Spanish airports performance and efficiency benchmark. A PESA-AGB study

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Abstract

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 used. This study has never been applied before in Spanish airports.

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, the MCDA-MACBETH (with PESA-AGB) tool is applied to 4 Spanish airports.

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.

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. As far as known, this study has never been applied before in Spanish airports.

Keywords

Spanish Airports; Airport Performance; MCDA - MACBETH; Benchmarking

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Introduction

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 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 related with 2016 was 8.2%, while 2016 pointed to 230,231,359 people and an increase of 11.0% over 2015 [2]. This data enables 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 high levels of quality to address the 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: expand airport facilities, or improve their efficiency and performance. The last option is much more economical and maximises the airport infrastructure. Thus, this will increase stakeholders' satisfaction and will reduce airport costs. In Spain, the management of airports is centralised; that is, they operate as independent profit centres but are under the control of a central authority, AENA. This study focusses on large airports leaving small (less than 1 million passengers per year) behind as they are not considered profitable.

The motivation of this work is to use an MCDA tool that will suggest how to improve performance and efficiency of Spanish airports, and thus a holistic study using a mathematical tool such as MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) is used to do so. For this purpose, this was the Multi-Criteria Decision Analyses (MCDA) methodology chosen using the PESA–AGB (Performance Efficiency Support Analysis – Airport Global Benchmarking) model. 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 to achieve improvements in many key areas of the airport, such as core, safety and security, quality service, productivity and effectiveness, financial and environment, where specific measures can be taken to reduce costs and thus improving satisfaction. Moreover, therefore, to achieve a global evaluation of the infrastructure. The study will be performed throughout two benchmarking studies.

Methodology

Four airports have been chosen in Spanish territory: Adolfo Suárez Madrid-Barajas, Josep Tarradellas Barcelona-El Prat, Valencia and Sevilla. From these airports, we will obtain data from 6 key performance areas (KPA): Core, Safety and Security, Quality, Productivity/Cost Effectiveness, Financial/Commercial, and Environmental. These six areas are those of Airport Council International (ACI), and they have 42 key performance indicators (KPI), associate. For this study, we gathered for each airport data for each KPA and the related KPI for the last five years (2014, 2015, 2016, 2017 and 2018). Once we have completed our database, we must allocate all these data to MACBETH. 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 gathered, it is necessary to analyse and draw conclusions from the outputs of the model and understand what will be the efficiency and performance proposals for the improvement of Spanish airports, and this will be achieved by carrying out internal and external Benchmarking studies. Figure 1 depicts the sequence of the methodological process.

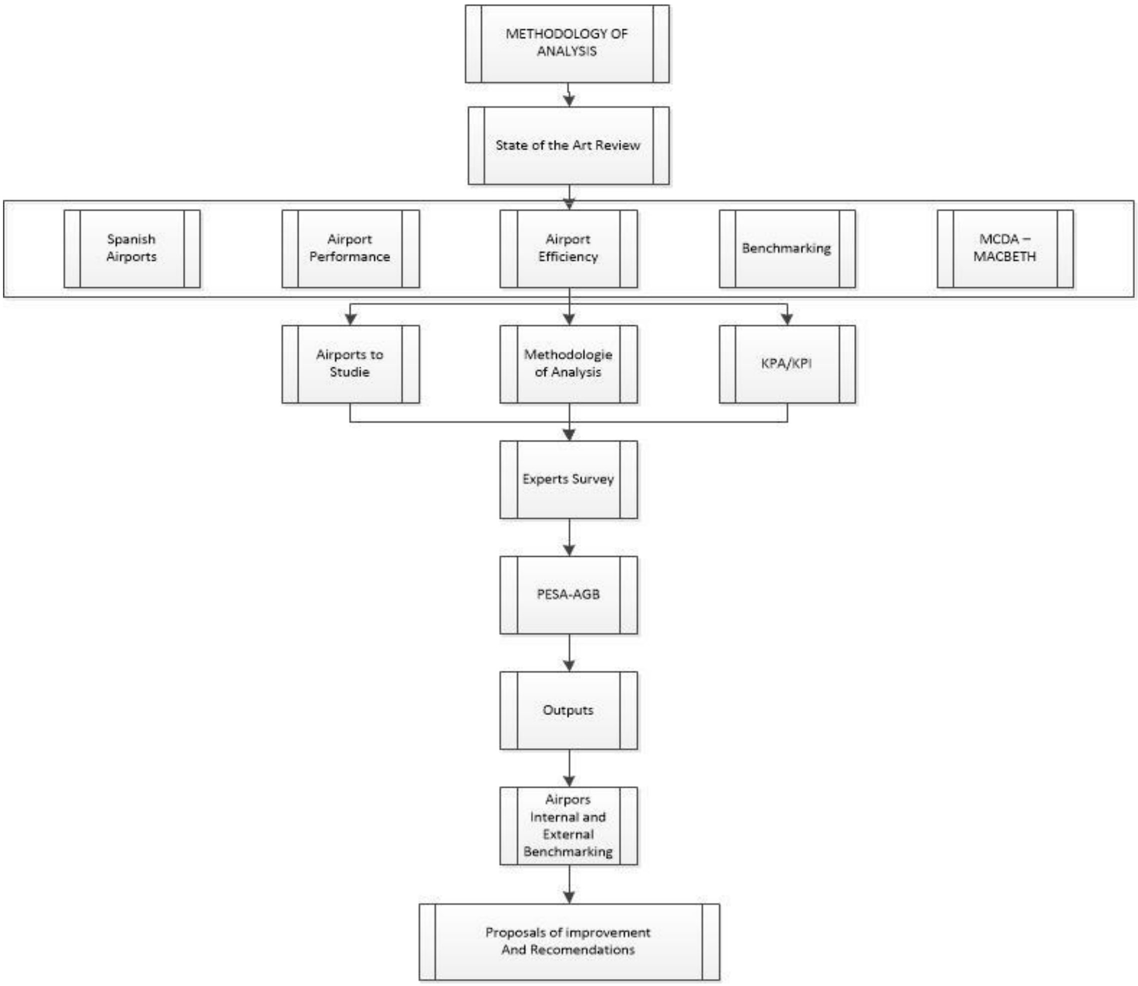


Figure 1 - Analysis Process Methodology
Source: [3]

Measuring Attractiveness by a Categorical Based Evaluation Technique (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 [4]. When the judgments of the evaluator are established, their consistency is verified; nevertheless, many corrections may be necessary to avoid unconscious errors [5]. 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 [6]. We can divide the process into three distinct phases [7]:

1.Structuring:

a. Criteria: Values under 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 a model, it is necessary to have a global vision of the subject under analysis. After, we may create a MACBETH value tree. The value tree has nodes that correspond to KPA and KPI to be considered. The next step is to obtain data for each indicator. After, it is necessary to decide how attractive each indicator is, based on a previously defined scale. For each node, some decisions must be made individually so that in the end the model is consistent. However, it will be possible to vary them later to give robustness to the system.

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 [8]. 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 supported on the work of Bana e Costa et al. [5].

It is structured in a six steps arrangement (Figure 2): 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.

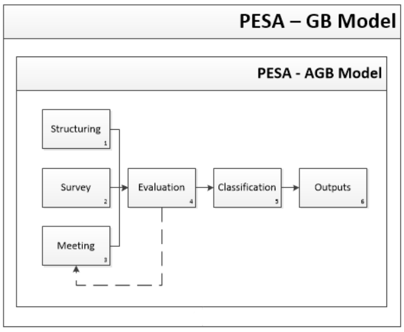


Figure 2 - PESA-AGB Model Tasks
Source: [9]

MACBETH mathematical foundations allow the development with a PESA-AGB model incorporating 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.

Case Studies

Case I - 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 analyse their KPIs and their KPAs, as depicted in Figure 3.

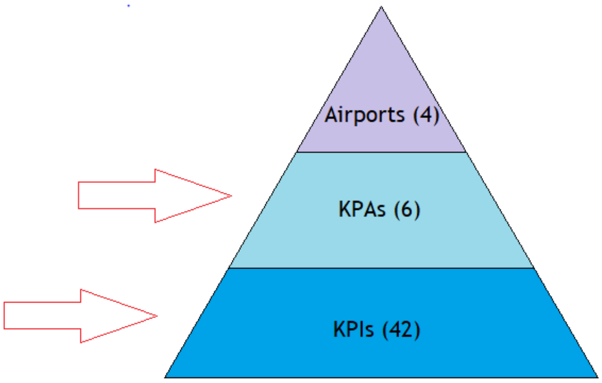


Figure 3 – Triangle of KPIs, KPAs, and Airports
Source: Authors

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 weights. Thus, we started the process. Once we have all 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 main node. All the nodes named so far are non-criteria ones. We can see how it looks in Figure 4.

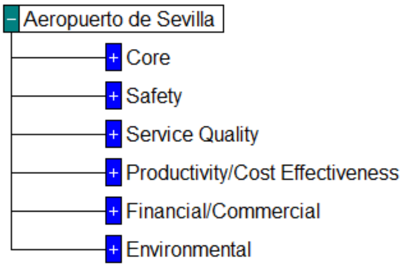


Figure 4 – MACBETH KPAs
Source: Authors

Next, we proceed to the creation of the KPI nodes as depicted in Figure 5. In this Figure, we may see only the KPIs of KPAs Core, and Safety and Security because it is just an example. In this example, 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 provides data on Security. For specialists, this is the KPA that has a more expressive weight.

Figure 5 - MACBETH KPIs
Source: Authors

The KPI nodes are criterion ones and belong to the quantitative level as depicted in Figure 66.

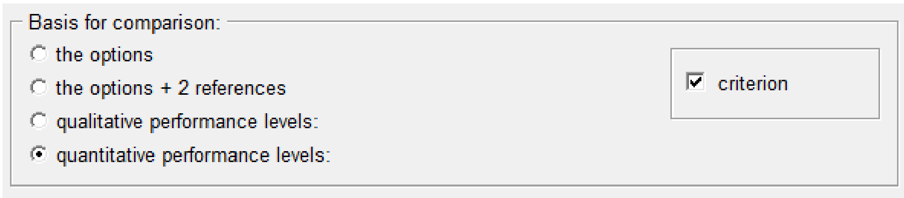


Figure 6 - MACBETH Basis for Comparison (Self Benchmarking)
Source: Authors

Once the decision tree is finished, we begin with the manual introduction of data for each year and its related (appropriate) KPI (Figure 7). In Figure 7 we only see the Core KPIs because it is an example. The complete Table of Performances contains 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 7 - MACBETH Table of Performance
Source: Authors

When we have entered all data we have to mark performance levels. To obtain these it will be necessary to take from each KPI the biggest and smallest values of the 5 years period. The biggest one will be the upper reference (marked in green in Figure 8) and the smallest one the lower reference (marked in blue in Figure 8). The two central data are 1/3 and 2/3 of the *distance* between upper and lower references. Figure 8 is an example for the KPI Passengers of Airport 4. For all other KPIs, the exercise is the same.

Performance levels:

	Quantitative level
1	6380465
2	5548788
3	4717111
4	3885434

Figure 8 – MACBETH Performance Levels
Source: Authors

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 step the opinion of the specialists is incorporated, which makes our study realistic. We see in Figure 9 how the table incorporates the judgments of the specialists, separated between different performance levels.

Passengers

	6380465	5548788	4717111	3885434	Current scale
6380465	no	moderate	strong	strg-vstr	100.00
5548788		no	moderate	strong	66.67
4717111			no	moderate	33.33
3885434				no	0.00

extreme / v. strong / strong / moderate / weak / very weak / no

Consistent judgements

Figure 9 – Matrix of Judgements
Source: Authors

Figure 9 is an example for the KPI Passengers of Airport 4. Each KPI of the study has its own matrix that has been constructed based on specialists inputs. We verify that the judgments are consistent and we scale them from 0 to 100 as depicted in Figure 10.

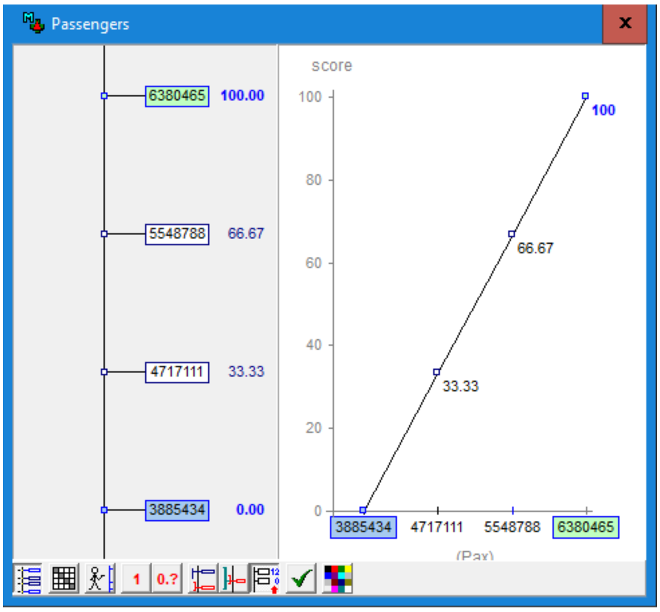


Figure 10 – New Scale
Source: Authors

Again, Figure 10 is an example for KPI Passengers of Airport 4. For each KPI we construct a new scale. Thus, we achieved data in a punctuation scale from 0 to 100. Now we are ready to apply the weights. Again we apply for the specialits opinion. The sum of weights is 100 and the result is that of Table 1.

Table 1 – KPIs Weights
Source: Authors

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
PRODUCTIVITY-COST EFFECTIVENESS	Total Cost per Passenger	2.44
	Total Cost per Movement	2.27
	Operating Cost per Movement	2.09
	Aircraft Movement per Gate	1.92
	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 11. We can see below all the weights that are going to be applied. On the left we have 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 Figure we observed scores of PAX, AM, and OD already scaled. Figure 11 is an example of Airport 4 and so in the Figure are missing 39 KPIs. Overall corresponds to Airport 4 efficiency for 5 years. For the other airports, we made the same procedure, with the related 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 11 – MACBETH Table of Scores
Source: Authors

With all data collected and inserted into M-MACBETH, we are ready to proceed with the study.

Case II - 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 12.

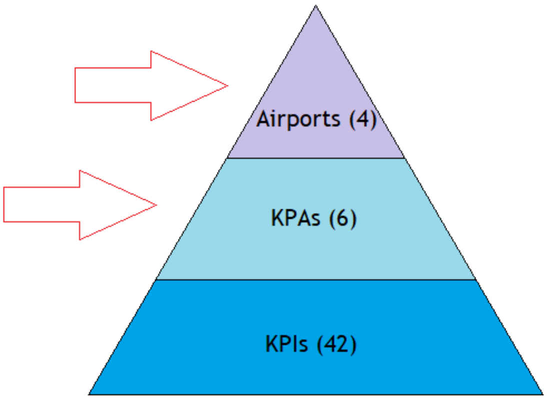


Figure 12 - Triangle of KPAs, KPIs, and Airports
Source: Authors

We emphasize this because the opinion of the specialists is applied in these two areas (Airports and KPAs) by means of judgments matrices and weights. Thus, we start with the process. First, we proceed with the creation of the decision tree, with 4 non-criteria nodes that correspond to the 4 Airports of the study (Figure 13).

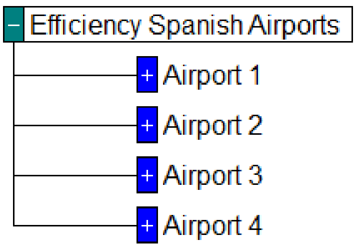


Figure 13 – Peer-Benchmarking Tree non-Criteria Nodes
Source: Authors

Within each Airport, we will have 6 KPAs as node, that is our criteria nodes.

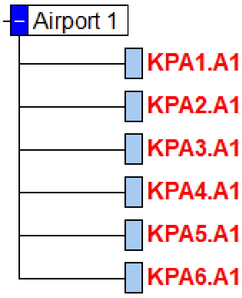


Figure 14 – Peer-Benchmarking Criteria Nodes
Source: Authors

Each Airport is a non-criterion node, with 6 criterion nodes associated. In all places/nodes, we have a KPA followed by A1, A2, A3 or A4 that identified each airport, as it can be depicted from Figure 14. The Figure is an example of Airport 1; for other airports the process is the same.

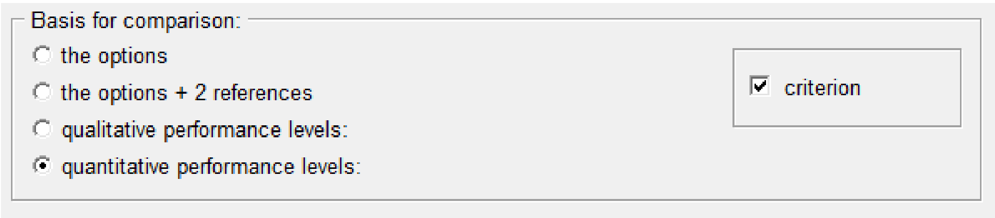
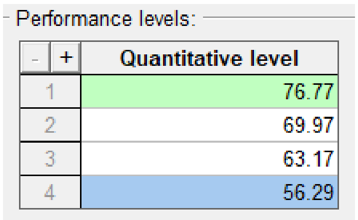


Figure 15 - MACBETH Basis for Comparison (Peer Benchmarking)
Source: Authors

In the nodes of the KPAs, the assigned Quantitative Performance Levels mode is as depicted in Figure 15.


Performance levels:

	Quantitative level
1	76.77
2	69.97
3	63.17
4	56.29

Figure 16 - Peer-Benchmarking Performance Levels
Source: Authors

The KPAs data is taken from study of Case I, and inserted in the performance level table as in Figure 16. The biggest score will be the upper reference (marked in green in Figure 16) and the smallest one the lower reference (marked in blue in Figure 16). The two central values are 1/3 and 2/3 of the *distance* between the upper and lower references. These data will be used below in the matrix of judgments. Figure 16 is an example where we use data of KPA 1 of Airport 1. For the other KPAs of the other airports the process is identical, but with related data.

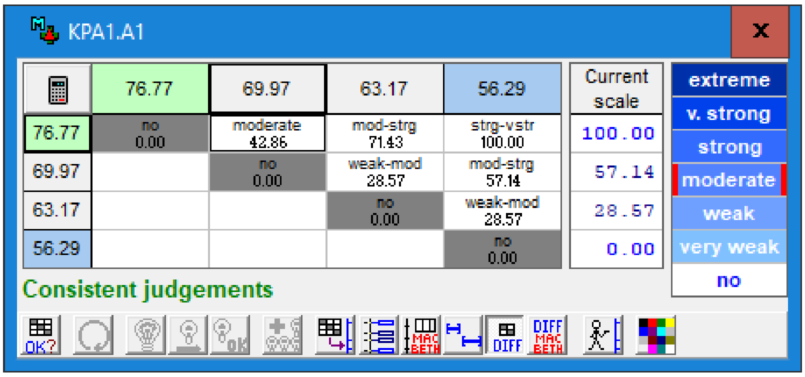


Figure 17 – Peer-Benchmarking Matrix of Judgements
Source: Authors

The matrix of judgments of Figure 17 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 based on the specialists opinion and it causes the Current Scale depicted in Figure 18 and Figure 19. We underline that these scales take into account the opinion of specialists.

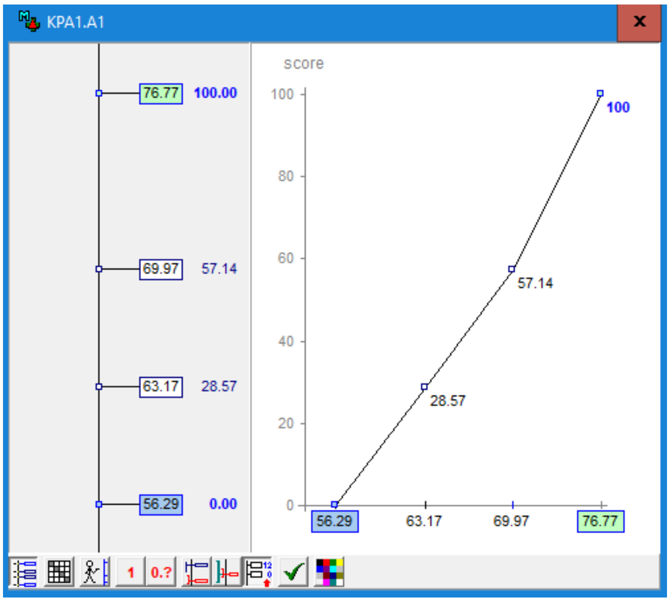


Figure 18 – Peer-Benchmarking Scale
Source: Authors

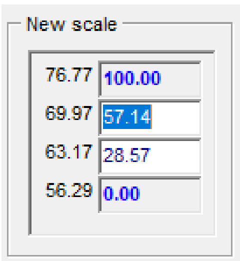


Figure 19 - Peer-Benchmarking Scale
Source: Authors

Finally, we must consider airports weights accordingly to the specialist's opinion, as in Table 2. Table 3 depicts KPAs weights.

Table 2 – Peer-Benchmarking Airports Weights
Source: Authors

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

Table 3 – KPAs Weights
Source: Authors

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 several factors ordered from the most to the 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 was disabled;
- If there are close and real transport infrastructures alternatives to the airport.

Conclusion

Through these two case studies, we were able to better understand the functioning of MACBETH and know the strengths and weaknesses of 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 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 (Self-Benchmarking), 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. Moreover, 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. Moreover, the worst are KPA 4 - Service Quality, and KPA 5 - Financial / Commercial.

On the other hand, in Case II (Peer-Benchmarking) 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 finally 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. We overcomed this problem using data from similar (American) airports.

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