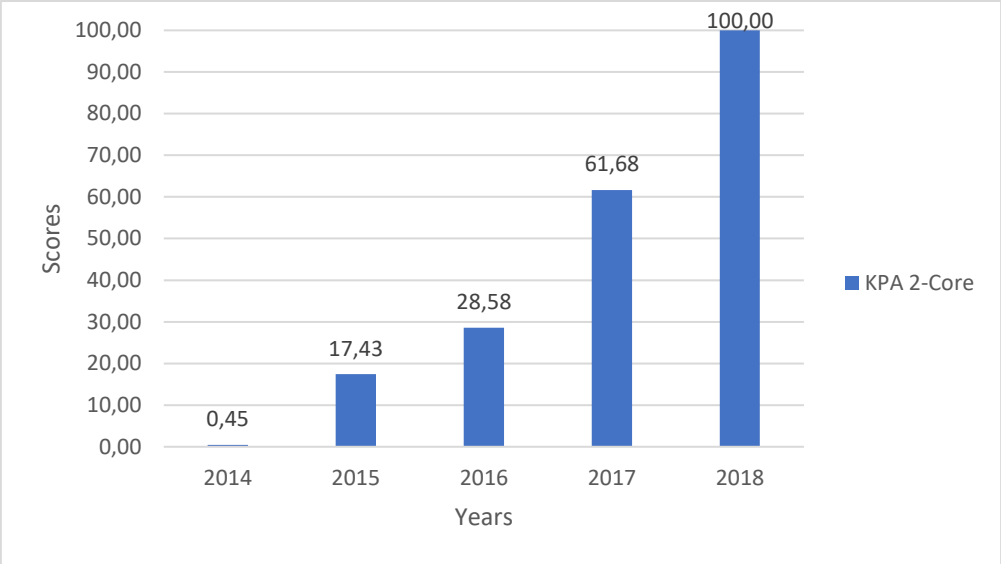

Figure 3.50 - KPA 2 - Core

Source: Own Elaboration

Now we proceed to the analysis of KPA 2 - Core of Airport 3 (Table 3.43 and Figure 3.50). The difference in values observed in Table 3.43 shows a very large increase in this KPA. And in Figure 3.50 we can also see how this KPA has been increasing and an equally good future is expected if the improvements continue.

Table 3.44 - KPIs Productivity / Cost Effectiveness Airport 3

Source: Own Elaboration

Productivity / Cost Effectiveness	2014	2015	2016	2017	2018	Weight (%)
Total Cost per Passenger	0,13	11,74	45,24	80,26	99,9	14,29
Total Cost per Movement	14,82	-0,03	25,13	66,62	100,02	13,27
Operating Cost per Movement	44,3	0	6,87	42,76	100	12,24
Aircraft Movement per Gate	0,05	13,28	32,84	59,84	100	11,22
Total Cost per WLU	30,97	46,91	-1,22	49,18	97,25	11,22
Operating Cost per WLU	96,89	85,39	-2,28	37,78	99,39	10,20
Operating Cost per Passenger	0,21	3,79	33,24	78,34	99,97	10,20
Passengers per Employee	-0,05	12,33	34,36	72,3	100	9,18
Aircraft Movement per Employee	2,19	14,32	32,4	57,34	94,45	8,16

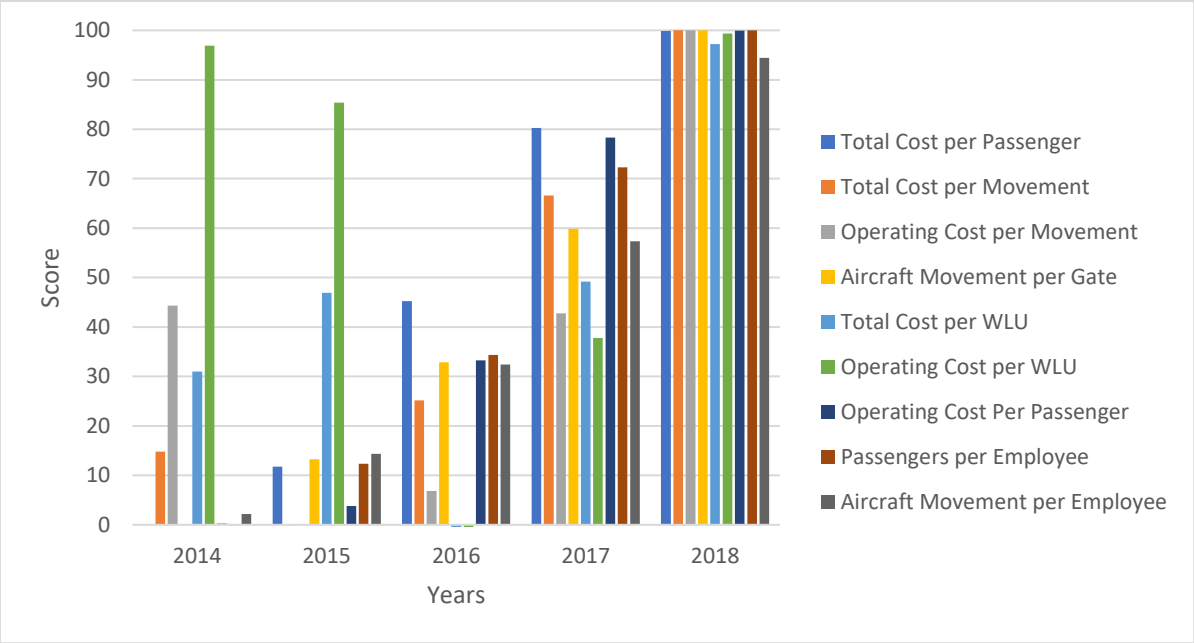

Figure 3.51 - KPIs Productivity / Cost Effectiveness Airport 3

Source: Own Elaboration

In Table 3.44 and Figure 3.51 we see the representation of the KPIs of the KPA 3 - Productivity / Cost Effectiveness of the Airport 3. The KPIs that have a growth behaviour from 2014 to 2018 are Total Cost per Passenger, Total Cost per Movement, Aircraft Movement per Gate, Operating Cost per Passenger, Passengers per Employee, and Aircraft Movement per Employee. All these KPIs have their maximum in 2018. On the other hand, we have the KPI Operating Cost per WLU, which goes down from 2014 to 2016 where reaches a minimum and then rises to a score of 100 points in 2018. The behaviour of the KPI Operating Cost per Movement is like the previous one, a decreases from 2014 to 2015, reaching its minimum, and from here increases until 2018. And finally, a comment on the KPI Total Cost per WLU, which increases from 2014 to 2015, in 2016 it has a score of 0 and from here it ascends to its maximum in 2018.

Table 3.45 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

KPA 3	2014	2015	2016	2017	2018
Productivity / Cost Effectiveness	20,97	19,82	23,14	60,94	94,14

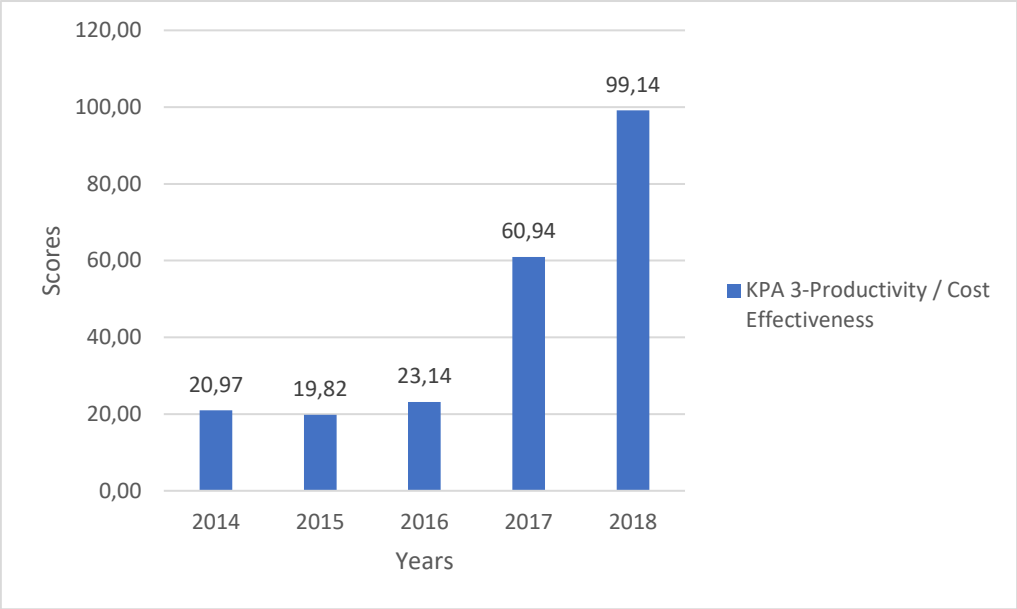

Figure 3.52 - KPA 3 Productivity / Cost Effectiveness

Source: Own Elaboration

Table 3.45 and Figure 3.52 show the current good state of this KPA. Between 2014 and 2016 it has an average of 20 points, in 2017 there is a very notable improvement until obtaining a score of 60. And from 2017 to 2018 there is an improvement of 40 points, leaving the airport in a very good current place. The improvements made by the airport have yielded results and undoubtedly in recent years has increased this KPA. There is a good foresight for the future regarding this KPA.

Table 3.46 - KPIs Service Quality Airport 3

Source: Own Elaboration

Service Quality	2014	2015	2016	2017	2018	Weight (%)
Customer Satisfaction	0	36,27	10,09	32,9	100	15,85
Gate Departure Delay	41,28	100	75,65	0	22,73	14,63
Baggage Delivery Time	0	20,17	100	84,87	72,27	13,41
Taxi Departure Delay	42,86	100	0	78,57	42,86	12,20
Security Clearing Time	100	16,07	0	73,21	89,29	12,20
Border Control Clearing Time	90,11	100	57,14	8,79	0	10,98
Check-in to Gate Time	67,23	0	100	70,87	52,67	10,98
Practical Hourly Capacity	100	100	100	100	100	9,76

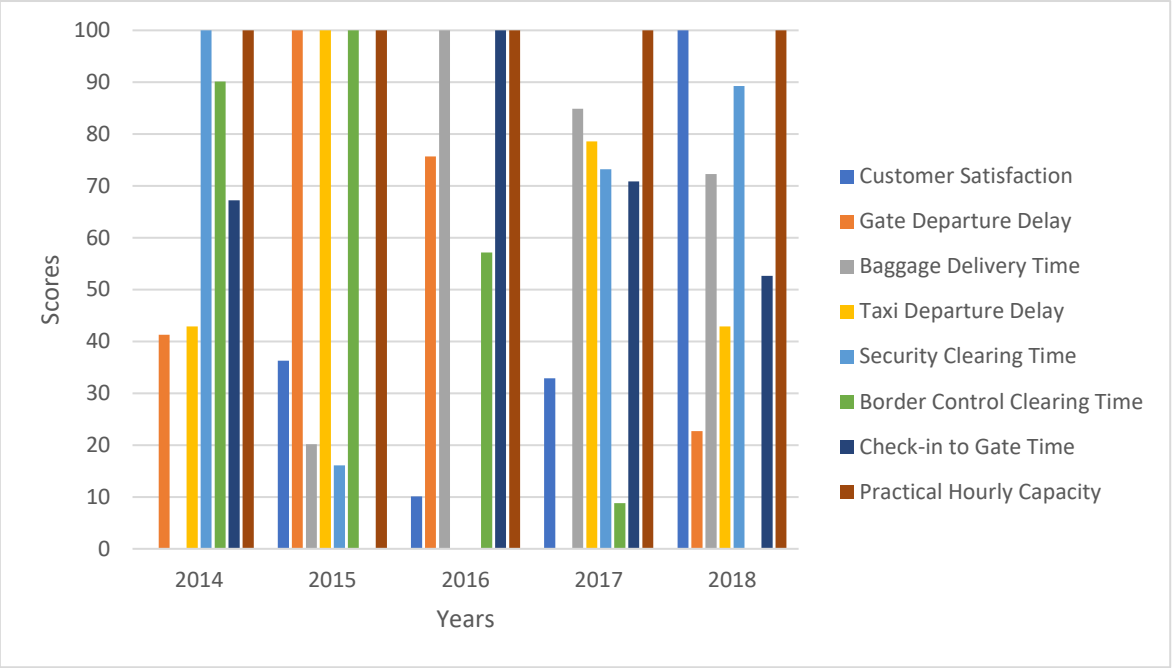

Figure 3.53 - KPIs Service Quality Airport 3

Source: Own Elaboration

In Table 3.46 and Figure 3.53 we can see the different KPIs of Airport 3 for Service Quality KPA. The results of the graph seem quite random since we can find maximums in each of the 5 different years. In 2014 we can find the maximums of the KPIs Security Clearing Time, and Practical Hourly Capacity. On the other hand, in 2015 we can observe the maximum of Gate Departure Delay, Taxi Departure Delay, Border Control Clearing Time, and Practical Hourly Capacity. In 2016 we found the maximum of Baggage Delivery Time, Check-in to Gate Time and, again, Practical Hourly Capacity. In 2017 we only found the maximum of Practical Hourly Capacity. It is necessary to comment that this KPI that corresponds to 34 movements per hour is repeated during the 5 years according to the reports of AENA, reason why in all the years it appears with 100 points. To finish, we see how in 2018 we have the maximum KPI that has more weight according to the specialists, Customer Satisfaction. And we also have in 2018, as in all others, the maximum of Practical Hourly Capacity.

Table 3.47 - KPA 4 - Service Quality

Source: Own Elaboration

KPA 4	2014	2015	2016	2017	2018
Service Quality	50,50	57,98	53,09	53,62	60,53

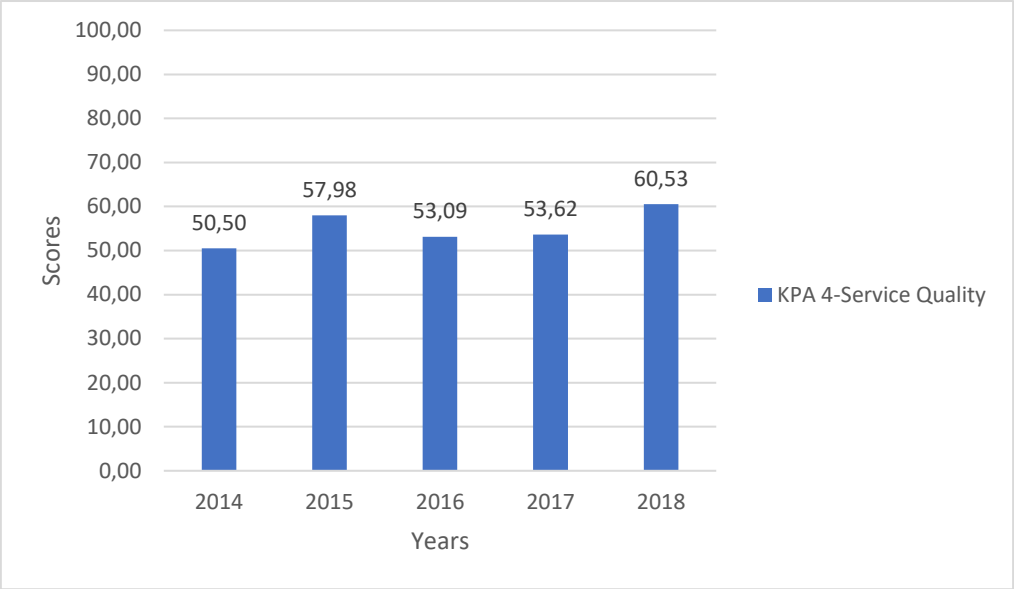

Figure 3.54 - KPA 4 - Service Quality
Source: Own Elaboration

In Table 3.47 and Figure 3.54 we can see the KPA 4 -Service Quality of Airport 3. We see a very balanced graph where the difference between the maximum value and the minimum value is only 10 points. The minimum value is in 2014 and the maximum value is in 2018. The results of this KPA are not bad, but they can be improved. The last few years have risen slowly, and the forecasts for the future is positive, but more improvements must be applied by the airport to reduce waiting times and improve customer opinion.

Table 3.48 - KPIs Financial / Commercial Airport 3
Source: Own Elaboration

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Aeronautical Revenue per Passenger	98,43	99,94	69,92	37,54	-0,15	16,05
Aeronautical Revenue per Movement	0	57,35	84,4	100,01	56,6	14,81
Non-Aeronautical Operating Revenue per Passenger	0,7	100,2	63,65	39,92	25,8	13,58
EBITDA per Passenger	93,45	100,06	77,43	56,9	-0,18	13,58
Non-Aeronautical Revenue as Percentage of Total Operating Ratio	0	52,69	52,58	65,79	100,08	12,35
Debt to EBITDA Ratio	-0,13	38,23	65,82	88,61	99,87	11,11
Debt Service as Percentage of Operational Revenue	100,57	81,81	55,19	24,47	0,43	9,88
Long-Term Debt Passenger	0,01	28,83	53,18	80,33	99,99	8,64

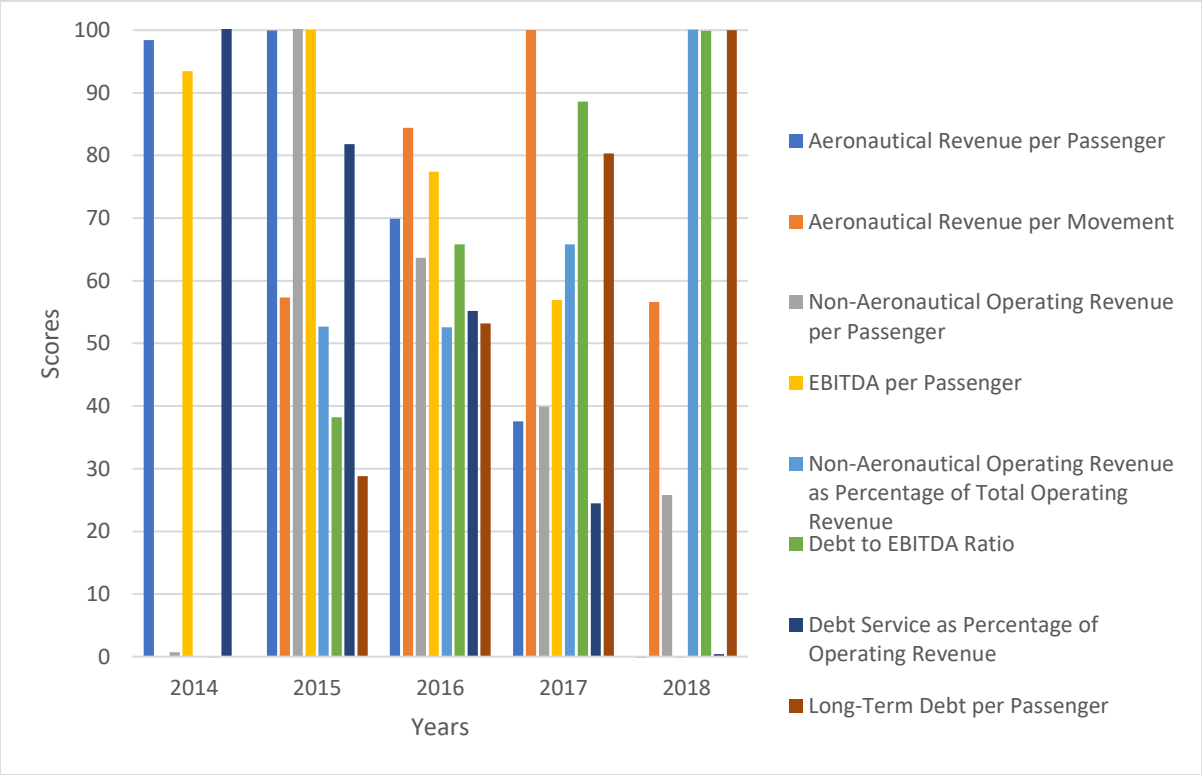

Figure 3.55 - KPIs Financial / Commercial Airport 3

Source: Own Elaboration

Next, we will comment on Table 3.48 and Figure 3.55 where the KPIs of KPA 5 - Financial / Commercial of Airport 3 are shown. We see how in 2014 and 2015 we have maximums in the KPIs Aeronautical Revenue per Passenger, Non-Aeronautical Operating Revenue per Passenger, EBITDA per Passenger, and Debt Service as Percentage of Operating Revenue. From here, the 3 mentioned KPIs fall until reaching its minimum in 2018 with 0 points. On the opposite situation, we have the Non-Aeronautical Operating Revenue KPIs as Percentage of Total Operating Revenue, Debt to EBITDA Ratio, and Long-Term Debt per Passenger. These increase from 2014 to 2018, where they reach their maximum. And finally a comment on the KPI Aeronautical Revenue per Movement, which increases from 2014 to 2017 but in the end decreases from 2017 to 2018.

Table 3.49 - KPA 5 - Financial / Commercial

Source: Own Elaboration

KPA 5	2014	2015	2016	2017	2018
Financial / Commercial	38,51	73,06	66,73	61,31	43,97

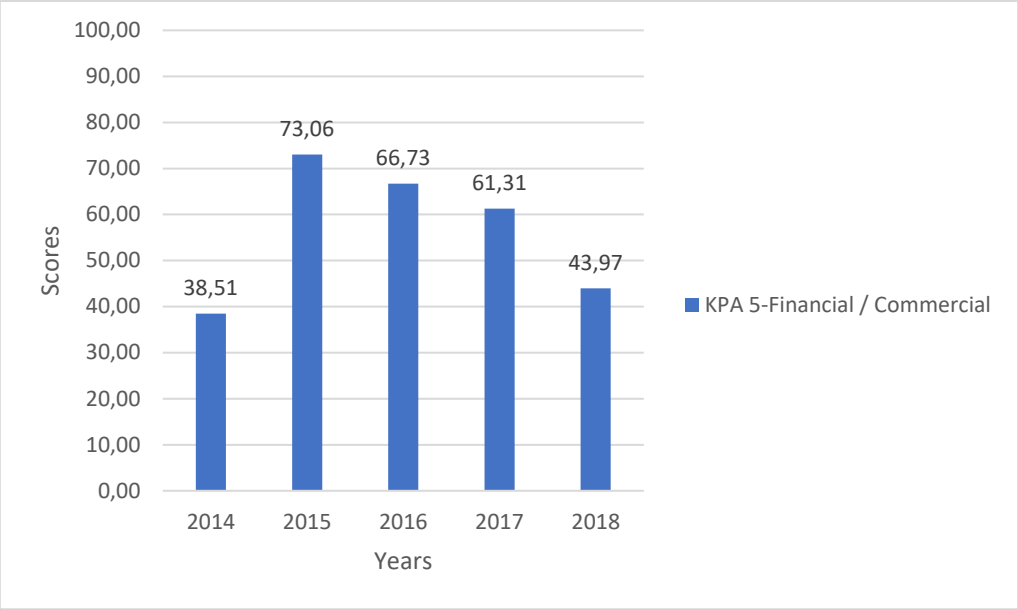

Figure 3.56 - KPA 5 - Financial / Commercial

Source: Own Elaboration

In Table 3.49 and Figure 3.56 we see the results of KPA 5 - Financial / Commercial of Airport 3. There is a very large gap from 2014 to 2015 of 34,55 points. As of 2015, it goes down until reaching a final value of 43,97 in 2018. When starting the study, we were aware that AENA is a centralized organization that focuses on large airports for profits, while small ones produce losses. We see how Airport 3 at KPA Financial / Commercial does not seem to be going very well. It shows a decrease in recent years despite having increased the number of passengers, operations, etc.. The airport must take measures to improve this KPA and turn around this decline in the score of recent years.

Table 3.50 - KPIs Environmental Airport 3

Source: Own Elaboration

Environmental	2014	2015	2016	2017	2018	Weight (%)
Carbon Footprint	47,62	47,62	100	47,62	0	21,21
Waste Recycling	32,55	79,34	0	74,34	100	18,18
Renewable Energy Purchased by the Airport (%)	0	100	8,33	73,15	62,04	18,18
Waste Reduction (%)	35,43	52,72	0	100	9,78	15,15
Energy Usage per Square Meter of Terminal	100	82,03	6,84	34,25	0	15,15
Water Consumption per Passenger	0	12,52	64,02	45,33	100	12,12

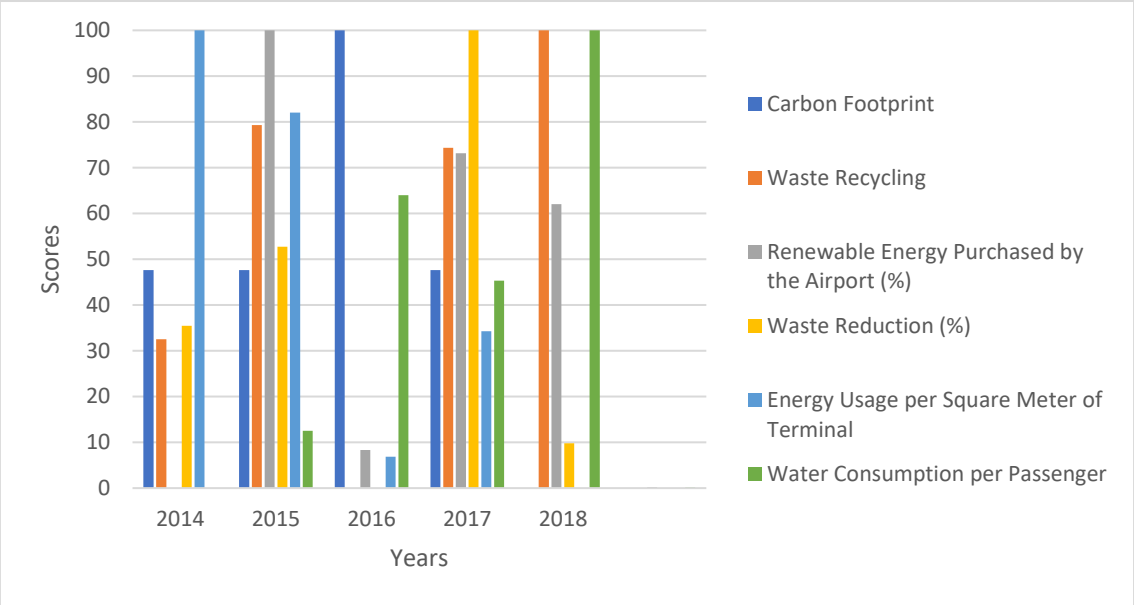

Figure 3.57 - KPIs Environment Airport 3

Source: Own Elaboration

We now proceed to comment on Table 3.50 and Figure 3.57 which contains the KPIs of the KPA 6 - Environmental of Airport 3. First, we observe that KPI Carbon Footprint reaches its maximum in 2016 and descends to its minimum in 2018. On the other hand, the KPI Waste Recycling increases from 2014 to 2015, then decreases until it reaches a minimum in 2016, and increases from there to its maximum in 2018. Regarding the KPI Renewable Energy Purchased by the Airport, the year with the highest score is 2015, followed by 2017 and 2018. The KPI Waste Reduction increases from 2014 to 2015, then decreases from 2015 to 2016, increases in 2017 and decreases in 2018. The KPI Energy Usage per Square Meter of Terminal has its maximum value in 2014 and its minimum value in 2018. This is because there has been a very large increase in the number of passengers in recent years and the airport has not increased its terminal, that is, it follows the same surface area for many more passengers. And finally, a comment on the KPI Water Consumption per Passenger, which increases the score from 2014 to 2018, which means that have reduced water consumption per passenger.

Table 3.51 - KPA 6 - Environmental

Source: Own Elaboration

KPA 6	2014	2015	2016	2017	2018
Environmental	36,54	64,64	31,52	62,75	43,06

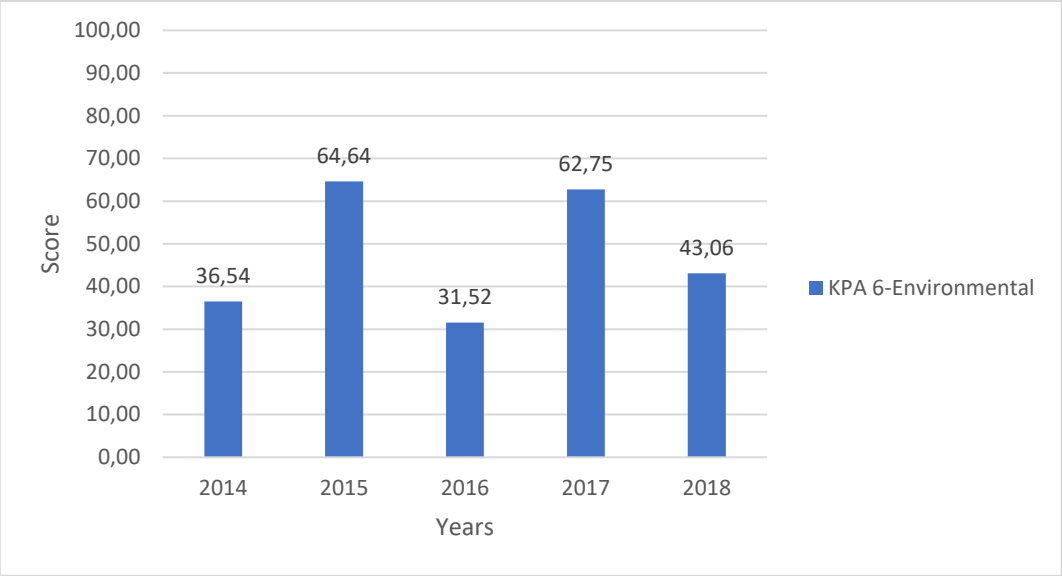

Figure 3.58 - KPA 6 - Environmental

Source: Own Elaboration

We see how Table 3.51 and Figure 3.58 shows the evolution of KPA 6 - Environmental of Airport 3. We see in the graph how this KPA is irregular, as it goes up and down every year but each time with higher values. Airport 3 must propose measures to improve this KPA, although these measures are not of extreme urgency.

Table 3.52 - KPAs Airport 3

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018	Weight (%)
Safety and Security	46,21	41,82	84,52	73,62	63,17	22,00
Core	0,45	17,43	28,58	61,68	100,00	20,00
Productivity / Effectiveness	20,97	19,82	23,14	60,94	99,14	17,00
Service Quality	50,50	57,98	53,09	53,62	60,53	15,00
Financial / Commercial	38,51	73,06	66,73	61,31	43,97	15,00
Environmental	36,54	64,64	31,52	62,75	43,06	12,00

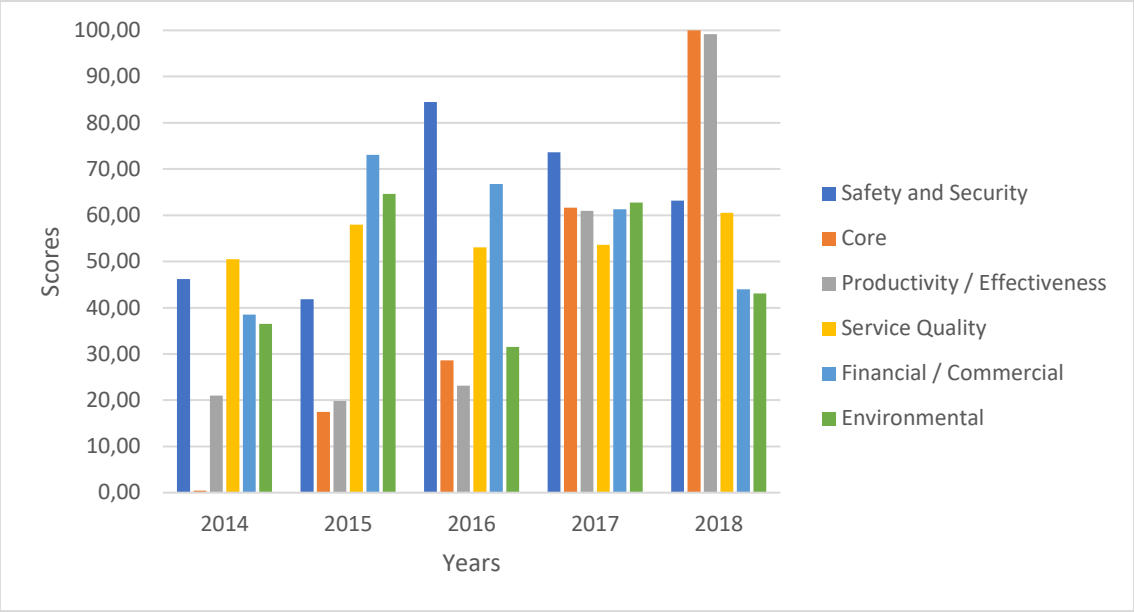

Figure 3.59 - KPAs Airport 3

Source: Own Elaboration

In Table 3.52 and Figure 3.59 we can see the different KPAs of Airport 3 during the last 5 years. We see that the graph despite being quite constant has growth from 2014 to 2018. The year with most maximum KPAs is 2018, followed by 2015.

Table 3.53 - % Efficiency Airport 3

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018
% Efficiency	31,29	43,02	49,46	63,06	70,84

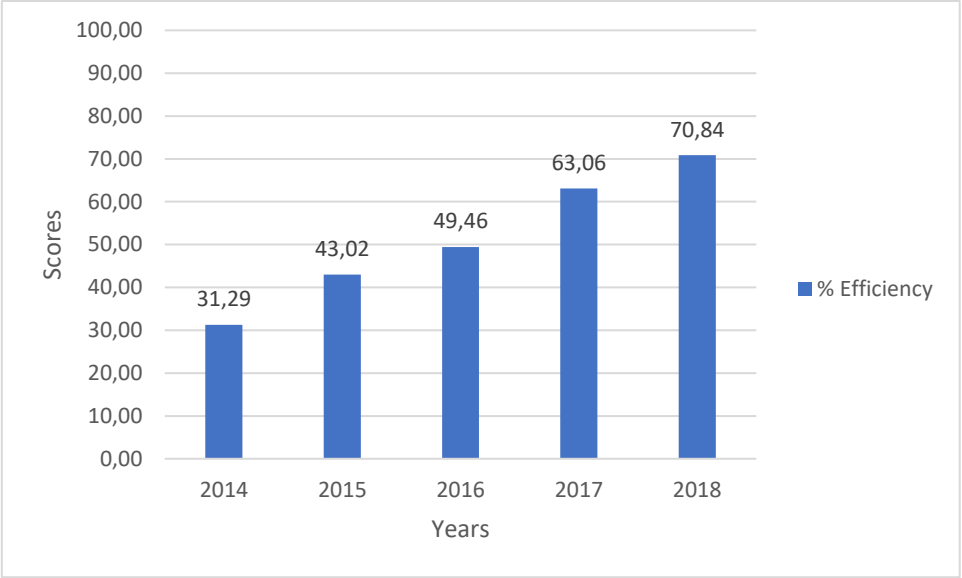

Figure 3.60 - % Efficiency Airport 3

Source: Own Elaboration

In Table 3.53 and Figure 3.60 we see the final analysis of the efficiency of Airport 3. As we have already mentioned, AENA is an organization that focuses on large airports to generate income while the rest generate losses that are financed by the revenues of large airports. In the case of Airport 3, we have seen how the KPA 5 - Financial / Commercial is in decline and could improve if the necessary measures were applied. We must also highlight the 2018 values of KPA 2 – Core, and KPA 3 - Productivity / Cost Effectiveness which are very high in 2018, reaching 100 points or being very close to them. Having these KPA so much weight according to specialists this have made 2018 the best year with a score of 70,84.

As proposals for the future, Airport 3 must continue to maintain the measures that benefit its three best KPAs. But it must promote new measures to improve KPA 1 - Security and Safety, KPA 5 - Financial / Commercial, and KPA 6 – Environmental, too.

3.3.4 Airport 4 – Sevilla. Partial Data Analysis

We will proceed now to the analysis of the efficiency of the last airport, Airport 4. As we have been doing, we will first analyze the 6 KPAs with the order according to the weight of the specialists and within each KPA, we will analyze their KPIs also by the weight order assigned by the specialists.

Table 3.54 - KPIs Safety and Security Airport 4

Source: Own Elaboration

Safety and Security	2014	2015	2016	2017	2018	Weight (%)
Runway Accidents	100	99,89	100	100	100	21,57
Runway Incursions	56,67	100	53,33	26,66	70	19,61
Bird Strikes	86,67	53,33	53,33	63,34	43,33	17,65
Public Injuries	54,28	51,43	-4,29	95,71	45,71	15,69
Occupational Injuries and Accidents	0,56	19,44	95,56	71,67	45,33	13,73
Lost Work Time from Employee Accidents and injuries	10,31	50,32	-0,42	100,2	65,7	11,76

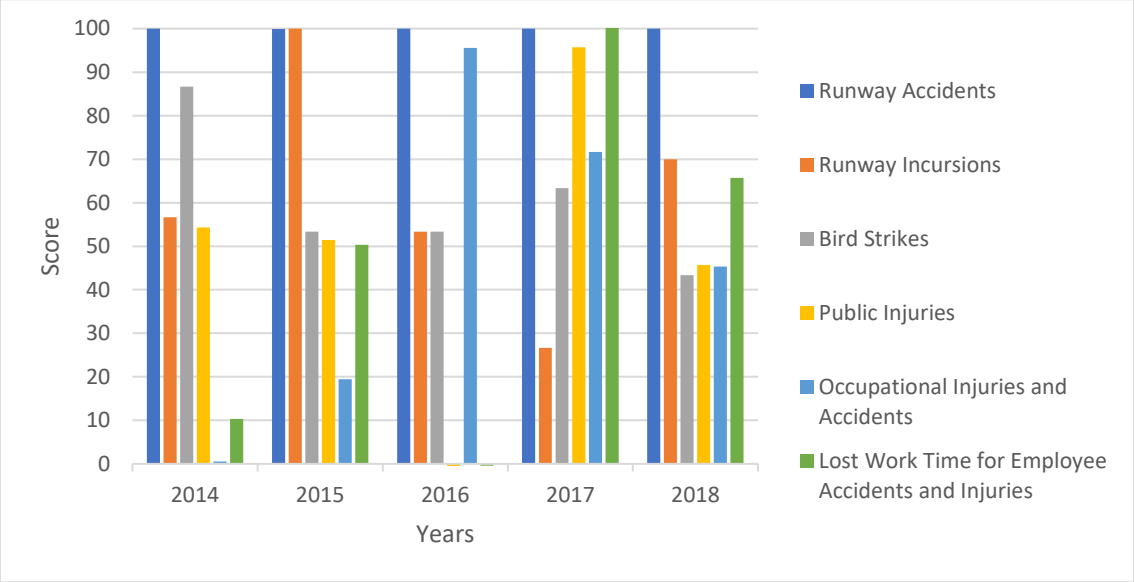

Figure 3.61 - KPIs Safety and Security Airport 4

Source: Own Elaboration

We now look at Table 3.54 and Figure 3.61, where the KPIs of KPA 1 - Safety and Security are represented. First, focus on the KPI with more weight of this KPA according to specialists, Runway Accidents. All KPIs achieved 100 points except for 2015, since in the Airport 4 that year there was an accident; it's why its score is 99,89. Then we have the KPI Runway Incursions, which increases from 2014 to 2015 - reaching then its maximum, decreases until 2017 and increases in 2018 staying at a value of 70 points. The KPI Bird Strikes decreases over the years until 2018, which means that they have increased over time. Concerning the KPI Public Injuries, a comment on it has its maximum in 2017 and its minimum in 2016. Occupational Injuries and Accidents had its maximum in 2016 and its minimum in 2014. Finally, the KPI LWT for Employee Accidents and Injuries increases in 2014 to 2015, falls in 2016 reaching the minimum, and increases in 2017 reaching its maximum.

Table 3.55- KPA 1 - Safety and Security

Source: Own Elaboration

KPA 1	2014	2015	2016	2017	2018
Safety and Security	57,79	67,23	53,84	74,62	64,04

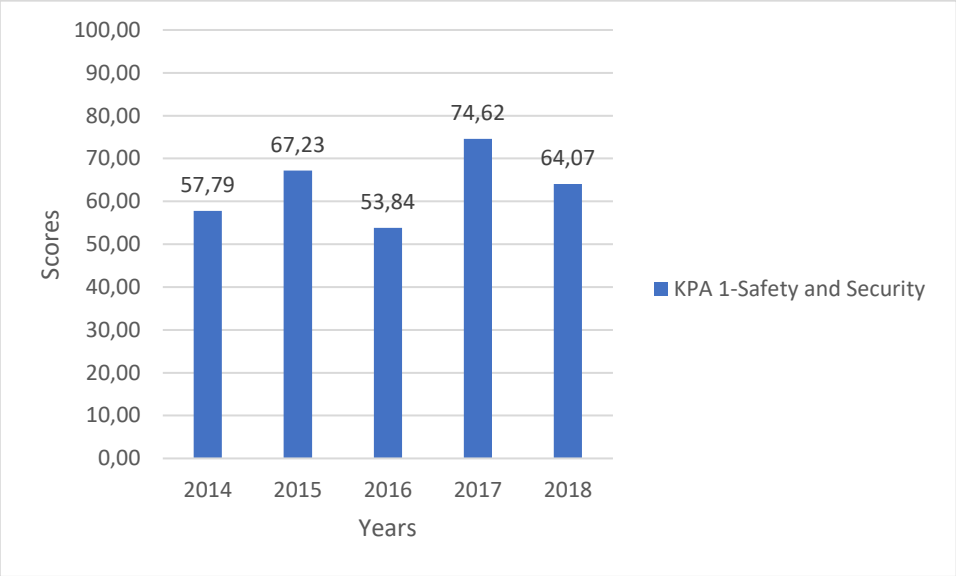

Figure 3.62 - KPA 1 - Safety and Security

Source: Own Elaboration

In Table 3.55 and Figure 3.62 we can see the KPA 1 - Safety and Security of Airport 4. We see how the score range over these 5 years is very tight, about 20 points. We can realize it by looking at the last two years, where the scores from 2017 to 2018 have gone down 10 points, that is, of all the proposed measures from 2016 to 2017 that served to improve 20 points, half of the score has been lost. This can be due to many factors, among others may be the large increase in passengers and movements that has suffered this airport in the last year. Although this can't be taken as an excuse to not improve these KPA. The airport must take the necessary measures to improve KPA Safety and Security.

Table 3.56 - KPIs Core Airport 4

Source: Own Elaboration

Core	2014	2015	2016	2017	2018	Weight (%)
Passengers	0	16,97	29,65	49,03	100	25,71
Aircraft Movements	0	23,87	22,28	40,45	100	22,86
Origin and Destination Passengers	0	16,97	29,65	43,03	100	20,00
Freight and Mail Loaded Unloaded	0	4,22	11,92	65,57	100	17,14
Destinations - Nonstop	0	5,53	2,77	55,31	100	14,29

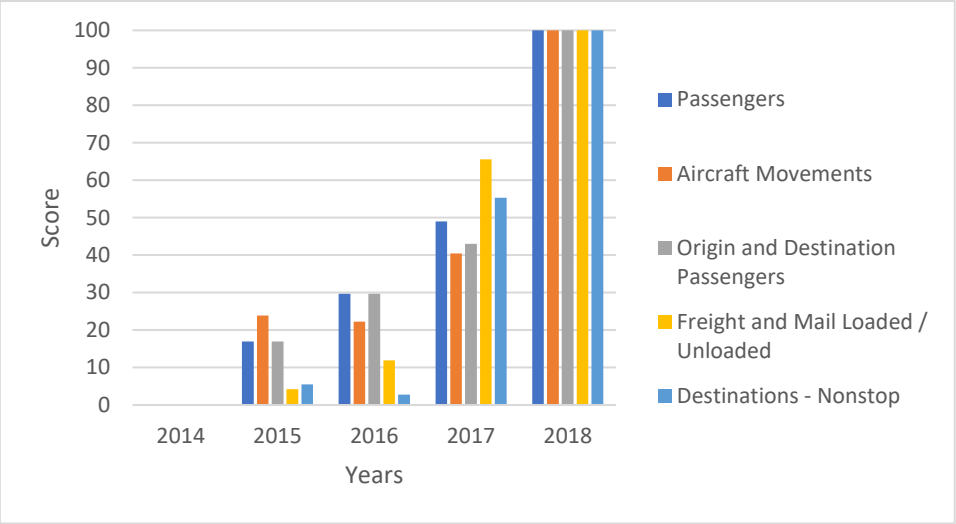

Figure 3.63 - KPIs Core Airport 4

Source: Own Elaboration

Next, we will see Table 3.56 and Figure 3.63 where the KPIs of KPA 2 - Core are displayed. At first glance, all KPIs are always growing except KPI Destinations - Nonstop, which increases from 2014 to 2015, but decreases in 2016 to increase again until its maximum in 2018. The importance of the graph is to see the tremendous increase that has occurred in this airport from 2017 to 2018. For this reason, we will analyze certain values of Table 3.56, as a difference of more than 50 points of the three most important KPIs of this KPA according to specialists, which are: Passengers, Aircraft Movements, and Origin and Destinations Passengers between 2017 and 2018. Next, we will look at Table 3.57 the real data, to observe better the improvement of these last years.

Table 3.57 - Real Data Core Airport 4

Source: Own Elaboration

	Passengers	Origination and Destination P.	Aircraft Movements	Freight and Mail Loaded / Unloaded	Destinations-Nonstop
2014	3.885.434	3.691.162	42.379	5.667	45
2018	6.380.465	6.061.442	57.909	12.561	76
Difference	2,5 million	2,4 million	15.530	6.894	31

Table 3.58 - KPA 2 - Core

Source: Own Elaboration

KPA 2	2014	2015	2016	2017	2018
Core	0,00	14,73	21,09	49,60	100,00

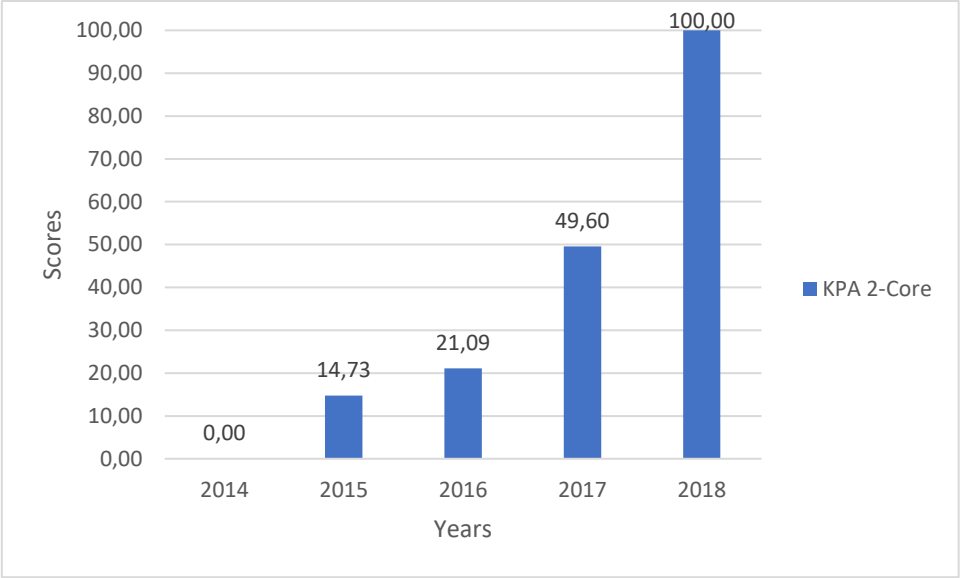

Figure 3.64 - KPA 2 - Core

Source: Own Elaboration

As we have already mentioned in the previous graph, Airport 4 has had a very intense development compared to KPA 2 - Core in recent years, especially in this last year (Table 3.58 and Figure 3.64). The difference between 2017 and 2018 is more than 50 points, and that from 2016 to 2017 is also important with 30 points of separation. This airport should propose measures to maintain this level and to continue growing and increasing. Although with such a large number of people, the measures will have to be forceful and important, for example, the creation of another terminal or extension of the current one, creation of a new track, etc.. These measures must be done after the necessary studies. In conclusion, this KPA is working very well and there are good insights for the future.

Table 3.59 - KPIs Productivity / Cost Effectiveness Airport 4

Source: Own Elaboration

Productivity / Cost Effectiveness	2014	2015	2016	2017	2018	Weight (%)
Total Cost per Passenger	-0,05	15,76	29,18	52,59	100,09	14,29
Total Cost per Movement	12,83	30,04	-0,03	22,51	100,02	13,27
Operating Cost per Movement	47,07	46,09	0	7,72	100	12,24
Aircraft Movement per Gate	0,01	23,86	22,28	40,43	100,04	11,22
Total Cost per WLU	-0,06	3,89	16,96	81	99,96	11,22
Operating Cost per WLU	2,18	-0,07	8,67	78,34	100,12	10,20
Operating Cost per Passenger	-0,04	7,29	13,39	34,75	99,92	10,20
Passengers per Employee	0,08	14,55	25,37	48,69	100,02	9,18

Productivity / Cost Effectiveness	2014	2015	2016	2017	2018	Weight (%)
Aircraft Movement per Employee	-0,09	12,64	11,15	28,25	97,3	8,16

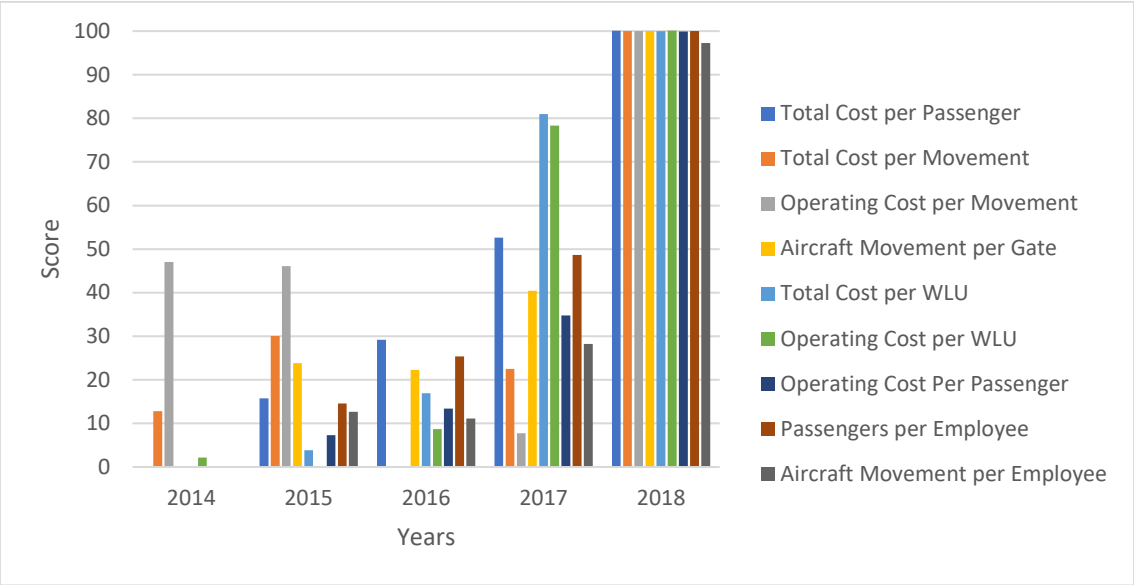

Figure 3.65 - KPIs Productivity / Cost Effectiveness Airport 4
Source: Own Elaboration

Next, we will discuss the KPIs of KPA 3 - Productivity / Cost Effectiveness of Airport 4 (Table 3.59 and Figure 3.65). We can see how all the KPIs have their maximums in 2018. This indicates the good management of this airport in this KPA. We also see KPIs as Total Cost per Passengers, Total Cost per WLU, and Passengers per Employee increase positively from 2014 to 2018. On the other hand, we see KPIs as Aircraft Movement per Gate, or Aircraft Move per Employee that increase from 2014 to 2015 and decrease in 2016 then increase to its maximum in 2018. Also, we have the KPI Total Cost per Movement that increases from 2014 to 2015, decreases to its minimum in 2016, to increase after until 2018. Almost the same as the KPI Operating Cost per Movement that descends from 2014 to 2016 and from here it increases to its maximum in 2018, we must bear into mind that both the value of Total Cost per Movement and that of Operating Cost per Movement in 2017 are lower than these in 2015. And finally, a comment on the Operating Cost per WLU value, which decreases slightly from 2014 to 2015 and from now on it increases to its maximum in 2016.

Table 3.60 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

KPA 3	2014	2015	2016	2017	2018
Productivity / Cost Effectiveness	7,67	18,10	14,06	43,38	99,78

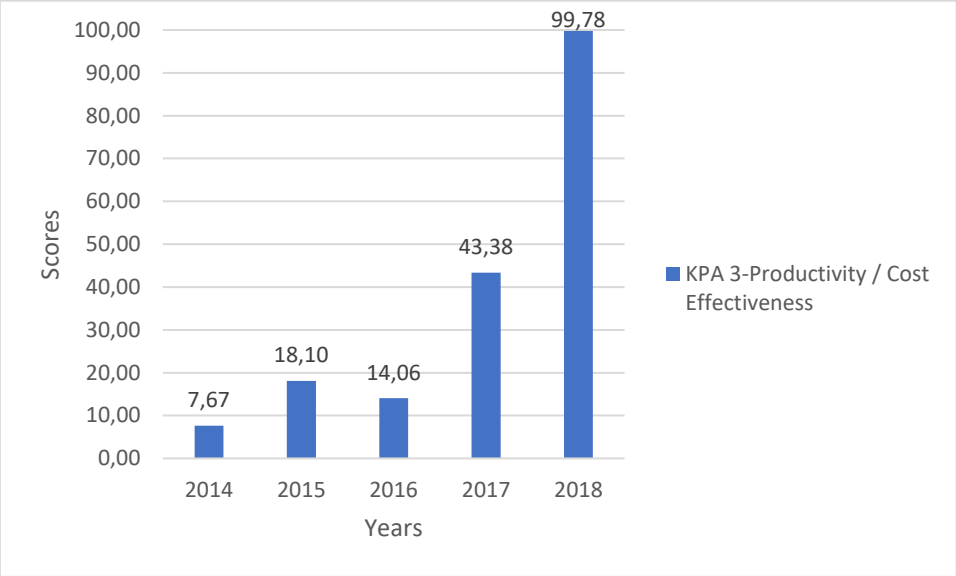

Figure 3.66 - KPA 3 - Productivity / Cost Effectiveness

Source: Own Elaboration

Table 3.60 and Figure 3.66 represent the KPA 3 - Productivity / Cost Effectiveness of Airport 4. It is a graph very similar to that of KPA 2 - Core. We *are* in 2018, which is close to 100 points of valuation, while 2017 is more than 55 points away from it. Which means that in the last year under evaluation there has been a huge improvement. And the values of 2014, 2015 and 2016 are very similar in Figure 3.66 too; values that are practically in a range of 10 very similar points.

The tremendous increase that occurs in 2018 is due mainly to the large increase in the number of passengers and movements of aircraft that has suffered this airport in 2018. To conclude, this KPA shows good feelings for a future where it is expected to continue improving.

Table 3.61 - KPIs Service Quality Airport 4

Source: Own Elaboration

Service Quality	2014	2015	2016	2017	2018	Weight (%)
Customer Satisfaction	2,43	0	56,52	83,7	100	15,85
Gate Departure Delay	15,15	77,27	100	32,72	0	14,63
Baggage Delivery Time	100	57,14	0	73,21	10,71	13,41
Taxi Departure Delay	51,08	0	25,21	100	74,02	12,20

Service Quality	2014	2015	2016	2017	2018	Weight (%)
Security Clearing Time	100	68,75	89,58	4,17	0	12,20
Border Control Clearing Time	33,33	100	64,28	0	28,57	10,98
Check-in to Gate Time	100	16,67	0	37,5	59,38	10,98
Practical Hourly Capacity	100	100	100	100	100	9,76

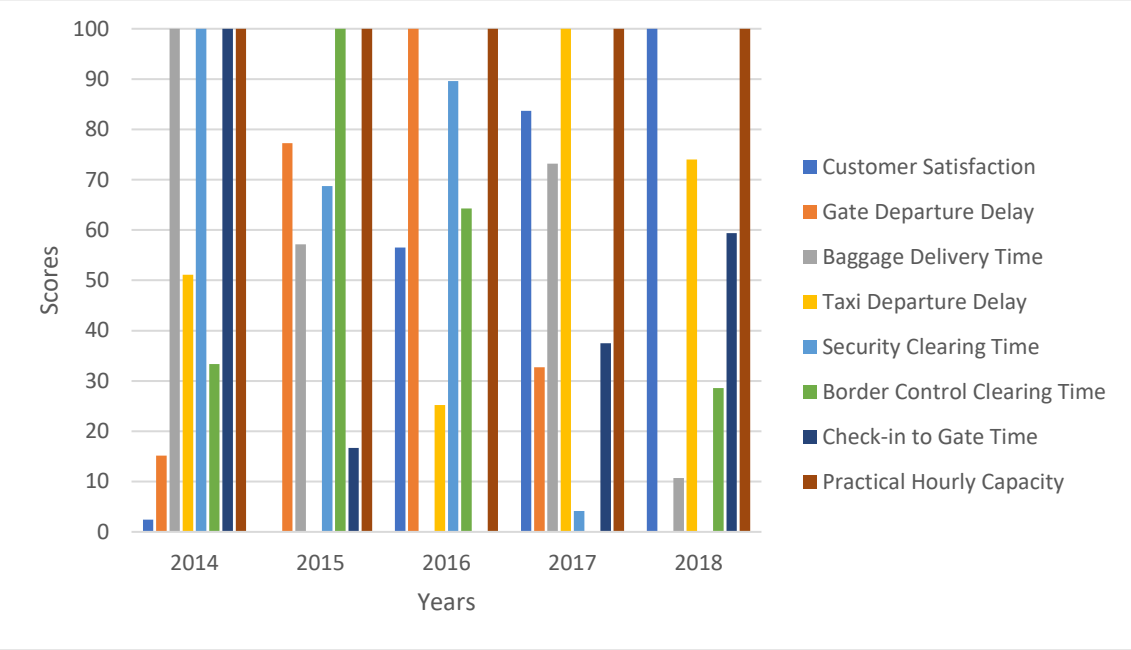

Figure 3.67 - KPIs Service Quality Airport 4

Source: Own Elaboration

Table 3.61 and Figure 3.67 represent the KPIs of KPA 4 - Service Quality of Airport 4. As in the other airports, the graph of this KPA is characterized by its randomness, having several maximums in all the years, which we will analyze next. First of all, it should be noted that the KPI Practical Hourly Capacity obtained 100 points (the maximum score) the 5 years. From AENA reports we saw that has 25 movements per hour during the five years. The KPI Customer Satisfaction is increasing throughout 5 years reaching its maximum in 2018 with a score of 78,8 out of 100. In 2014 we can see 3 maximum KPIs: Baggage Delivery Time, Security Clearing Time, and Check- in to Gate Time. In 2015 we can see the maximum of the KPI Border Control Clearing and in 2016 that of the KPI Gate Departure Delay. Finally, it should be noted that the KPI Taxi Departure Delay has its maximum in 2017.

Table 3.62 - KPA 4 - Service Quality

Source: Own Elaboration

KPA 4	2014	2015	2016	2017	2018
Service Quality	58,84	49,92	54,41	54,46	45,73

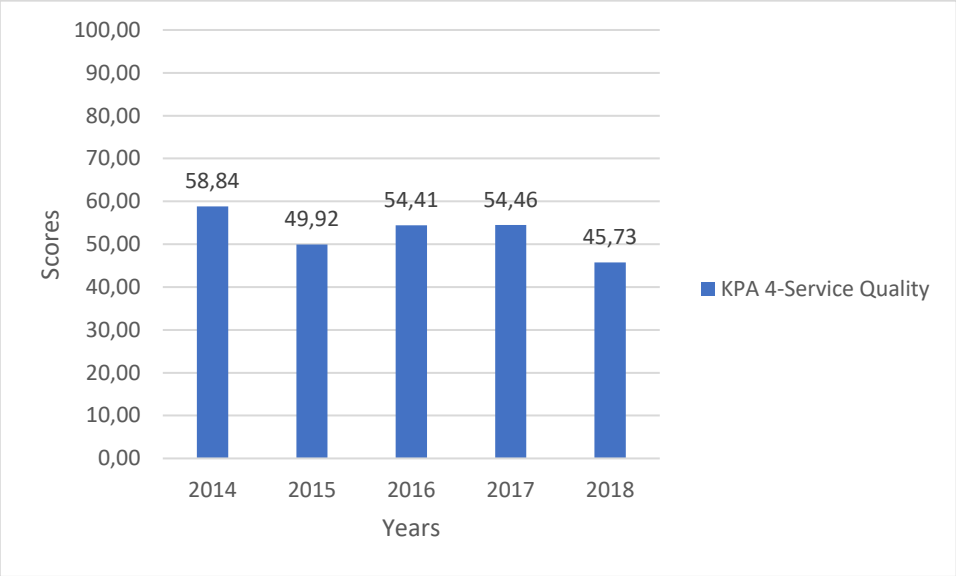

Figure 3.68 - KPA 4 - Service Quality

Source: Own Elaboration

Table 3.62 and Figure 3.68 are very interesting to analyze since we see how the KPA 4 - Service Quality of Airport 4 is practically in decline since 2014, which was its best year within the last 5 and 2018 which is the worst year of the last 5. It is understandable that waiting time grows with the disproportionate increase of people of this last year, maintaining the dimensions of the terminal. But this is no excuse for these bad results. The airport must take measures to reduce the times of many of the KPIs, such as Gate Departure Delay and Security Clearing Time, where 2018 has been the worst of the last 5 years. If the airport does not take measures, there will be more and more passengers and therefore the waiting times will also increase and the value of this KPI will decrease.

Table 3.63 - KPIs Financial / Commercial Airport 4

Source: Own Elaboration

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Aeronautical Revenue per Passenger	93,42	89,37	99,89	96,01	0,11	16,05
Aeronautical Revenue per Movement	0,01	9,16	74,31	100,01	24,14	14,81

Financial / Commercial	2014	2015	2016	2017	2018	Weight (%)
Non-Aeronautical Operating Revenue per Passenger	0,73	79,25	88,68	100,07	38,26	13,58
EBITDA per Passenger	64,09	64,46	86	100	0,12	13,58
Non-Aeronautical Revenue as Percentage of Total Operating Ratio	0	52,69	52,58	65,79	100,08	12,35
Debt to EBITDA Ratio	-0,13	38,23	65,82	88,61	99,87	11,11
Debt Service as Percentage of Operational Revenue	100,73	76,61	47,3	20,94	0,37	9,88
Long-Term Debt Passenger	0	30,28	49,02	70,82	99,99	8,64

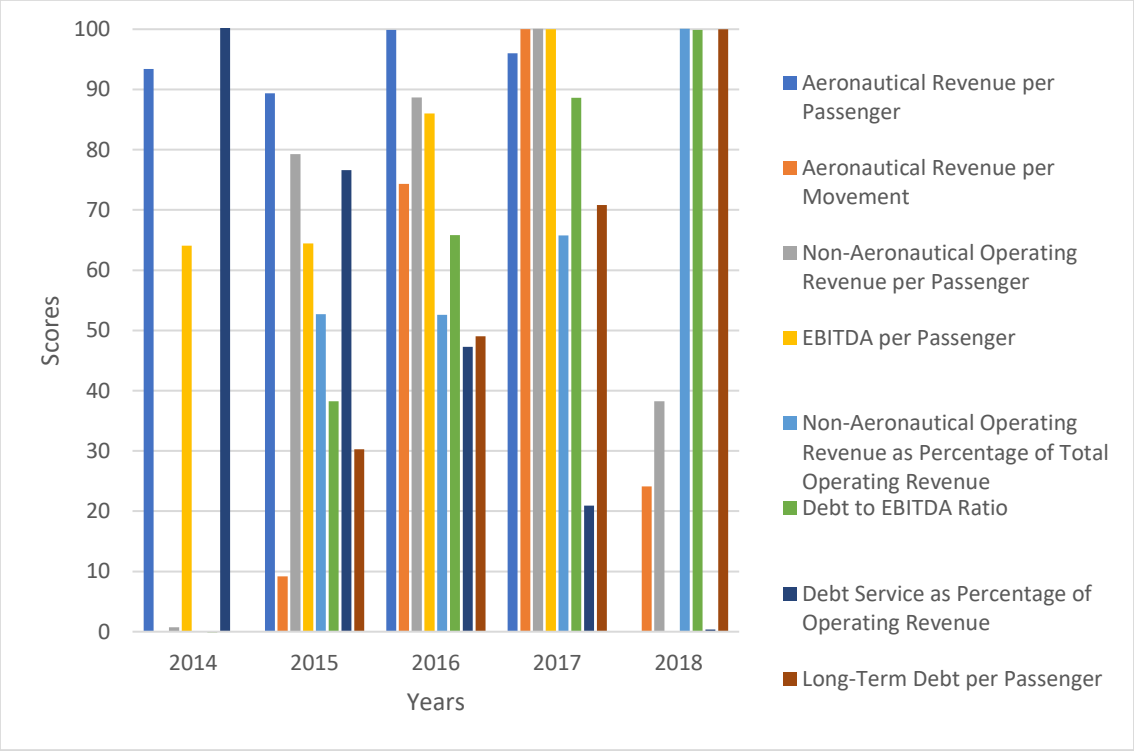

Figure 3.69 - KPIs Financial / Commercial Airport 4

Source: Own Elaboration

Next, we are going to analyse Table 3.63 and Figure 3.69, which contains the KPIs of KPA 5 - Financial / Commercial of Airport 4. At first glance, we see 2 highly dense years that are 2016 and 2017 where 4 of the 8 KPIs of this KPA are. We see that Non-Aeronautical Revenue as Percentage of Total Operating Revenue, Debt to EBITDA Ratio, and Long-Term Debt per Passenger are increasing from 2014 to 2018, having their maximum here. On the other hand, we have KPIs as Aeronautical Revenue per Movement, Non-Aeronautical Operating Revenues per Passenger, and EBITDA per Passenger, which are increasing until 2017, where they have a

maximum, and fall sharply in 2018. The KPI that has more weight according to the specialists is Aeronautical Revenue per Passenger and this is characterized by having very high values in the first 4 years and descending very sharply in 2018. Finally, a comment on a value that is contrary to all others for the Debt Service as Percentage of Operating Revenue KPI, which has its maximum in 2014 and decreases until 2018 - reaching the minimum.

Table 3.64 - KPA 5 - Financial / Commercial

Source: Own Elaboration

KPA 5	2014	2015	2016	2017	2018
Financial / Commercial	33,74	56,16	73,47	83,55	40,94

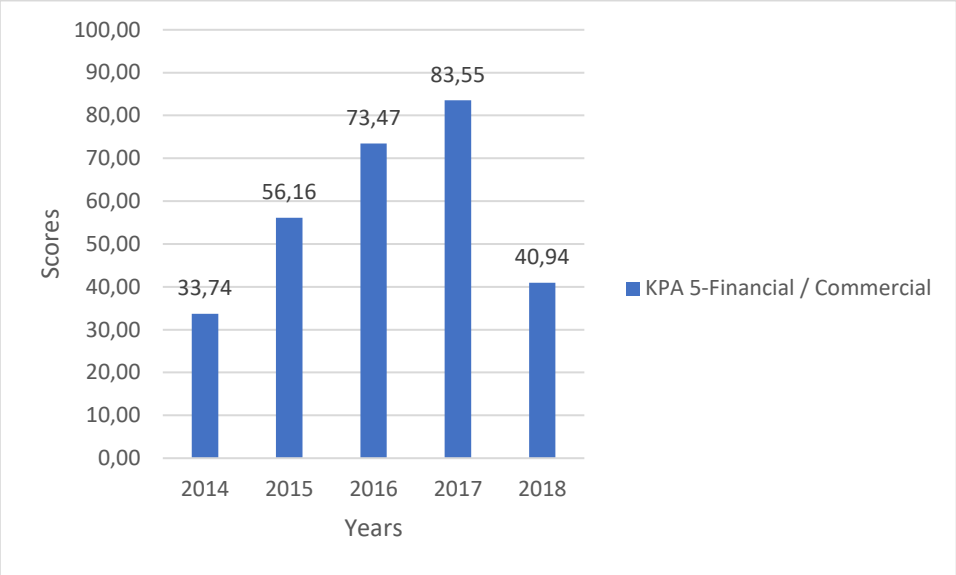

Figure 3.70 - KPA 5 - Financial / Commercial

Source: Own Elaboration

In Table 3.64 and Figure 3.70 we observe the poor results of this KPA 5 of Airport 4. The tendency of this KPA was to grow every year around 20 points. What happens is that this last year has a balance of -40 points. 2018 has lost all that it had taken it several years to achieve. It is known that AENA being a centralized organization cares about the largest airports to generate revenues and the rest of the airports, generate losses. The airport must focus on this KPA and try to reverse the situation. If Airport 4 do not take measures and more passengers arrive, etc., the results will get worse.

Table 3.65 - KPIs Environmental Airport 4

Source: Own Elaboration

Environmental	2014	2015	2016	2017	2018	Weight (%)
Carbon Footprint	44,44	0	83,34	66,67	100	21,21

Environmental	2014	2015	2016	2017	2018	Weight (%)
Waste Recycling	0	73,59	69,77	98,54	100	18,18
Renewable Energy Purchased by the Airport (%)	0	0	0	0	0	18,18
Waste Reduction (%)	55,33	100	0	63,88	6,08	15,15
Energy Usage per Square Meter of Terminal	100	73,49	17,67	23,56	0	15,15
Water Consumption per Passenger	78,36	34,65	100	0	91,34	12,12

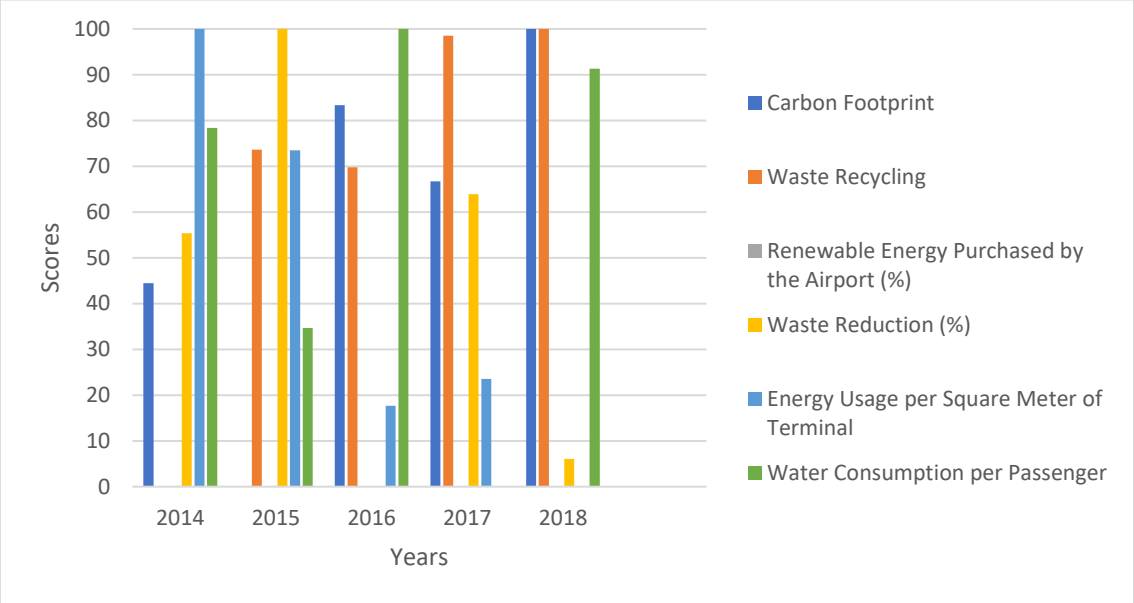

Figure 3.71 - KPIs Environmental Airport 4

Source: Own Elaboration

In Table 3.65 and Figure 3.71 we can see the KPIs of KPA 6 of the Airport 4. The maximums of these KPIs are so divided over the years. We comment first the KPI Carbon Footprint: it goes down from 2014 to 2015 reaching its minimum, it increases from 2015 to 2016, and it decreases again in 2017, and from 2017 it increases until its maximum in 2018. The environmental task of the airport to achieve in 2018 a reduction on the carbon footprint, despite having considerably increased its number of passengers, must be highlighted. The second KPI with more weight according to the specialists is Waste Recycling that practically is increasing the whole graph until reaching in 2018 the highest score. On the other hand, if we look at the graph, we will only see in 5 years 5 KPIs and this is because the KPI Renewable Energy Purchased by the Airport is 0 in the Airport 4 in all the years. The KPI Waste Reduction has its maximum in 2015 and its minimum in 2016 and in 2018 has a very bad score. The KPI Energy Usage per Square Meter of Terminal is decreasing in score from 2014 to 2018, that is, every year more energy is spent. This data shows that for the same square meters of terminal we have greatly increased the

number of passengers, therefore, the energy expended goes up. And finally, the KPI Water Consumption per Passenger has the maximum in 2016, the minimum in 2017, and the value of 2018 is quite good with 91,34 points of valuation as can be seen in Table 3.65.

Table 3.66 - KPA 6 - Environmental

Source: Own Elaboration

KPA 6	2014	2015	2016	2017	2018
Environmental	42,46	43,86	45,16	45,30	51,38

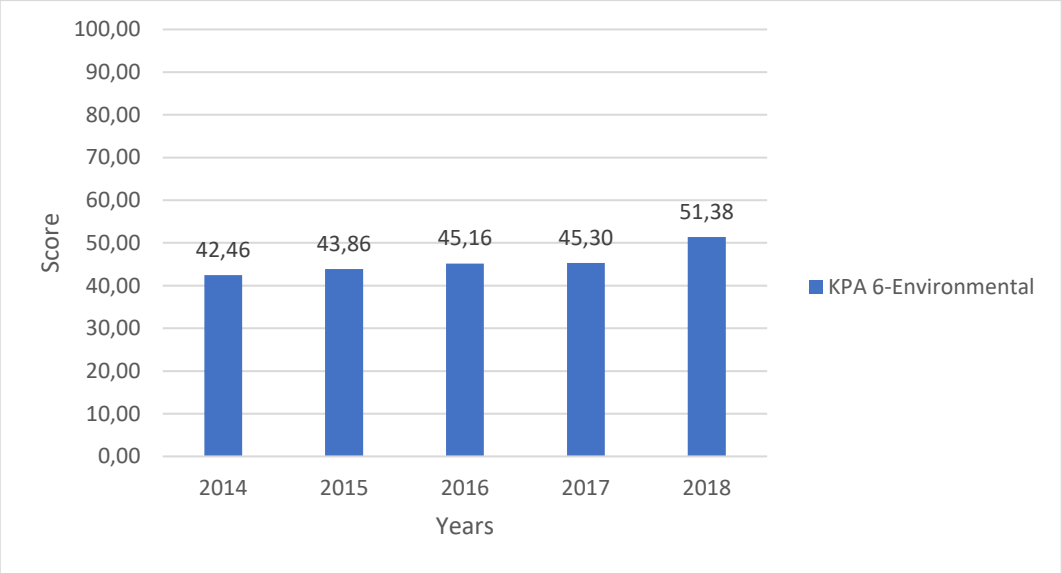

Figure 3.72 - KPA 6 - Environmental

Source: Own Elaboration

In Table 3.66 and Figure 3.72 we can observe the KPA 6 - Environmental of Airport 4. We see how 2018 is the year with the best score, but the range between the maximum and the minimum of those 5 years is 9 points. This KPA leads to a growing trend, but with very little inclination. The airport must take measures to improve this KPA and thus take it to higher values.

Table 3.67 - KPAs Airport 4

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018	Weight (%)
Safety and Security	57,79	67,23	53,84	74,62	64,07	22,00
Core	0,00	14,73	21,09	49,60	100,00	20,00
Productivity / Effectiveness	7,67	18,10	14,06	43,38	99,78	17,00
Service Quality	58,84	49,92	54,41	54,46	45,73	15,00
Financial / Commercial	33,74	56,16	73,47	83,55	40,94	15,00
Environmental	42,46	43,86	45,16	45,30	51,38	12,00

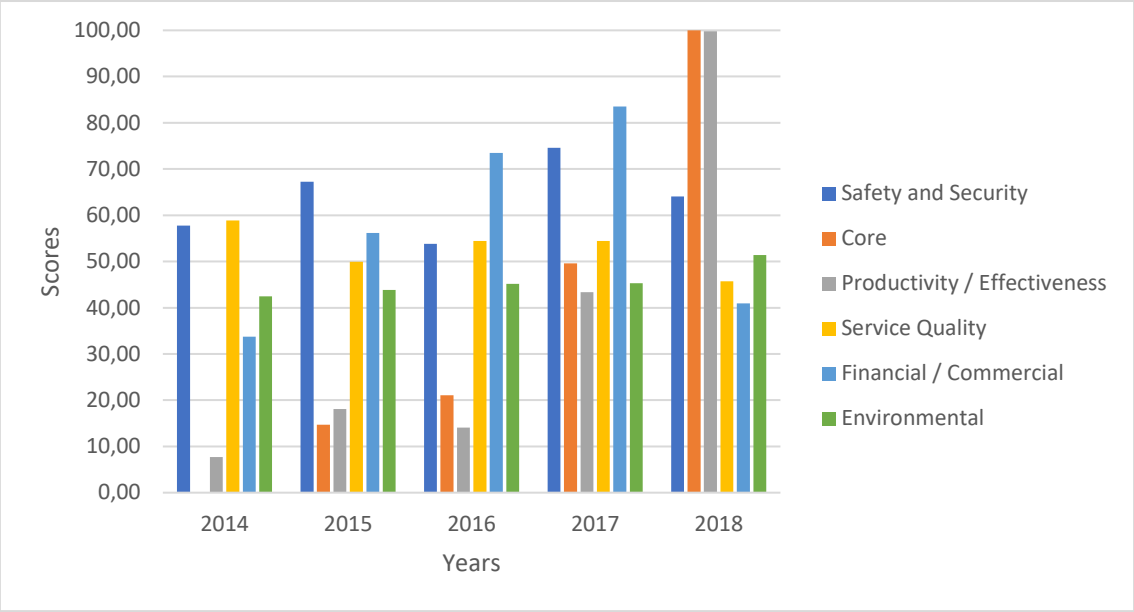

Figure 3.73 - KPAs Airport 4

Source: Own Elaboration

In Table 3.67 and Figure 3.73 we can see all the Airport 4 KPAs throughout the 5 years of study. In 2018 we can find 3 maximums of different KPAs, KPA 2 – Core, and KPA 3 - Productivity / Cost Effectiveness, that reach practically the maximum score. Both have improved more than 50 points from 2017 to 2018. The other maximum we found in 2018 is that of KPA 6 - Environmental. This is constant from 2014 to 2017, and from 2017 to 2018 it has a small improvement. Airport 4 must propose measures to improve this KPA. On the other hand, in 2018 the Airport 4 has an acceptable score in the KPA 1 - of Safety and Security, although the maximum is in 2017, that is to say there has been loss of score. And finally, a comment on the lowest scores of KPAs in 2018 which are the KPA 4 - Service Quality, and the KPA - 5 Financial / Commercial. The airport must propose measures now to improve these scores since as we have verified year after year, they are losing score.

Table 3.68 - % Efficiency Airport 4

Source: Own Elaboration

KPA	2014	2015	2016	2017	2018
% Efficiency	32,72	41,59	42,55	59,18	69,55

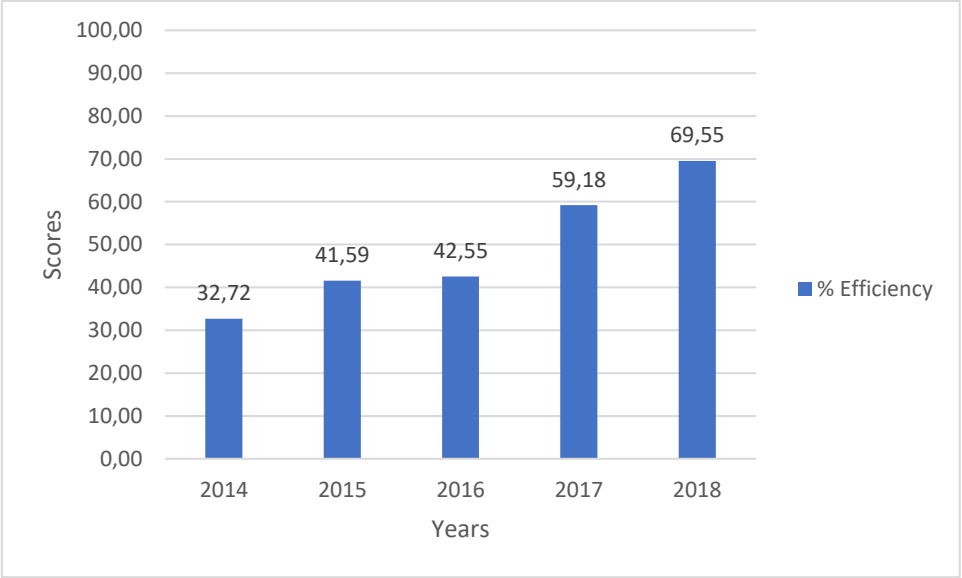

Figure 3.74 - % Efficiency Airport 4

Source: Own Elaboration

Finally, we have Table 3.68 and Figure 3.74 that show the percentage of efficiency that Airport 4 has. This graph has been done by applying the weights of the specialists to each KPA and adding the results for each year. We can see how it is a growing graph, where from 2015 to 2016 it remains constant, then there is a big rise in 2017 and then until 2018 with a score of 69,55. We have seen in the previous graphs the different deficiencies of certain KPIs in this airport, especially the KPIs 4 and 5. The airport in recent years is going through a process of change, due to the large increase in passengers, movements, etc.. It is necessary to adapt/change to improve. Therefore, it must take the appropriate measures for a continuous growing.

3.4 CASE II – Spanish Airports Peer-Benchmarking Study

Airport 1, Airport 2, Airport 3, Airport 4.

Then we will perform the Peer-Benchmarking of the 4 airports. First, we will analyze each KPA during the 5 years study of the 4 airports. Then the weights of the KPAs are applied to remove the variable of the years and to enable us to observe each KPA in each airport. Finally, airport weights are applied and we are able to see the efficiency of each of them. The order of the KPAs throughout this study goes from higher to lower weight assigned by the specialists.

Table 3.69 - KPA 1 Peer-Benchmarking

Source: Own Elaboration

KPA 1	Airport 1	Airport 2	Airport 3	Airport 4
2014	100	0	8,81	16,31
2015	4,19	46,44	0	55,28
2016	0	100	100	0
2017	37,86	42,51	67,19	100
2018	54,2	95,97	42,87	42,24

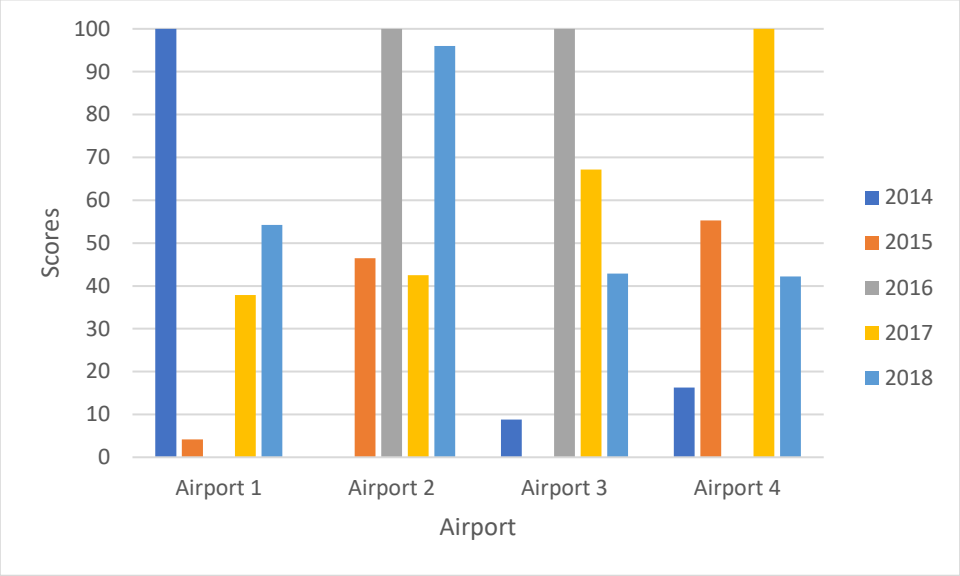

Figure 3.75 - KPA 1 Peer-Benchmarking

Source: Own Elaboration

In Table 3.69 and Figure 3.75 we can see **KPA 1 - Safety and Security** of the 4 airports during the 5 years of study. Highlights 2016 as the Airport 2 and Airport 3 achieve their maximum score. On the other hand, we observe that 2016 is also a year of minimum score with Airport 1 and Airport 4. The maximum of this KPA in Airport 1 is in 2014 and the maximum of Airport 4 is in 2017. After having analyzed Figure 3.75 we observe there is no relationship between airports with the ups and downs of the points in the KPA Safety and Security.

Table 3.70 - KPA 1 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 1	43,17	62,68	48,15	47,04

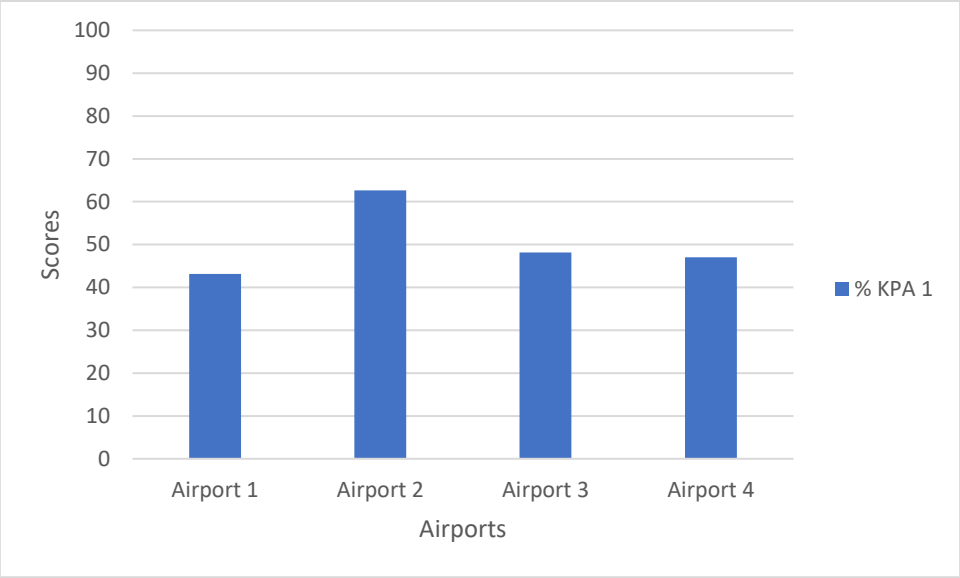

Figure 3.76 - KPA 1 TOTAL Peer-Benchmarking

Source: Own Elaboration

Now, we analyze Figure 3.76 which is obtained from the application of the weight of KPA 1 that specialists have given to Table 3.69. We can see how Airport 2 stands out among the rest in a clear way. Nevertheless, it is remarkable the behaviour of Airport 1, which despite of being the largest airport (highest number of passengers) is the most neglected, due to the fact that has its KPA with 43,7 of punctuation. Note that according to specialists, this KPA is the one that has more weight.

Table 3.71 - KPA 2 Peer-Benchmarking

Source: Own Elaboration

KPA 2	Airport 1	Airport 2	Airport 3	Airport 4
2014	0	0	0	0
2015	26,09	8,58	17,06	14,73
2016	45,62	39,13	28,26	21,09
2017	68,52	68,48	61,52	49,6
2018	100	100	100	100

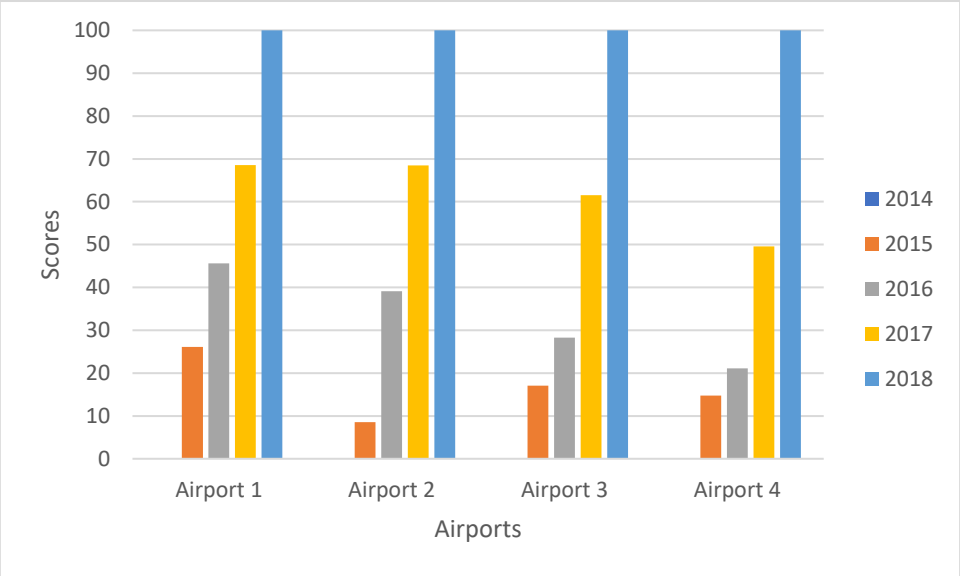

Figure 3.77 - KPA 2 Peer-Benchmarking

Source: Own Elaboration

Next, we analyze Figure 3.77 and Table 3.71, which is the **KPA 2 - Core** of the 4 airports from 2014 to 2018. On this occasion, airports are closely related, so that we are able to observe certain details. First of all, it should be noted that KPA 2 grows at all airports every year, reaching the maximum in 2018 with 100 points. But the most important thing in Figure 3.77 is the evolution of this KPA. We can see that in the two largest airports (Airport 1 and Airport 2) the score of the KPAs increases regularly over the years. On the other hand, the evolution of the KPAs of medium-sized airports (Airport 3 and Airport 4) is not regular. We see a large increase from 2016 to 2017 and above all from 2017 to 2018, where in Airport 3 it increases 38.48 points and in Airport 4 it increases 50.4 points.

Table 3.72 - KPA 2 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 1	48,04	43,23	41,36	37,08

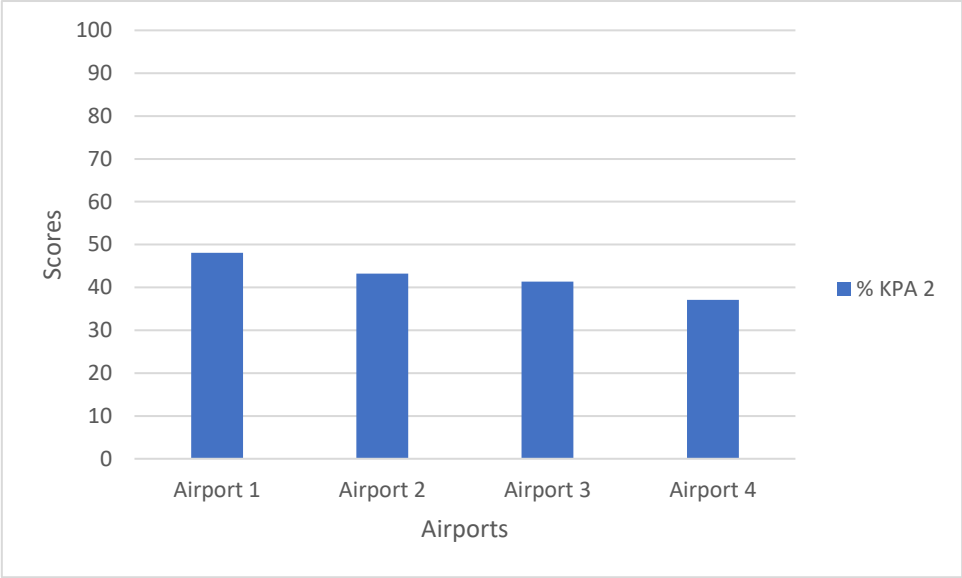

Figure 3.78 - KPA 2 TOTAL Peer-Benchmarking

Source: Own Elaboration

In Figure 3.78 and Table 3.72 we have applied the weight of the specialists to KPA - 2. Due to the regular way of increasing the KPA at large airports (Airport 1 and Airport 2) year by year, we see that when applying the KPA weights, better results are obtained than at medium airports (Airport 3 and Airport 4). The maximum of Figure 3.78 is for Airport 1 and the minimum for Airport 4. Despite this, the results of this KPA are very good in all airports.

Table 3.73 - KPA 3 Peer-Benchmarking

Source: Own Elaboration

KPA 3	Airport 1	Airport 2	Airport 3	Airport 4
2014	24,24	14,52	1,09	0
2015	0	0	0	8,49
2016	42,88	41,67	3,14	5,2
2017	100	100	45,82	31,12
2018	95,13	96,21	100	100

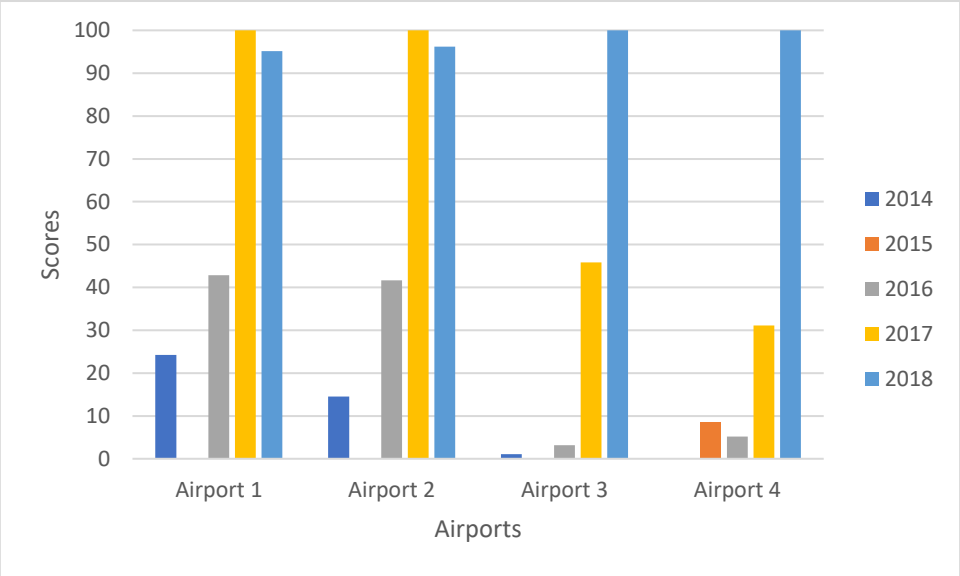

Figure 3.79 - KPA 3 Peer-Benchmarking

Source: Own Elaboration

Figure 3.79 and Table 3.73 analyze the evolution of **KPA 3 - Productivity / Cost Effectiveness** over the 5 years of study for the 4 airports. In this KPA we can divide the airports in large airports and medium airports. On the one hand, we have large airports (Airport 1 and Airport 2) where we have a bad 2014, the minimum in 2015 and from there, it rises to reach maximum values in 2017 and keep them quite well in 2018. On the other hand, we have medium airports (Airport 3 and Airport 4) where all the scores are quite low and in 2018 there is an incredible improvement. The results show that both Airport 3 and Airport 4 have implemented measures for this KPA and these measures have yielded results. So even though the results of the big airports are better than the results of the medium ones, the 4 airports are in a good direction improving this KPA every year.

Table 3.74 - KPA 3 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 3	44,58	42,90	25,50	24,61

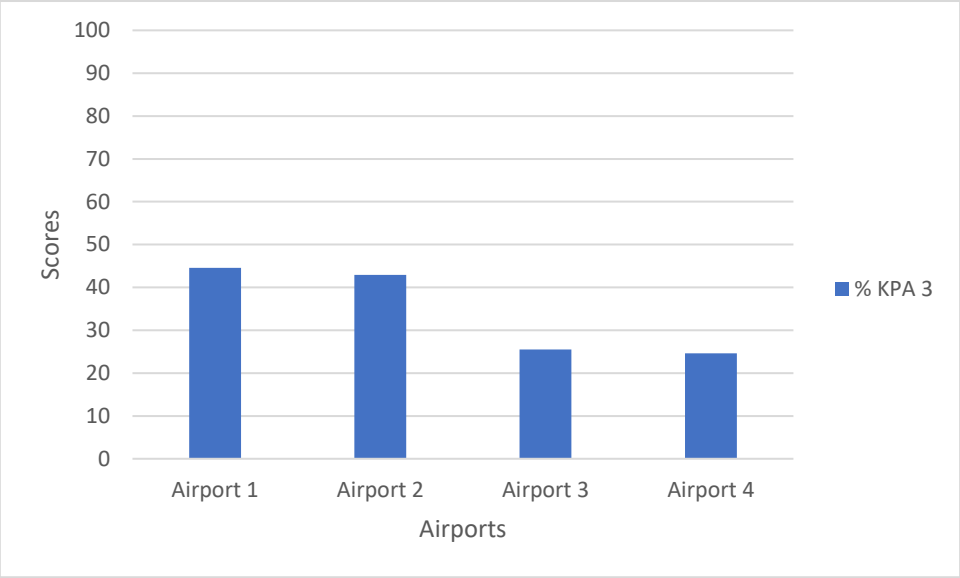

Figure 3.80 - KPA 3 TOTAL Peer-Benchmarking

Source: Own Elaboration

In Table 3.74 and Figure 3.80 we can observe KPA 3 after the application of its weight. After having analyzed Figure 3.79, these results are understandable where the group of large airports (Airport 1 and Airport 2) almost doubled the middle group (Airport 3 and Airport 4). These results can be justified because AENA is a centralized organization where large airports generate wealth and the rest generates losses. Despite this, we have seen in Figure 3.79 how airports that are not large are also applying measures to improve this KPA.

Table 3.75 - KPA 4 Peer-Benchmarking

Source: Own Elaboration

KPA 4	Airport 1	Airport 2	Airport 3	Airport 4
2014	56,42	0	0	100
2015	100	100	78,19	27,39
2016	12,08	39,43	22,15	70,84
2017	0	7,39	26,69	71,33
2018	7,24	24,26	100	0

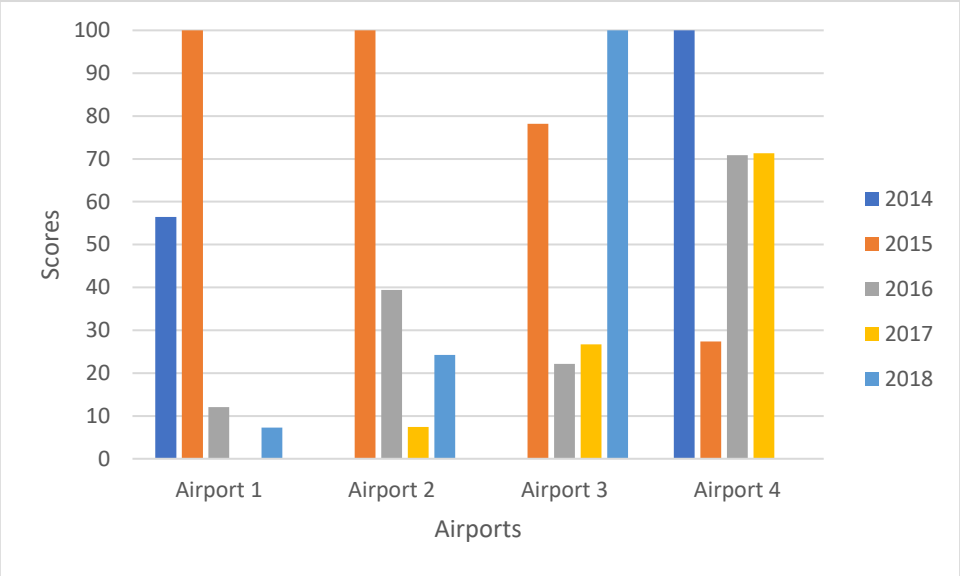

Figure 3.81 - KPA 4 Peer-Benchmarking

Source: Own Elaboration

Next, in Figure 3.81 and Table 3.75 we can observe the **KPA 4 - Service Quality** in the 4 airports during the 5 years of study. At first glance, we observe how in general the results of the 4 airports do not have any relation to each other. We are able to see how the maximum of Airport 1 and Airport 2 is 2015, but there is no reasonable resemblance anymore. And we can also observe that in the scores of the medium airports (Airport 3 and Airport 4) are higher than the scores of the large airports (Airport 1 and Airport 2). We can also see that except in Airport 3, the value of time progresses are losing punctuation. This may be due to the fact that in recent years there has been an increase in very large passengers, which is why waiting times have increased and the airport must adapt to this. We see how, in general, each airport has to propose measures to improve this KPA in the coming years.

Table 3.76 - KPA 4 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 4	26,36	25,66	34,05	40,43

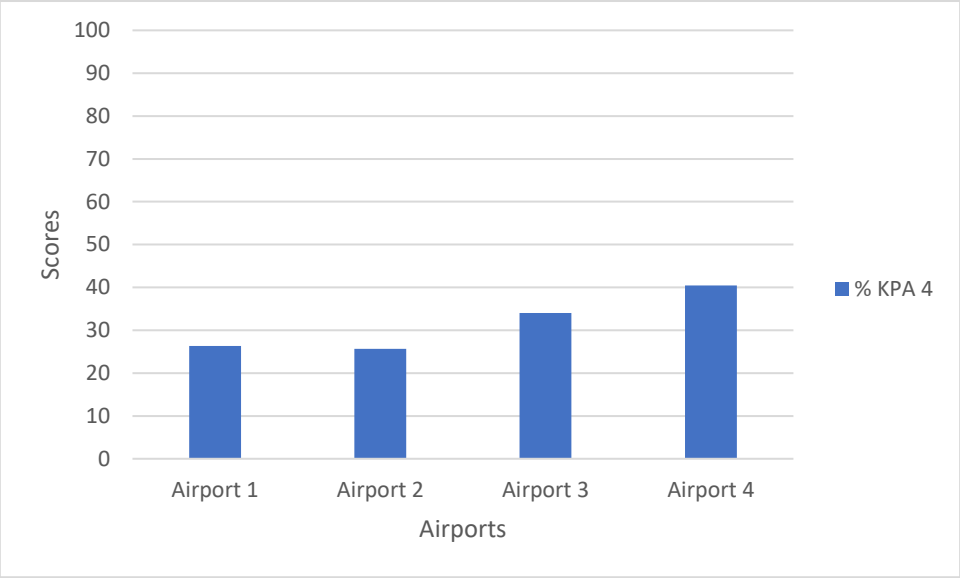

Figure 3.82 - KPA 4 TOTAL Peer-Benchmarking

Source: Own Elaboration

In Table 3.76 and Figure 3.82, we observe KPA 4 after applying the weight of this KPA. As we have been saying after observing Figure 3.82, medium airports (Airport 3 and Airport 4) have better results than large airports (Airport 1 and Airport 2). Airport 2 has the minimum score while the Airport 4 has the maximum. Regardless of this, the results of this KPA are not good and airports should propose measures to improve this KPA.

Table 3.77 - KPA 5 Peer-Benchmarking

Source: Own Elaboration

KPA 5	Airport 1	Airport 2	Airport 3	Airport 4
2014	0	0	0	0
2015	91,68	91,68	100	45,02
2016	69,82	73,06	81,69	79,77
2017	76,56	77,96	66	100
2018	100	100	15,81	14,46

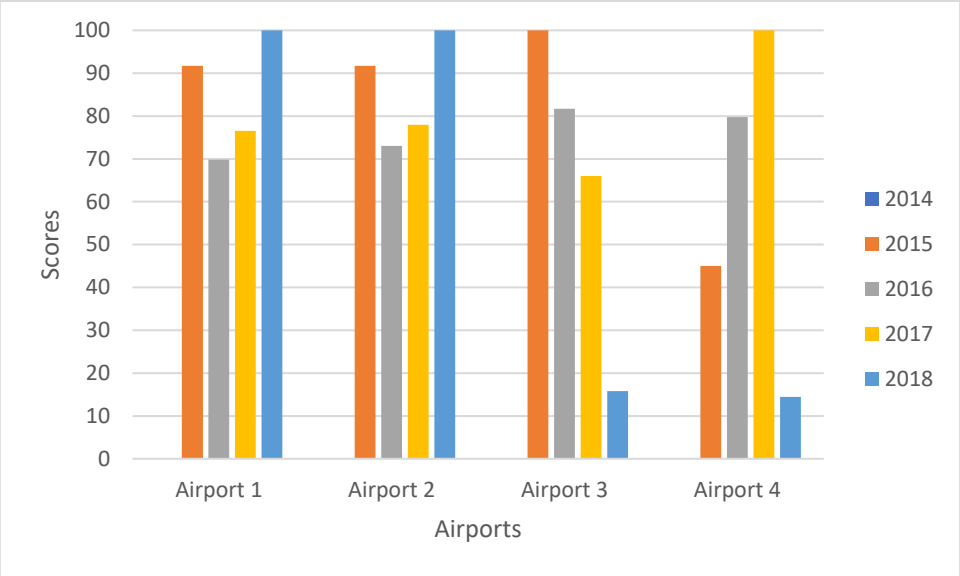

Figure 3.83 - KPA 5 Peer-Benchmarking

Source: Own Elaboration

In Table 3.77 and Figure 3.83 we can see the representation of **KPA 5 - Financial / Commercial** for the 4 study airports from 2014 to 2018. Again, we can differentiate into two groups: large airports (Airport 1 and Airport 2) and medium (Airport 3 and Airport 4). On the part of large airports, we see how the results look very similar. Both airports have their maximum score in 2018, their minimum score in 2014 and the values of 2015, 2016 and 2017 quite high. While the group of medium-sized airports, have very bad results for 2014 and 2018, and it does not seem that they will improve. As we have already mentioned several times, the results of this KPA are due to the fact that AENA is a centralized organization, where the economic benefits are produced by large airports while the losses are produced by the rest. As we can see in Figure 3.83 in large airports, the improvement measures and the good road they take are observed, while the small ones need urgent improvement measures.

Table 3.78 - KPA 5 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 5	50,70	51,40	39,52	35,88

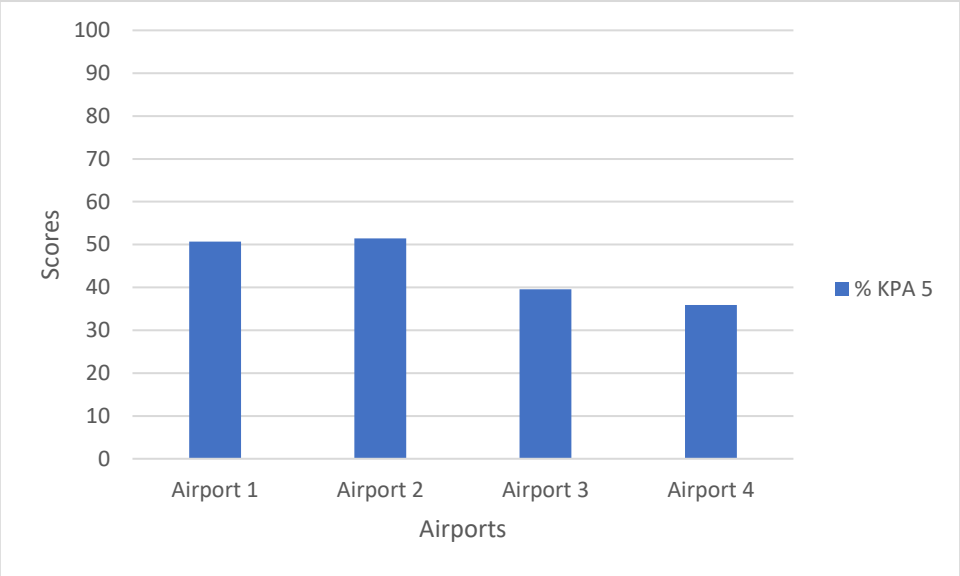

Figure 3.84 - KPA 5 TOTAL Peer-Benchmarking

Source: Own Elaboration

In Figure 3.84 and Table 3.78 we can observe KPA 5 after the weight application of KPA. After having seen graph 3.83, these are the results we expected. Airport 1 and Airport 2 with high and similar values. And Airport 3 and Airport 4 with lower than normal values. Airport 3 and Airport 4 need improvement measures for this KPA.

Table 3.79 - KPA 6 Peer-Benchmarking

Source: Own Elaboration

KPA 6	Airport 1	Airport 2	Airport 3	Airport 4
2014	0	68,89	15,16	0
2015	46,44	0	100	15,71
2016	100	60,48	0	30,3
2017	42,51	97,9	94,29	31,87
2018	95,97	100	34,84	100

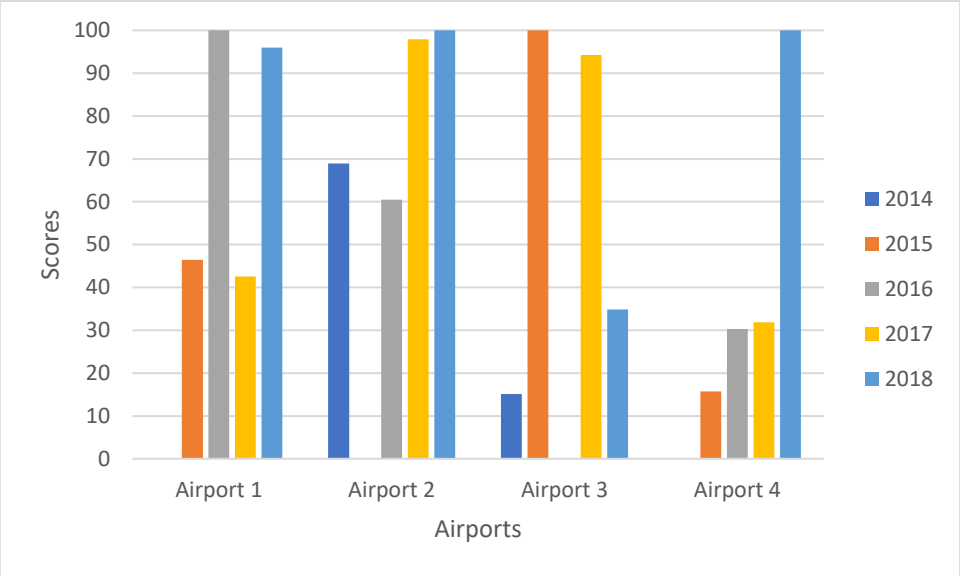

Figure 3.85 - KPA 6 Peer-Benchmarking

Source: Own Elaboration

To finish the KPAs, in Figure 3.85 and Table 3.79 we see the last KPA of the study, the **KPA 6 - Environmental**, during the 5 years of study for the 4 airports. We can see how the results of this KPA are quite random although we can draw some similarities between airports. For instance, in 2018, with the exception of Airport 3, all airports have quite high scores. And in 2014, with the exception of Airport 2, all airports have fairly low scores. We can see how Airport 1, Airport 2 and Airport 4 have a growing trend while Airport 3 has a decreasing trend. After analyzing the 4 airports we reached the conclusion that measures must be implemented to improve this KPA in the 4 airports.

Table 3.80 - KPA 6 TOTAL Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 6	34,19	39,27	29,31	21,34

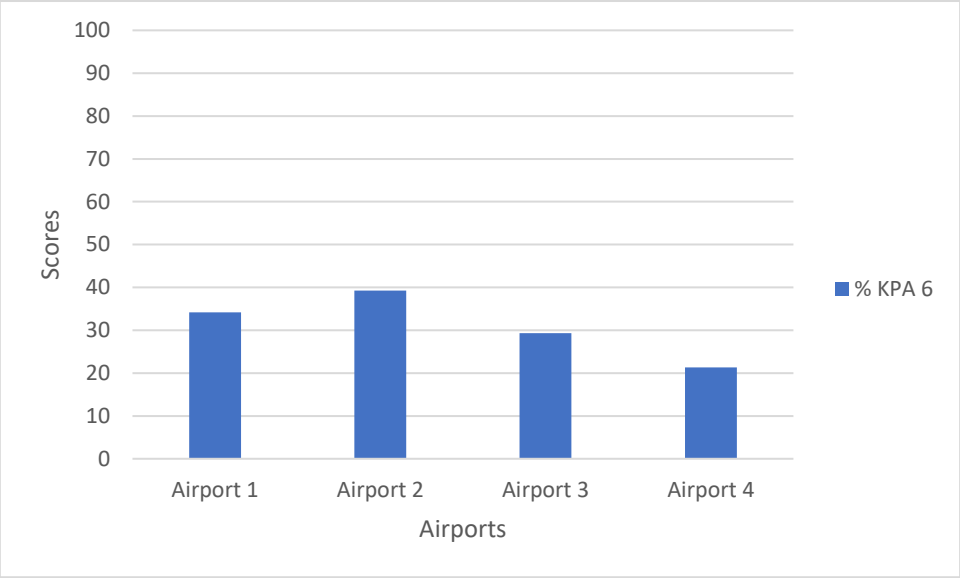

Figure 3.86 - KPA 6 TOTAL Peer-Benchmarking

Source: Own Elaboration

In Table 3.80 and Figure 3.86 we observe KPA 6 after the application of the weights of the specialists. We can see how the highest score is that of Airport 2, followed by Airport 1, Airport 3 and finally Airport 4. This KPA has been the last to join the list and is the least weight for specialists, but little by little is getting more importance. However, it needs to improve at the 4 airports.

Table 3.81 - KPAs Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
KPA 1	43,17	62,68	48,15	47,04
KPA 2	48,04	43,23	41,36	37,08
KPA 3	44,58	42,90	25,50	24,61
KPA 4	26,36	25,66	34,05	40,43
KPA 5	50,70	51,40	39,52	35,88
KPA 6	34,19	39,27	29,31	21,34

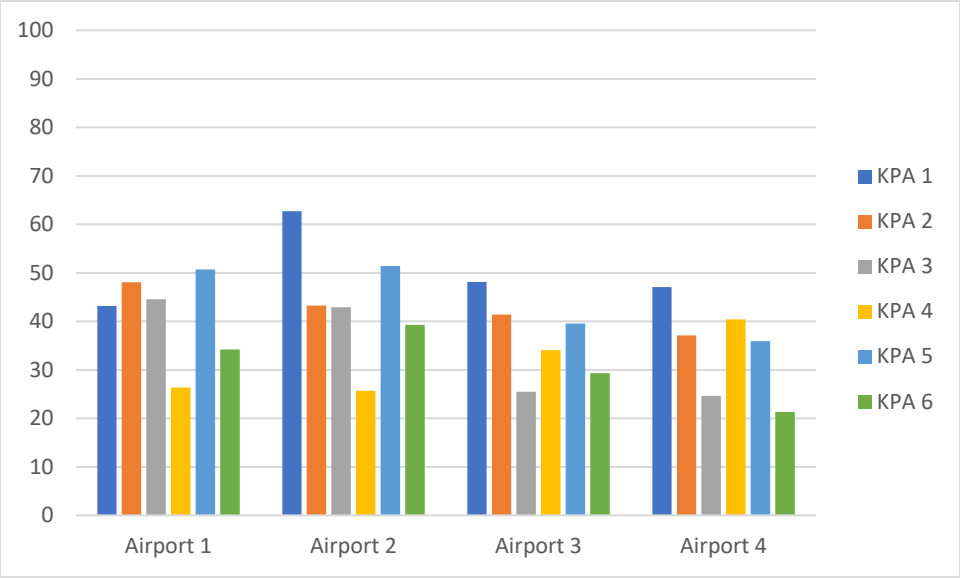

Figure 3.87 - KPAs Peer-Benchmarking

Source: Own Elaboration

We can see in Figure 3.87 and Table 3.81 the representation of the KPAs for each airport after having applied the weights of the specialists during the 5 years of study. We see how maximum values are usually on the left side of the airport, since they are the values whose weight of the specialists was higher. Airport 3 is the airport with the least difference between its maximum and its minimum values. The maximum of the graph belongs to the KPA 1 of Airport 2 and the minimum value belongs to KPA 6 of Airport 4. We can see again the similarity between Airport 1 and Airport 2 (large airports) and Airport 3 and Airport 4 (small airports).

Table 3.82 - % Efficiency Peer-Benchmarking

Source: Own Elaboration

	Airport 1	Airport 2	Airport 3	Airport 4
% Efficiency	95,73	79,55	37,04	29,41

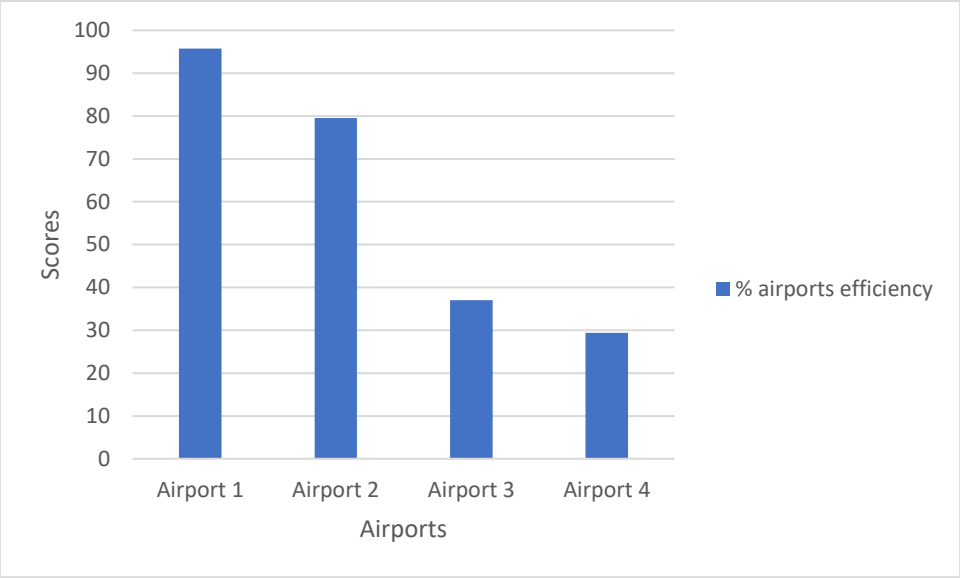

Figure 3.88 - % Efficiency Peer-Benchmarking

Source: Own Elaboration

And to conclude this we observe Figure 3.88 and Table 3.82 where we find the result after applying to the airport weights assigned by the specialists. We see how Airport 1 is located in the first position, followed by Airport 2, Airport 3 and Airport 4.

3.5 Conclusion

Through this chapter and the analysis of the two case studies, we have been able to better understand the functioning of MACBETH and know the strengths and weaknesses of the different airports. Case I of the study consists in carrying out a Self-Benchmarking analysis of 4 airports, that is, an internal analysis of each airport over a period of 5 years, where data was introduced for several KPIs within 6 KPAs, balanced by the opinion of specialists/experts. On the other hand, Case II was a Peer-Benchmarking Analysis of the 4 airports, that is, to compare these airports along the same period of 5 years.

We recall that in Case I we have carried out 4 Self-Benchmarking studies: Airport 1 that owns most of the data of the airport A.S. Madrid-Barajas, Airport 2 that owns most of the data of J.T. Barcelona-El Prat, Airport 3 that owns most of the data of the airport of Valencia, and Airport 4 that holds most of the data of Sevilla airport. From Case I, we have drawn these conclusions:

- Regarding Airport 1, we can see the good evolution it has from 2014 to 2018 since the efficiency analysis in 2014 has the value of 35,55 and in 2018 75,27, the highest score

of the 4 airports under study. We have verified in this study that the KPAs that have the best punctuation within this airport is KPA 2 – Core, and KPA 3 - Productivity / Cost Effectiveness. While the KPAs that must be improved are mainly KPA 1 - Safety and Security, and KPA 4 - Service Quality;

- Airport 2 has a good evolution of efficiency from 2014 to 2018. In 2014 it receives a score of 27,27 and in 2018 74,64. The KPAs with the best results are KPA 2 – Core, and KPA 3 Productivity / Cost Effectiveness, and the KPAs with the worst results are KPA 1 - Safety and Security, and KPA 4 - Service Quality. We can see that both (the best KPAs and the worst KPAs) are the same as Airport 1. This is due to the centralization of AENA and the application of similar measures as for the group of large airports;

- Airport 3 also has a good evolution of efficiency from 2014 to 2018. In 2014 it has a value of 31,29 and in 2018 it is 70,84. The best KPAs of this airport are KPA 2 – Core, and KPA 3 - Productivity / Cost Effectiveness. And the worst KPAs that this airport presents are KPA 5 - Financial / Commercial, and KPA 6 - Environmental. It is normal for KPA 5 to be low since AENA focuses on large airports to earn revenue;

- Regarding Airport 4, we can see a good evolution of the efficiency values from 2014 to 2018. It ranges from 32,72 in 2014 to 69,55 in 2018. The best KPAs of this airport are KPA 2 – Core, and KPA 3 - Productivity / Cost Effectiveness. And the worst are KPA 4 - Service Quality, and KPA 5 - Financial / Commercial.

On the other hand, in Case II we have also worked with Airport 1, Airport 2, Airport 3 and Airport 4 with the respective data. The results of the Peer-Benchmarking study are the following:

- We can see that in the KPA 1 the airport that was the best score was Airport 2 with 62,68 points and the worst was Airport 1 with 43,17 points. For the KPA 2, the best airport was Airport 1 with 48,04 points and the worst airport was Airport 4 with 37,08 points. For KPA 3 the airport that was the best was Airport 1 with 44,58 points and the worst was Airport 4 with 24,61 points. For the KPA 4, the airport which was the best was Airport 4 with 40,43 points and the worst was Airport 2 with 2566 points. For the KPA 5, the best airport was Airport 2 with 51,40 and the worst one was Airport 4 with 35,88. For KPA 6, the best airport was Airport 1 with 34,19 and the worst Airport 4 with 21,34.

  After applying the airport weights, we found that in first position is Airport 1, then Airport 2, then Airport 3 and then Airport 4.

The only negative aspect of this study has been not to get all the required data from Spanish airports because AENA did not provide them in time. But we overcomed the problem with a good solution: the use of similar airports (American) and the use of trend lines.

Chapter 4 – Conclusions

4.1 Dissertation Synthesis

This work was carried out to assess the performance and efficiency of 4 Spanish airports using MCDA MACBETH tool with the PESA-AGB model, by assessing results, and depicting its representation, and propose improvements. The Benchmarking studies were conducted both externally and internally: Case I (Self-Benchmarking) and Case II (Peer-Benchmarking).

Thus, we established 3 specific objectives: to choose KPA / KPI to use, as there are many and our data entry program is limited; to choose the analysis method to use; and to perform the airport Benchmarking (self and peer) with the previous relevant data collection, throughout the study of cases. Once the results were obtained, we represented and analysed them and proposed some improvements for the next future.

In the second chapter of the thesis, we explained the method that we carried out for the realization of the thesis. We also did a theoretical review, starting with the explanation of the Spanish airports chosen for the study, why we have chosen these airports, the current situation of these airports and AENA responsibility. Also we made a deep literature review on the thesis' Key Words: Benchmarking - explaining both internal (Self-Benchmarking) and external (Peer-Benchmarking) analysis; MACBETH - evidencing its functioning and the mathematical bases by which it moves. Also we reviewed the concepts of PESA-AGB, Airports Performance, and Airports Efficiency – the essence of PESA-AGB model, and the definitions, advantages and disadvantages for Airport Performance and Efficiency evaluation.

In the third chapter, we considered two case studies. Firstly we proceed with Case I, which consisted in the Self-Benchmarking of 4 airports, during 5 years, based on 6 KPAs and several related KPIs. Secondly, the Case II, a Peer-Benchmarking study involving those 4 airports, along 5 years period too, based on the referred 6 KPAs and related KPIs. In both cases, we used MCDA MACBETH tool with the PESA-AGB model, because it enabled to incorporate the specialists opinion: to conceive the matrix of judgments, and to incorporate the weights.

The obtained results were very useful because they enable us to suggest some improvements on each air infrastructure, even taking into account that the information processed does not fully correspond to each of the Spanish airports that we intended to study. Nevertheless, the great advantage of this work is to demonstrate that, having the appropriate information, the methodology used allows a behavioural analysis of any complex transportation infrastructure, including any airport, with the detail that the stakeholders understand.

4.2 Concluding Remarks

The main objective of this work was to carry out a study of the performance and efficiency of 4 Spanish airports through the MCDA MACBETH tool with PESA-AGB model. Thus, we carried out two Benchmarking study of cases (self and peer). Accordingly, we defined 3 specific objectives:

- The choice of the corresponding KPIs and KPAs for the correct performance of the study; effectively we chose the KPAs (6) and KPIs (42) proposed by ACI and most suitable for the study. Therefore, **goal fulfilled**;

- The choice of the most suitable methodology to carry out the study; effectively we chose the MCDA MACBETH tool with PESA-AGB model, the most suitable for the study as we could apply opinions of specialists for matrices of judgments and weights, thus validating the results. Therefore, **goal fulfilled**;

- And finally, the realization of Benchmarking (Self and Peer); we carried out 4 Self-Benchmarking studies at Airport 1 (with partial data from the AS Madrid-Barajas airport), Airport 2 (with partial data from the JT Barcelona-El Prat airport), Airport 3 (with partial data from the Valencia airport) and Airport 4 (with partial data from Sevilla airport); we have conducted a Peer-Benchmarking study with Airport 1, Airport 2, Airport 3 and Airport 4 too. Therefore, **goal fulfilled**.

We realize that we have achieved all the specific objectives that we proposed at the beginning of the work.

Unfortunately, we must underline that we could not use all data from Spanish airports. Effectively, the only information available on the AENA website is general one about itself, such as the 46 airports and the 2 heliports characteristics, but not specific airport data. We sent more than 100 emails, both to airports and corresponding departments (environment, marketing...), as well as to AENA central and private workers of AENA. Among all, only 37 emails were answered, being the majority unable to provide us with any type of data. We called 23 phone numbers and they have not provided us with any information too. Also, we contacted 2 workers from this study airports (Madrid and Valencia) and they have not granted any data either. To the airports that answered us, we sent a document with reference to data required; that document was signed by the tutor and the university to let them know that those data were to be used strictly for academic use. Thus, we sent 19 requests and received 0 data. Specifically, for the environmental issue, we made three official requests asking for data and none of them was answered. After receiving this many unanswered questions, we decided to

look for solutions elsewhere, since we considered this topic very interesting and nobody had done a study like this before.

For this reason, we could not say with certainty that the real results will be exactly as we showed, but we are sure that the differences (if any) are perhaps minimal, and even so they are not the most important conclusion from this research work: as referred previously, the great advantage of this work is to demonstrate that, having the appropriate information, the methodology used allows a behavioural analysis of any airport with the detail that the stakeholders understand.

4.3 Prospects for Future Work

This thesis can be the beginning of a wide research work on the efficiency and development of AENA's airports. In the future, studies could be carried out with these recommendations:

1. To get real data of all the KPIs of the airports; this task was not possible for us in time, but we are sure that it is not impossible in the future;
2. To incorporate the 46 airports of AENA; although our study is coherent the results will be more accurate if using more (all AENA) infrastructures;
3. To use others MCDA tools and compare the obtained results.

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Annex I – Matrix of Judgments of Specialists

Table A-I 1 - Judgements matrix of Airports

Source: Specialists

Airports		
Weak- Mod	Strong	Strg-Vstr
	Strg-Vstr	Strong
		Very Weak

Table A-I 2 - Judgements matrix of KPAs

Source: Specialists

KPA 1 - Safety and Security		
Moderate	Mod-Strg	Strg-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

KPA 2 - Core		
Moderate	Strong	Strong
	Moderate	Mod-Strg
		Moderate

KPA 3 - Productivity / Cost Effectiveness		
Weak-Mod	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

KPA 4 - Service Quality		
Moderate	Strong	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

KPA 5 - Financial / Commercial		
Weak-Mod	Mod-Strg	Strg-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

KPA 6 - Environmental		
Weak-Mod	Mod-Strg	Strong
	Weak	Moderate
		Weak

Table A-I 3 - Judgements matrix of KPIs Safety and Security

Source: Specialists

Runway Accidents		
Moderate	Strong	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Runway Incursions		
Moderate	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg
		Moderate

Bird Strikes		
Weak-Mod	Mod-Strg	Strg-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

Public Injuries		
Moderate	Mod-Strg	Strong
	Weak-Mod	Mod-Strg
		Weak-Mod

Occupational Injuries			Lost Work Time from Employee Accident		
Weak-Mod	Moderate	Strong	Weak-Mod	Moderate	Strong
	Weak	Moderate		Weak	Moderate
		Weak			Weak

Table A-I 4 - Judgements matrix of KPIs Core

Source: Specialists

Passengers			Aircraft Movements		
Moderate	Strong	Strg-Vstr	Mod-Strg	Strong	Very Strong
	Moderate	Strong		Moderate	Strong
		Moderate			Moderate
Original and Destination Passengers			Freight and Mail Loaded Unloaded		
Moderate	Strong	Strg-Vstr	Moderate	Mod-Strg	Strong
	Moderate	Mod-Strg		Weak-Mod	Mod-Strg
		Moderate			Weak-Mod
Destinations Non-Stop					
Moderate	Weak-Mod	Strong			
	Weak-Mod	Mod-Strg			
		Weak-Mod			

Table A-I 5 - Judgements matrix of KPIs Productivity / Cost Effectiveness

Source: Specialists

Total Cost per Passenger			Total Cost per Movement		
Moderate	Strong	Strg-Vstr	Moderate	Strong	Strg-Vstr
	Moderate	Strong		Moderate	Strong
		Moderate			Moderate
Operating Cost per Movement			Aircraft Movements per Gate		
Moderate	Strong	Strg-Vstr	Weak-Mod	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg		Weak-Mod	Moderate
		Weak-Mod			Weak-Mod
Total Cost per WLU			Operating Cost per WLU		
Weak-Mod	Mod-Strg	Strg-Vstr	Moderate	Strong	Strg-Vstr
	Weak-Mod	Mod-Strg		Moderate	Mod-Strg
		Weak-Mod			Moderate

Operating Cost per Passengers		
Weak-Mod	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Passengers per Employee		
Weak-Mod	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Aircraft Movements per Employee		
Weak-Mod	Mod-Strg	Strg-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

Table A-I 6 - Judgements matrix of KPIs Service Quality

Source: Specialists

Customer Satisfaction		
Moderate	Strong	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Gate Departure Delay		
Moderate	Mod-Strg	Strg-Vstr
	Moderate	Mod-Strg
		Weak

Baggage Delivery Time		
Moderate	Strong	Strong-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

Taxi Departure Delay		
Moderate	Mod-Strg	Strong
	Weak-Mod	Moderate
		Weak

Security Clearing Time		
Moderate	Strong	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Border Control Clearing Time		
Moderate	Mod-Strg	Strong
	Weak-Mod	Mod-Strg
		Weak

Check-in to Gate Time		
Moderate	Strong	Strong
	Moderate	Mod-Strg
		Weak-Mod

Practical Hourly Capacity		
Moderate	Strong	Strg-Vstr
	Moderate	Mod-Strg
		Weak-Mod

Table A-I 7 - Judgements matrix of KPIs Financial / Commercial

Source: Specialists

Aeronautical Revenue per Passenger		
Weak-Mod	Strong	Strg-Vstr
	Weak-Mod	Mod-Strg
		Weak-Mod

Aeronautical Revenue per Movement		
Weak-Mod	Mod-Strg	Strg-Vstr
	Weak-Mod	Strogn
		Weak-Mod

Non-Aeronautical Operating Rev. per Pass.			EBITDA per Passenger		
Weak-Mod	Strong	Strong	Moderate	Strong	Strg-Vstr
	Weak-Mod	Mod-Strg		Moderate	Strong
		Weak-Mod			Moderate
Non-Aero.Op.Rev. as Perc. Of Tot.Op.Rev.			Debt to EBITDA Ratio		
Moderate	Strong	Strg-Vstr	Weak-Mod	Mod-Strg	Strong
	Weak-Mod	Mod-Strg		Weak-Mod	Mod-Strg
		Weak-Mod			Weak-Mod
Debt Service as Percentage of Op. Rev.			Long-Term Debt per Passenger		
Weak	Moderate	Strong	Moderate	Mod-Strg	Strong
	Weak	Moderate		Weak-Mod	Mod-Strg
		Weak			Weak

Table A-I 8 – Judgements matrix of KPIs Environmental

Source: Specialists

Carbon Footprint			Waste Recycling		
Mod-Strg	Strg-Vstr	V.Strong	Weak-Mod	Mod-Strg	Strong
	Moderate	Strong		Weak	Moderate
		Moderate			Weak
Renewable Energy Purchased by the Airp.			Waste Reduction Percentage		
Weak-Mod	Moderate	Strong	Weak	Weak-Mod	Moderate
	Weak	Moderate		Weak	Weak-Mod
		Weak			VWeak-Weak
Energy Usage per Square Meter of Termin.			Water Consumption per Passenger		
Moderate	Strong	Strg-Vstr	Weak	Moderate	Strong
	Weak-Mod	Mod-Strg		Weak	Moderate
		Weak			Weak

Annex II – Airports Data

Table A-II 1 – Data Madrid

Source: [53][54][55][56][57][58][59][60][61][62][63][64][65][66][67][68][69][70][71][72][73]

			AIRPORT 1 - MADRID				
			2014	2015	2016	2017	2018
Safety and Security	**Runway Accidents**	Accidents /1000MOVS	0	0	0	0	0
	Runway Incursions	Incursions /1000MOVs	0,086	0,102	0,094	0,08	0,097
	Bird Strikes	BS /1000MOVs	0,07	0,073	0,071	0,132	0,141
	Public Injuries	Plnj /1000MOVs	0,311	0,286	0,416	0,279	0,188
	Occupational Injuries	Ocplnj /1000Hours Worked	0,962	0,921	1,043	0,865	0,792
	Lost work Time from Employee Accidents and Injuries.	LWT/1000 Hours Worked	3,6556	5,3418	4,2763	4,5845	3,8016
Core	**Passengers**	n° PAX	41833686	46824838	50418909	53400844	57891340
	Origination and destination passengers	n° PAX O&D	28195904	31091692	31763913	34176540	37050458
	Aircraft Movements	n° MOVS	342604	366608	378151	387568	409832
	Freight and Mail Loaded/Unloaded	Metric TONs	366993,8	381594,78	416332,23	472248,85	518858,99
	Destinations non-stop	n° AIRP non-stop	181	187	202	211	218
Productivity / Cost Effectiveness	**Passengers Per Employee Aircraft**	PAX/EMP	1394,46	1560,83	1680,63	1780,03	1929,71
	Movement per Employee Aircraft	MOVs/EMP	11,42	12,22	12,61	12,92	13,66
	Movement per Gate	MOVs/GATES	1502,65	1607,93	1658,56	1699,86	1797,51
	Total Cost per Passenger	Tcost/PAX	10,81	10,93	10,01	9,26	9,34
	Total Cost per Movement	Tcost/MOVs	1319,96	1396,66	1334,73	1275,60	1319,88
	Total Cost per WLU	Tcost/WLU	1,11	1,20	1,08	0,94	0,94

			AIRPORT 1 - MADRID				
			2014	2015	2016	2017	2018
	Operating Cost per Passenger	OP Cost/Pax	6,60	6,84	6,40	6,02	6,07
	Operating Cost per Movement	OP Cost/MOVs	806,39	873,59	853,01	829,51	857,60
	Operating Cost per WLU	OP Cost/WLU	0,68	0,75	0,69	0,61	0,61
Service Quality	**Practical hourly Capacity**	MAxMOVs /hour	48	48	48	48	48
	Gate Departure Delay	ΣAGTj /nFligths	8,7	7,8	7,1	14,6	13,8
	Taxi Departure Delay	ΣATTj /nFligths	3,1	2,9	3,4	4,6	4,8
	Customer Satisfaction	%	72,2	74,1	72,5	75,7	76,3
	Baggage Delivery Time	ΣABDTj /nFlights	29,3	29,8	32,5	29,7	28,6
	Security Clearing Time	ΣASCTj/nPAX	21,5907	19,34811	21,7692	22,0506	22,93268
	Border Control Clearing Time	ΣABCCTj /nPAX	10,2	9,5	9,8	10,7	11,2
	Check-in to Gate Time	Σ(ATjxPAXj) /ΣnPAX	24,8	26,2	29,7	28,6	28,1
Financial / Commercial	**Aeronautical Revenue per Passenger**	REV/PAX	16,19	16,98	16,39	16,14	16,34
	Aeronautical Revenue per Movement	REV/MOVs	1976,95	2168,71	2184,78	2223,88	2308,56
	Non-Aeronautical Operating Revenue as Percentage of total Operating Revenue	NonAeroOp REV /TotalOpVER(%)	0,41	0,51	0,51	0,53	0,57
	Non-Aeronautical Operating Revenue per Passenger	NonAeroOp REV /PAX	4,72	5,72	5,52	5,57	5,92
	Debt Service as Percentage of Operating Revenue	Debt/OP Ver %	0,21	0,25	0,30	0,37	0,42

			AIRPORT 1 - MADRID				
			2014	2015	2016	2017	2018
	Long-Term Debt per Passenger	LT Debt /PAX	54,90	45,38	35,74	28,68	24,87
	Debt to EBIDTA Ratio	Debt/EBIDTA	5,72	4,48	3,59	2,84	2,47
	EBITDA per passenger	EBIDTA/PAX	9,59	10,13	9,96	10,09	10,05
Environmental	**Carbon Footprint (TONS/PAX)**	GHG/PAX	0,0023653	0,0022997	0,0018711	0,002049	0,00185
	Waste Recycling	%water recicled	25,23	28,80	31,86	28,42	32,06
	Waste Reduction Percentage	Waste red (%)	-6,98	7,80	4,33	-6,69	3,79
	Renewable Energy Purchased by the Airport (%)	REP (%)	3,45	3,34	4,11	3,54	3,87
	Utilities/Energy Usage per Square Meter of Terminal	KWh/m^2	286,84	287,06	292,34	290,46	292,78
	Water Consumption per Passenger	H2O(Lit)/PAX	25,28	24,21	21,94	20,96	20,11

Table A-II 2 – Data Barcelona

Source: [53][54][55][56][57][74][59][75][61][68][69][70][71][72][76][77][78][79][80][81]

			AIRPORT 2 - BARCELONA				
			2014	2015	2016	2017	2018
Safety and Security	**Runway Accidents**	Accidents /1000MOVS	0	0	0	0	0
	Runway Incursions	Incursions /1000MOVs	0,091	0,072	0,098	0,105	0,094
	Bird Strikes	BS /1000MOVs	0,21	0,152	0,15	0,137	0,151
	Public Injuries	Plnj /1000MOVs	0,34	0,326	0,276	0,213	0,236
	Occupational Injuries	Ocplnj /1000Hours Worked	0,821	0,911	0,846	0,749	0,848
	Lost work Time from Employee	LWT/1000 Hours Worked	3,9408	4,9194	4,1454	3,0709	3,3072

			AIRPORT 2 - BARCELONA				
			2014	2015	2016	2017	2018
	Accidents and Injuries.						
Core	**Passengers**	n° PAX	37558981	39711237	44154722	47284346	50172457
	Origination and destination passengers	n° PAX O&D	35981503,8	37805098	40622344	43501598	46660385
	Aircraft Movements	n° MOVS	283851	288879	307863	323535	335651
	Freight and Mail Loaded/Unloaded	Metric TONs	102706,112	117219,38	135815,69	156105,3	172940
	Destinations non-stop	n° AIRP non-stop	207	199	203	210	219
Productivity / Cost Effectiveness	**Passengers Per Employee Aircraft**	PAX/EMP	1877,95	1985,56	2207,74	2364,22	2508,62
	Movement per Employee Aircraft	MOVs/EMP	14,19	14,44	15,39	16,18	16,78
	Movement per Gate	MOVs/GATES	1774,07	1805,49	1924,14	2022,09	2097,82
	Total Cost per Passenger	Tcost/PAX	10,80	10,90	10,02	9,28	9,35
	Total Cost per Movement	Tcost/MOVs	1429,39	1497,96	1437,34	1356,69	1398,18
	Total Cost per WLU	Tcost/WLU	2,89	2,76	2,46	2,16	2,10
	Operating Cost per Passenger	OP Cost/Pax	6,60	6,82	6,40	6,04	6,08
	Operating Cost per Movement	OP Cost/MOVs	873,25	936,95	918,58	882,24	908,48
	Operating Cost per WLU	OP Cost/WLU	1,77	1,72	1,57	1,40	1,37
Service Quality	**Practical hourly Capacity**	MAxMOVs /hour	48	48	48	48	48
	Gate Departure Delay	ΣAGTj /nFligths	12,1	10,3	8,5	9,8	10,2
	Taxi Departure Delay	ΣATTj /nFligths	3,7	3,2	3,9	4,3	3,6
	Customer Satisfaction	%	75,1	75,6	75,1	77,8	78,1
	Baggage Delivery Time	ΣABDTj /nFlights	32,2	30,8	29,8	32,5	32,4

			AIRPORT 2 - BARCELONA				
			2014	2015	2016	2017	2018
	Security Clearing Time	ΣASCTj/nPAX	21,5792	18,34836	22,3732	24,44823	26,1068
	Border Control Clearing Time	ΣABCCTj /nPAX	9,5	10,6	11,7	12	10,8
	Check-in to Gate Time	Σ(ATjxPAXj) /ΣnPAX	24,4	20,3	24,9	23,2	25,1
Financial / Commercial	**Aeronautical Revenue per Passenger**	REV/PAX	16,18	16,92	16,40	16,18	16,36
	Aeronautical Revenue per Movement	REV/MOVs	2140,84	2326,02	2352,73	2365,26	2445,51
	Non-Aeronautical Operating Revenue as Percentage of total Operating Revenue	NonAeroOp REV /TotalOpVER(%)	0,41	0,51	0,51	0,53	0,57
	Non-Aeronautical Operating Revenue per Passenger	NonAeroOp REV /PAX	4,72	5,70	5,52	5,58	5,93
	Debt Service as Percentage of Operating Revenue	Debt/OP Ver %	0,21	0,25	0,30	0,37	0,42
	Long-Term Debt per Passenger	LT Debt /PAX	54,87	45,22	35,78	28,75	24,89
	Debt to EBIDTA Ratio	Debt/EBIDTA	5,72	4,48	3,59	2,84	2,47
	EBITDA per passenger	EBIDTA/PAX	9,58	10,09	9,97	10,12	10,06
Environmental	**Carbon Footprint (TONS/PAX)**	GHG/PAX	0,00113	0,0012	0,0011299	0,001065	0,001016
	Waste Recycling	% water recicled	33,81	25,90	35,79	29,88	30,09
	Waste Reduction Percentage	Waste red (%)	4,96	6,58	-3,80	8,20	4,89
	Renewable Energy Purchased by the Airport (%)	REP (%)	15,52	20,34	23,17	25,17	26,72
	Utilities/Energy Usage per Square Meter of Terminal	KWh/m^2	259,70	262,69	264,43	260,30	265,67

			AIRPORT 2 - BARCELONA				
			2014	2015	2016	2017	2018
	Water Consumption per Passenger	H2O(Lit)/PAX	24,90	26,71	23,90	24,60	22,80

Table A-II 3 - Data Valencia

Source:[56][57][59][61] [68][69][70][71][72][82][83][84][85][86]

			AIRPORT 3 - VALENCIA				
			2014	2015	2016	2017	2018
Safety and Security	**Runway Accidents**	Accidents /1000MOVS	0	0	0	0	0
	Runway Incursions	Incursions /1000MOVs	0,038	0,056	0,032	0,037	0,044
	Bird Strikes	BS /1000MOVs	0,054	0,065	0,039	0,047	0,049
	Public Injuries	Plnj /1000MOVs	0,148	0,167	0,098	0,136	0,111
	Occupational Injuries	Ocplnj /1000Hours Worked	0,502	0,435	0,398	0,437	0,459
	Lost work Time from Employee Accidents and Injuries.	LWT/1000 Hours Worked	2,3594	2,001	2,3482	1,8791	2,1573
Core	**Passengers**	n° PAX	4597095	5055127	5798853	6745231	7769867
	Origination and destination passengers	n° PAX O&D	4137386	4549614,3	5218968	6070708	6992880
	Aircraft Movements	n° MOVS	56438	59007	62804	68042	75834
	Freight and Mail Loaded/Unloaded	Metric TONs	12640,34	13539,904	12581,48	13125,74	14499,79
	Destinations non-stop	n° AIRP non-stop	59	60	67	83	85
Productivity / Cost Effectiveness	**Passengers Per Employee Aircraft**	PAX/EMP	656,73	722,16	828,41	963,60	1109,98
	Movement per Employee Aircraft	MOVs/EMP	8,06	8,43	8,97	9,72	10,83
	Movement per Gate	MOVs/GATES	2565,36	2682,14	2854,73	3092,82	3447,00
	Total Cost per Passenger	Tcost/PAX	13,91	13,45	12,12	10,75	9,97

			AIRPORT 3 - VALENCIA				
			2014	2015	2016	2017	2018
	Total Cost per Movement	Tcost/MOVs	1132,65	1151,86	1119,25	1065,26	1021,92
	Total Cost per WLU	Tcost/WLU	3,71	3,66	3,82	3,65	3,48
	Operating Cost per Passenger	OP Cost/Pax	8,50	8,41	7,75	6,99	6,48
	Operating Cost per Movement	OP Cost/MOVs	691,96	720,47	715,30	692,73	664,00
	Operating Cost per WLU	OP Cost/WLU	2,27	2,29	2,44	2,37	2,26
Service Quality	**Practical hourly Capacity**	MAxMOVs /hour	34	34	34	34	34
	Gate Departure Delay	ΣAGTj /nFligths	9,3	8,1	8,6	10,4	9,7
	Taxi Departure Delay	ΣATTj /nFligths	2,8	2,5	3,1	2,6	2,8
	Customer Satisfaction	%	71,5	74,4	72,4	74,2	78,2
	Baggage Delivery Time	ΣABDTj /nFlights	23,6	22,4	18,5	19,1	19,6
	Security Clearing Time	ΣASCTj/nPAX	18,3	21,6	22,5	19,3	18,7
	Border Control Clearing Time	ΣABCCTj /nPAX	7,1	6,8	8,1	10,3	10,7
	Check-in to Gate Time	Σ(ATjxPAXj) /ΣnPAX	14,5	16,7	13,6	14,4	14,9
Financial / Commercial	**Aeronautical Revenue per Passenger**	REV/PAX	20,83	20,88	19,84	18,73	17,45
	Aeronautical Revenue per Movement	REV/MOVs	1696,40	1788,60	1832,07	1857,18	1787,41
	Non-Aeronautical Operating Revenue as Percentage of total Operating Revenue	NonAeroOp REV /TotalOpVER(%)	0,41	0,51	0,51	0,53	0,57
	Non-Aeronautical Operating Revenue per Passenger	NonAeroOp REV /PAX	6,08	7,03	6,68	6,46	6,32

			AIRPORT 3 - VALENCIA				
			2014	2015	2016	2017	2018
	Debt Service as Percentage of Operating Revenue	Debt/OP Ver %	0,21	0,25	0,30	0,37	0,42
	Long-Term Debt per Passenger	LT Debt /PAX	70,63	55,80	43,28	33,29	26,54
	Debt to EBIDTA Ratio	Debt/EBIDTA	5,72	4,48	3,59	2,84	2,47
	EBITDA per passenger	EBIDTA/PAX	12,34	12,45	12,06	11,71	10,73
Environmental	**Carbon Footprint (TONS/PAX)**	GHG/PAX	0,001563	0,00160272	0,001503	0,001642	0,001691
	Waste Recycling	%water recicled	33,56	36,55	31,48	36,23	37,87
	Waste Reduction Percentage	Waste red (%)	2,84	5,62	-6,06	13,21	-2,92
	Renewable Energy Purchased by the Airport (%)	REP (%)	1,74	2,82	1,83	2,53	2,41
	Utilities/Energy Usage per Square Meter of Terminal	KWh/m^2	337,9	338,6	342,5	340,9	342,9
	Water Consumption per Passenger	H2O(Lit)/PAX	30,2	29,4	26,1	27,3	23,8

Table A-II 4 - Data Sevilla

Source:[56][57][59][61] [68][69][70][71][72][87][88][89][90][91]

			AIRPORT 4 - SEVILLA				
			2014	2015	2016	2017	2018
Safety and Security	**Runway Accidents**	Accidents /1000MOVS	0	0,001	0	0	0
	Runway Incursions	Incursions /1000MOVs	0,043	0,03	0,044	0,052	0,039
	Bird Strikes	BS /1000MOVs	0,014	0,024	0,024	0,021	0,027
	Public Injuries	Plnj /1000MOVs	0,122	0,134	0,163	0,111	0,128
	Occupational Injuries	Ocplnj /1000Hours Worked	0,539	0,505	0,378	0,421	0,462

			AIRPORT 4 - SEVILLA				
			2014	2015	2016	2017	2018
	Lost work Time from Employee Accidents and Injuries.	LWT/1000 Hours Worked	2,5872	2,222	2,6838	1,7682	2,079
Core	**Passengers**	n° PAX	3885434	4308845	4625314	5108817	6380465
	Origination and destination passengers	n° PAX O&D	3691162	4093403	4394048	4853376,15	6061442
	Aircraft Movements	n° MOVS	42379	46086	45840	48661	57909
	Freight and Mail Loaded/Unloaded	Metric TONs	5667,539	6007,279	6626,457	10715,967	12561,95
	Destinations non-stop	n° AIRP non-stop	45	47	46	65	76
Productivity / Cost Effectiveness	**Passengers Per Employee Aircraft**	PAX/EMP	706,44	783,43	840,97	928,88	1160,08
	Movement per Employee Aircraft	MOVs/EMP	7,71	8,38	8,33	8,85	10,53
	Movement per Gate	MOVs/GATES	3027,07	3291,86	3274,29	3475,79	4136,36
	Total Cost per Passenger	Tcost/PAX	16,45	15,77	15,20	14,19	12,15
	Total Cost per Movement	Tcost/MOVs	1508,40	1474,81	1533,45	1489,54	1338,24
	Total Cost per WLU	Tcost/WLU	6,69	6,59	6,25	4,58	4,09
	Operating Cost per Passenger	OP Cost/Pax	10,05	9,87	9,71	9,23	7,89
	Operating Cost per Movement	OP Cost/MOVs	921,51	922,47	980,01	968,63	869,53
	Operating Cost per WLU	OP Cost/WLU	4,09	4,12	3,99	2,98	2,66
Service Quality	**Practical hourly Capacity**	MAxMOVs /hour	25	25	25	25	25
	Gate Departure Delay	ΣAGTj /nFligths	8,4	7,8	7,6	8,2	8,6
	Taxi Departure Delay	ΣATTj /nFligths	3,1	3,7	3,4	2,7	2,9
	Customer Satisfaction	%	72,8	72,6	76,4	77,9	78,8

			AIRPORT 4 - SEVILLA				
			2014	2015	2016	2017	2018
	Baggage Delivery Time	ΣABDTj /nFlights	20,8	21,6	23,2	21,3	22,9
	Security Clearing Time	ΣASCTj/nPAX	17,1	18,6	17,6	22,2	22,5
	Border Control Clearing Time	ΣABCCTj /nPAX	8,4	7,3	7,8	9,1	8,5
	Check-in to Gate Time	Σ(ATjxPAXj) /ΣnPAX	12,6	15,4	16,2	14,6	13,9
Financial / Commercial	**Aeronautical Revenue per Passenger**	REV/PAX	24,64	24,49	24,88	24,73	21,24
	Aeronautical Revenue per Movement	REV/MOVs	2259,17	2290,07	2510,06	2596,86	2340,68
	Non-Aeronautical Operating Revenue as Percentage of total Operating Revenue	NonAeroOp REV /TotalOpVER(%)	0,41	0,51	0,51	0,53	0,57
	Non-Aeronautical Operating Revenue per Passenger	NonAeroOp REV /PAX	7,19	8,25	8,38	8,53	7,70
	Debt Service as Percentage of Operating Revenue	Debt/OP Ver %	0,21	0,25	0,30	0,37	0,42
	Long-Term Debt per Passenger	LT Debt /PAX	83,56	65,46	54,26	43,95	32,32
	Debt to EBIDTA Ratio	Debt/EBIDTA	5,72	4,48	3,59	2,84	2,47
	EBITDA per passenger	EBIDTA/PAX	14,60	14,61	15,12	15,46	13,06
Environmental	**Carbon Footprint (TONS/PAX)**	GHG/PAX	0,00176	0,00208	0,001524	0,001560831	0,001401
	Waste Recycling	%water recicled	19,82	23,87	23,66	25,24	25,32
	Waste Reduction Percentage	Waste red (%)	4,87	9,94	-3,68	5,84	-2,3
	Renewable Energy Purchased by the Airport (%)	REP (%)	0	0	0	0	0

			AIRPORT 4 - SEVILLA				
			2014	2015	2016	2017	2018
	Utilities/Energy Usage per Square Meter of Terminal	KWh/m^2	322,5	323,1	324,8	324,6	325,4
	Water Consumption per Passenger	H2O(Lit)/PAX	28,6	29,6	28,1	30,4	28,3

Annex III - KPIs

Table A-III 1 - KPI's of CORE

Source: [45]

CORE		
KPI	**MEASUREMENT UNITS**	**DEFINITION**
Passengers	nºPAX	Passengers, including enplaning and deplaning, measured over the course of a year.
Origination and Destination	nºPAX o&D	Passengers whose air travel begins or ends at the airport, measured over the course of a year. Excludes passengers who are changing planes at the airport to embark on a flight to another destination.
Aircraft Movements	nºMOVs	Aircraft take-offs or landings at an airport, measured over the course of a year. One arrival and one departure are counted as two movements.
Freight or Mail Loaded/Unloaded	Metric TONs	Freight or mail loaded or unloaded at the airport, measured in metric tonnes over the course of a year.
Destinations-Nonstop	nº AIRPORTS non-stop	Number of airports with nonstop service, including destinations with only seasonal service, measured over the course of a year.

Table A-III 2 - KPI's of Safety and Security

Source: [45]

SAFETY AND SECURITY		
KPI	**MEASUREMENT UNITS**	**DEFINITION**
Runway Accidents	Accidents/1000 MOVs	Aircraft accidents involving a runway per thousand aircraft movements (takeoffs and landings are counted separately), measured over the course of a year.
Runway Incursions	Incursions/1000 MOVs	Number of occurrences per thousand movements involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designated for the landing and take-off of aircraft, measured over the course of a year.
Bird Strikes	BS/1000 MOVs	Number of incidents per thousand movements involving Bird Strikes, which are collisions of

SAFETY AND SECURITY		
KPI	MEASUREMENT UNITS	DEFINITION
		airborne animals (usually birds, but also including bats) with aircraft, measured over the course of a year.
Public Injuries	PInj/1000 MOVs	Number of public injuries per thousand passengers, measured over the course of a year.
Occupational Injuries	OcpInj/1000 Hours Worked	Occupational injuries to airport authority employees per thousand hours worked.
Lost Work Time from Employee Accidents And Injuries	LWT/1000 Hours Worked	Lost time due to employee accidents and injuries, measured per thousand hours worked.

Table A-III 3 - KPI's of Service Quality

Source: [45]

SERVICE QUALITY		
KPI	MEASUREMENT UNITS	DEFINITION
Practical Hourly Capacity	MAxMOVs/hour	Maximum aircraft movements per hour assuming average delay of no more than four minutes, or such other number of delay minutes as the airport may set.
Gate Departure Delay	ΣAGTj/nFligths	Average gate departure delay per flight in minutes— measured from scheduled departure time at average and peak times.
Taxi Departure Delay	ΣATTj/nFligths	Average taxi delay for departing aircraft per flight in minutes— measured by comparing actual taxi time versus unimpeded taxi time at average and peak times.
Customer Satisfaction	A-100-90% B-90-70% C-70-50% D-30-50% E-30-0%	Overall level of passenger satisfaction as measured by survey responses.
Baggage Delivery Time	ΣABDTj/nFlights	Average time for delivery of first bag and last bag— measured over the course of a year.
Security Clearing Time	ΣASCTj/nPAX	Average security clearing time from entering queue to completion of processing—measured at average and peak times.

SERVICE QUALITY		
KPI	MEASUREMENT UNITS	DEFINITION
Border Control Clearing Time	ΣABCCTj/nPAX	Average border control clearing time from entering queue to completion of processing—measured at average and peak times.
Check-in Gate Time	Σ(ATjxPAXj)/ ΣnPAX	Average time from entering the check-in queue to arrival at the boarding gate—measured at average and peak times.

Table A-III 4 - KPI's of Productivity

Source: [45]

PRODUCTIVITY/COST EFFECTIVENESS		
KPI	MEASUREMENT UNITS	DEFINITION
Passengers per Employee	PAX/EMP	Total passengers per employee, expressed as full time equivalents (FTEs), measured over the course of a year.
Aircraft Movements per Employee	MOVs/EMP	Aircraft movements per employee, expressed as full time equivalents (FTEs), measured over the course of a year.
Aircraft Movements per Gate	MOVs/GATE	Aircraft movements per gate, measured over the course of a year.
Total Cost per Passenger	TCOST/PAX	Airport total costs per passenger, i.e., operating costs plus nonoperating costs, divided by passengers, measured over the course of a year.
Total Cost per Movement	TCOST/MOVs	Airport total costs per movement, i.e., operating cost plus nonoperating cost divided by movements, measured over the course of a year.
Total Cost per WLU	TCOST/WLU	Airport total costs per Work Load Unit, i.e., operating costs plus non-operating costs divided by Work Load Units.
Operating Cost per Passenger	OP Cost/PAX	Airport operating costs per passenger, divided by passengers, measured over the course of a year.
Operating Cost per Movement	OP Cost/MOVs	Airport operating cost per movement, measured over the course of a year.
Operating Cost per WLU	OP Cost/WLU	Airport operating costs per Work Load Unit, measured over the course of a year.

Table A-III 5 - KPI's of Financial/Commercial

Source: [45]

FINANCIAL/COMMERCIAL		
KPI	**MEASUREMENT UNITS**	**DEFINITION**
Aeronautical Revenue per Passenger	REV/PAX	Aeronautical charges per passenger, measured over the course of a year, net of discounts or fee waivers. Average of aeronautical revenues collected per passenger for use of airfield (landing fees, ramp/apron fees), gate charges, terminal space, passenger-related charges, and ground-handling user fees. Includes Passenger Facility Charges at U.S. airports. Excludes air traffic control fees and facility rentals for ancillary buildings, such as maintenance hangars and cargo buildings.
Aeronautical Revenue per Movement	REV/MOVs	Aeronautical charges per movement, measured over the course of a year. Average of aeronautical revenues collected per movement for ACI Guide to Airport Performance Measures 39 use of airfield (landing fees, ramp/apron fees), gate charges, terminal space, passenger-related charges, and ground-handling revenue. Includes Passenger Facility Charges at U.S. airports. Excludes air traffic control fees and facility rentals for ancillary buildings, such as maintenance hangars and cargo buildings.
Non-Aeronautical Operating Revenue as Percent of Total Operating Revenue	NonAeroOpREV / TotOpRev (%)	Total non-aeronautical operating revenue as a percentage of total operating revenue, measured over the course of a year.
Non-Aeronautical Operating Revenue per Passenger	NonAeroOpREV / PAX	Total non-aeronautical operating revenue per passenger, measured over the course of a year.
Debt Service as Percentage	Debt/OP REV (%)	Debt service (principal plus interest) as a percent of operating revenue, measured on an annual basis.

FINANCIAL/COMMERCIAL		
KPI	MEASUREMENT UNITS	DEFINITION
of Operating Revenue		
Long-Term Debt per Passenger	LT Debt/PAX	Long-term debt plus accrued interest payable less the balance in both the debt service reserve fund and debt service or sinking fund, per passenger measured at the end of the reporting period.
Debt to EBITDA Ratio	Debt/EBITDA	Debt-to-EBITDA (earnings before interest, taxes, depreciation, and amortization) measured at the end of the reporting period.
EBITDA per Passenger	EBITDA/PAX	EBITDA (or earnings before interest taxes depreciation and amortization) per Passenger, measured over the course of a year.

Table A-III 6 - KPI's of Environment

Source: [45]

ENVIRONMENTAL		
KPI	MEASUREMENT UNITS	DEFINITION
Carbon Footprint	GHG	The carbon footprint is the total set of greenhouse gas (GHG) emissions caused by activities at the airport within the airport's control, expressed in terms of the amount of carbon dioxide or its equivalent in other GHG emitted. Excludes emissions caused by airline/tenant operations and the public.
Waste Recycling	%water recycled	Percentage of solid waste that is recycled/reused/composted, including pre-consumer organics and post-consumer compostables, as well as airfield trash, measured over the course of a year. Does not include construction waste.
Waste Reduction Percentage	Waste red (%)	Percentage reduction over the previous year in tons of solid waste, including pre-consumer organics, and post-consumer compostables, as well as airfield trash. Does not include construction waste.
Renewable Energy	REP(%)	Amount of renewable energy purchased by the airport, as a percentage of total energy consumed by the airport. Excludes energy purchases by tenants.

ENVIRONMENTAL		
KPI	MEASUREMENT UNITS	DEFINITION
Purchased by the Airport (%)		
Utilities/Energy Usage per Square Meter of Terminal	KWh/m^2	Utilities and energy used per square meter of terminal building (conditioned space), measured in kilowatt hours and therms over the course of a year.
Water Consumption per Passenger	H2O(lit)/PAX	Water consumption in the terminal complex divided by number of passengers, measured over the course of a year.

Annex IV – Scientific Articles Accepted for Presentation and/or Publication

1. Scientific Article Accepted for Oral Presentation at 'VII RIDITA – International Congress of the Iberoamerican Air Transportation Research Society'.

'SPANISH AIRPORTS PERFORMANCE AND EFFICIENCY. A PESA-AGB STUDY.'

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Abstract

Spanish airports belonging to AENA transported 263,753,406 passengers in 2018 with an increase compared to 2017 of 5.8%. General data enables to conclude that Spanish air transportation system is growing annually and hence there is the need to improve airports performance and efficiency, also to maintain the high levels of quality to address the growing demand. For these reasons, we have decided to carry out this study. Firstly, a literature review related to this study keywords is conducted, as well as about benchmarking concept applied specifically to airports. Secondly, several methodologies in used to benchmark airports are reviewed and compared. Thirdly, airport performance and efficiency issues are addressed and described. Finally, this study uses a MCDA tool to analyse and improve Spanish airports performance and efficiency. Thus, a holistic study using MACBETH (with PESA-AGB) is applied to 4 Spanish airports and we conducted a self-benchmark and peer-benchmark study for these airports. This study has never been applied before in Spanish airports.

Spanish air transportation system is growing annually and is it upmost important to maintain high levels of quality to address such demand. Through this study, performance and efficiency improvements are seek within several airport key areas such as Safety and Security, Quality Service, Productivity and Effectiveness, Financial and Environment.

Keywords

Spanish Airports, Benchmarking, MCDA – MACBETH, Airport Performance, Airport Efficiency.