MacBeth as a MCDA Tool to Benchmark the Iberian Airports

José Braz[1*], Emília Baltazar[*], Jorge Silva[*] and Margarida Vaz[**]

*Aerospace Sciences Department

**Business and Economic Department

University of Beira Interior

Covilhã, Portugal

Abstract: This work relates to airports benchmarking which is a very important issue for stakeholders. Airports benchmarking depends on airport performance indicators which are also important issues for business and operational management, regulatory bodies, airlines and passengers. There are several sets of indicators to evaluate airports performance and also there are several techniques to benchmark airports. This work uses MacBeth - a MCDA (Multi-Criteria Decision Analysis) tool, to evaluate the attractiveness of the most important Iberian Airports. This approach is a new one and the preliminary results are very promising when compared with some traditional studies of airports benchmarking.

Key words: Airports Benchmarking, MCDA/MacBeth, Iberian Airports

1. Introduction

The main goal of this work - developed under AIRDEV (Business Models for Airport Development and Management), a Project of the MIT-Portugal Program - is to benchmark the most important Iberian Airports based on an MCDA tool called MacBeth. Besides using performance indicators to support the benchmark final results MacBeth may adapt each stakeholder point of view by easily changing the weight of each indicator. Thus Macbeth seems

[1] Corresponding Author: Tel: +351 275 329 732; Fax: +351 275 329 768; Email: josemiguelbraz@gmail.com

to be a user-friendly approach to evaluate not only the real importance of the selected indicators but also its correct weight.

As this work is a part of an MSc Thesis in Aeronautical Engineering data collected from ACI (Airports Council International) in 2006 is only related with airports airside, particularly: movements, passengers, and cargo. As previously mentioned the universe of this research is the most important Iberian Airports, that is, 9 infrastructures in Portugal and more 45 in Spain.

The work is structured as follows: a state of the art supporting some insights in airports benchmarking and performance indicators; a description of the Multi-criteria Decisions Analysis approach in general, and of the MacBeth tool in particular; a presentation of the Iberian Airports case study; and finally some conclusions about future research on this specific field.

2. Airports Benchmarking and Performance Indicators

Benchmarking is a self-improvement tool for any organization: it allows identifying own strengths and weaknesses, to compare itself with others, and to learn more how to improve efficiency. Benchmarking is an easy way to find and adopt the best practices to achieve the desired results.

Graham (2005) underlines that benchmarking within the airport industry began to be accepted as an important management achievement just fifteen to twenty years ago mainly because in the past commercial and business pressures within the airport sector were less pronounced and airports were quite almost under government ownership.

Airport benchmarking is a key component of the airports planning procedure. It is a process that being statistical is an accounting one too used to monitor airports performance indicators. Benchmarking is a key feature to the implementation of an airport's strategic plan and its importance goes so far as to identify best practices to increase efficiency and quality.

ACI (2006:5) summarizes the benchmarking process as follows:

- *Is about management and organizational change first, measurement and technology second;*
- *Provides a diagnostic tool to check whether all systems are in alignment and working properly;*

- *In a Self-Benchmarking basis is an excellent management tool to monitor performance improvements;*
- *When external is an effective way to identify best practices to see if they can be incorporated into an organization and to identify faulty practices to see if they can be eliminated;*
- *A tool to link strategic goals, employee involvement and productivity*.

Humphreys and Francis (2002) enumerate the ones that can be particularly interested in the airports benchmarking process:

- State/Government, for economic and environmental regulation reasons;
- Airlines, to compare costs and performance across airports;
- Managers, to run the own business;
- Passengers, to evaluate how they are served;
- Owners, to understand business performance and how to return the investment.

To accomplish with all those requirements in practice the benchmarking process may appear in two different ways (ACI, 2006):

- A partial one, assessing and comparing individual processes and functions, or even services;
- A holistic one, assuming a systematic approach to define and assess a critical set of processes and functions, or even services, which when taken all together may give a precise indication about the relative performance of the entire organization.

So there may be two different kinds of benchmarking too:

- Internal, comparing the organization performance of processes, functions, and services over time;
- External, comparing performance across organizations at a precise moment in time and through time.

As previously mentioned the main goal of this work is to achieve an airport ranking by using a (new) multi-criteria approach allowing the one who is applying the method to choose properly both the indicators and the related weights. This enables all the interested parts (including passengers) to do their own ranking, which may be compared at the end of the entire process. Another interesting feature of the method is the ability to compare the performance either of the airport with other similar infrastructures or of the own airport in different years thus offering to the airport manager the possibility to be in touch with the evolution of the infrastructure.

Benchmarking is viable when there are a limited amount of correlated indicators to take into account. So it is important to establish previously with careful the goal of the ranking to be produced. If the goal is concerning the airport management the number of passengers will be one of the key elements; but if the goal is concerning the passengers and their satisfaction the number of runways may be out of focus. So it is crucial to choose the proper indicators for each stakeholder.

There are several works on airport benchmarking each one using different performance indicators. Some of them use single indicators as the number of aircraft parking positions, while others consider complex indicators as the number of employees per number of passengers. As previously referred this work only use isolated airside indicators (movements, passengers and cargo) as it was easier to find data for such a set of (54) airports in the Iberian Peninsula:

- **(Aircraft) Movements,** includes the number of planes landing/taking-off on/from the airport;
- **(Commercial) Passengers,** includes the number of passengers who arrive and depart into/from the airport;
- **Cargo,** includes the number of tons of cargo that arrive and depart on/from the airport being domestic or international, freight or mail flights.

As it will be seen in Chapter 4 one uses the ACI (2006) World Traffic Report to collect data of the Iberian Airports Portuguese as shown in Table I.

	AIRPORT		MOVEMENTS	PASSENGERS	CARGO
	CITY	CODE	(Unit)	(Unit)	(Tons)
PORTUGAL	Faro	FAO	42 494	5 089 672	953
	Flores	FLW	1 458	37 820	310
	Funchal	FNC	25 828	2 360 857	9 200
	Horta	HOR	4 809	196 939	1 233
	Lisbon	LIS	137 109	12 314 314	99 483
	Oporto	OPO	49 215	3 402 816	34 444
	Ponta Delgada	PDL	12 165	909 609	8 593
	Porto Santo	PXO	6 300	153 052	343
	Santa Maria	SMA	3 439	96 831	360
SPAIN	A Coruña	LCG	17 406	1 000 091	554
	Albacete	ABC	1 347	16 280	-
	Alicante	ALC	76 816	8 882 521	4 931
	Almeria	LEI	18 452	1 048 387	47
	Asturias	OVD	17 987	1 347 681	370
	Badajoz	BJZ	4 434	69 332	-
	Barcelona	BCN	327 636	30 000 601	99 046
	Bilbao	BIO	58 573	3 863 881	3 420
	Ceuta	JCU	2 596	21 181	3
	Cordoba	ODB	9 212	2 389	-
	Fuerteventura	FUE	44 044	4 416 429	3 274
	Girona	GRO	33 436	3 592 700	502
	Gomera	QGZ	3 384	37 401	5
	Gran Canaria	LPA	114 938	10 279 594	42 234
	Granada	GRX	17 583	1 068 152	71
	Hierro	VDE	4 550	168 663	265
	Ibiza	IBZ	54 146	4 446 680	4 509
	Jerez	XRY	46 534	1 317 541	311
	La Palma	SPC	21 362	1 174 832	1 446
	Lanzarote	ACE	50 174	5 626 098	6 320
	Leon	LEN	6 296	126 469	1
	Logroño	RJL	3 333	51 887	-

	Madrid	MAD	435 018	45 501 168	350 758
	Madrid	MCV	57 925	174	-
	Madrid	TOJ	15 154	25 894	32
	Malaga	AGP	127 769	13 056 155	6 641
	Melilla	MLN	10 696	305 061	437
	Menorca	MAH	32 920	2 686 072	3 773
	Murcia	MJV	18 136	1 645 354	7
	Palma de Mallorca	PMI	190 280	22 402 257	26 251
	Pamplona	PNA	11 419	367 888	59
	Reus	REU	24 894	1 377 382	6
	Sabadell	QSA	48 695	-	-
	Salamanca	SLM	8 656	28 886	-
	San Sebastian	EAS	12 076	360 059	281
	Santander	SDR	15 195	649 067	3
	Santiago de Compostela	SCQ	24 712	1 993 521	4 559
	Sevilla	SVQ	58 565	3 868 606	12 111
	Tenerife Norte	TFN	65 295	4 023 511	23 181
	Tenerife Sur	TFS	65 774	8 816 745	9 911
	Valencia	VLC	87 906	4 964 361	13 082
	Valladolid	VLL	11 582	454 940	121
	Vigo	VGO	19 655	1 186 568	1 254
	Vitoria	VIT	12 348	172 574	31 123
	Zaragoza	ZAZ	11 405	431 879	5 930

Table I. Performance Indicators for the Iberian Airports (Adapted from ACI, 2006)

Also as it will be seen in Chapter 4 this work ranks the airports in two steps:

- Portuguese Airports;
- Iberian airports, also varying the weights of each indicator.

Therefore this work generates different rankings so underlying the importance of each indicator for each airport as well as the consequences of changing weights decided by different stakeholders.

3. Multi-Criteria Decision Analysis Approach and MacBeth Tool

Since the beginning of the history that Man takes decisions. Probably this is one of the most common tasks of Mankind. Every day one finds a set of problems and decisions that are neither easy nor linear to take. When deciding on something generally one takes into account several criteria more or less conflictive among them. In a stress situation if one must consider just one factor usually the option is the most relevant. According to Barrico (1998), cited by Raposo (2008:23), multi-criteria decisions processes are, for example:

- *Choosing the right spot to a bridge construction, where the criteria could be the cost, the impact on the river (environmental and the utilization of the river), the volume of traffic, the impact on the river banks, the esthetics, the crossing cost, etc.;*
- *Find the most economic routes to do the pick-up/delivery of products to the clients of a determined company, where the criteria could be the time, the distance, de delay, the traffic, etc.*.

For each one of the described examples there are conflicts between several criteria and so the decision maker has to consider the pros and cons of each one to reach the final solution. This is the basis of a multi-criteria decision problem.

According to Gomes *et al*., cited by Raposo (2008:4), one may define Multi-Criteria Decision Analysis (MCDA) *as the set of techniques which has the goal to investigate a several number of alternatives over multiple criteria and objectives in conflict*.

In fact MCDA is one of the available tools that the deciders may use to better understand complex situations and to solve multi-criteria problems; but even using this approach there are several different ways to obtain and analyze the final results. Boyssou (1990), cited by Raposo (2008:4), ranks this way the advantages of MCDA:

- *Construction of a dialogue basis between analysis and deciders, making use of diverse common views;*

- *Ease of incorporating uncertainties about the data on each point of view;*
- *Interpretation of each alternative as a compromise between objectives in conflict. This argument highlights the fact that rarely will be found one situation where one of the alternatives will be superior to the others in every point of view.*

From all the previously explanation it is easy to understand how important is to airport stakeholders a MCDA approach supporting a decision making process; being this work MCDA based it is necessary to choose the related most appropriate tool:

- First, it is necessary to define its requisites; it is necessary a consistent one simultaneously efficient and functional;
- Second, it has to be user friendly; the decision makers need a tool that as easily as the weights of each criteria change the interpretation of the results remains intuitive.

After analyzing several options one chose the MacBeth (Measuring Attractiveness by a Categorical Based Evaluation Technique) as the tool that fits all the mentioned requisites. As Bana e Costa *et al.* (2005) underlines this is a user friendly multi-criteria decision analysis approach that requires only qualitative judgments about differences of value to help a decision maker, or a decision-advising group, to quantify the relative attractiveness among several options. MacBeth is a Humanistic, a Interactive, and a Constructive tool because (Bana e Costa *et al.*, 2003:1):

- *Humanistic in the sense that it should be used to help decision makers ponder, communicate, and discuss their value systems and preferences;*
- *Interactive because this reflection and learning process can best spread through socio-technical facilitation sustained by straightforward question-answering protocols;*
- *Constructive because rest on the idea that full-bodied convictions about the kind of decision to make do not (pre-)exist in the mind of the decision maker, nor in the mind of each of the members of a decision advising group, but that it is possible to provide*

them with help to form such convictions and to build robust (shared) preferences concerning the different possible options to solve the problem.

Therefore before the development of any model it is necessary the larger data collection one may obtain about what is going to be studied; this first step led the decision group to have a global view about the decisions to be taken; this will turn the final result more robust.

After the collection of data the next step is to create a decision tree, that is, a decision model; in this tree the nodes correspond to the indicators that are going to be taken into account; so the choice of the nodes are one of the key questions in the development phase.

After the indicators choice the next step is to get the data needed to fill the performance table of each indicator; this is a crucial step even influencing the node choice because only if the data collection fills the performance table for each indicator is possible to use that indicator in the work.

In the next step each decider defines the attractiveness of each indicator in the tree; MacBeth divides the scale of attractiveness in seven verbal values: no difference, very weak, weak, moderate, strong, very strong and extreme; after considering the attractiveness of each node the deciders must define the attractiveness difference between each indicator in the model.

After the introduction of these values for each node it is possible to produce a robustness table still giving the opportunity to the decider to adjust the sensibility of the model.

4. The Iberian Airports Case Study

As previously mentioned the goal of this work is to create a ranking to compare Iberian Airports using three indicators having each one its own weight which may be easily modified and adapted by the decision maker or the decision-advising group.

So Airports and the Indicators are the ones of Table I referred in Chapter 2. First of all the MacBeth software requires the construction of a tree precisely with those indicators (Figure 1).

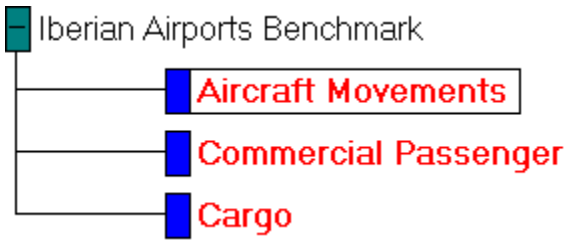


Figure 1. Value Tree for Iberian Airports Benchmark (Authors)

After introducing data for the Portuguese (9) Airports the Table of Performances is that one of Table II.

Table of performances

Options	AM	CP	Cg
FAO	42494	5089672	953
FLW	1558	37820	310
FNC	25828	2360857	9200
HOR	4809	196939	1233
LIS	137109	12314314	99483
OPO	49215	3402816	34444
PDL	12165	909609	8593
PXO	6300	153052	343
SMA	3439	96831	360

Table II. Portuguese Airports Performances (Authors)

Where: AM is the number of Aircraft Movements, CP is the number of Commercial Passenger, and Cg is the tons of Cargo.

After filing the Table of Performances it is necessary to attribute weights to each indicator thus judging the importance of each one facing the others. In a first attempt one attributes the same importance to every indicator, that is, 33.33 %, as shown in Table III.

Weighting (Iberian Airports Benchmark)

	[AM]	[CP]	[Cg]	[tudo inf.]
[AM]	no	no	no	positive
[CP]	no	no	no	positive
[Cg]	no	no	no	positive
[tudo inf.]				no

Consistent judgements

extreme
v. strong
strong
moderate
weak
very weak
no

Table III. Weighting for Portuguese Airports (Authors)

This way MacBeth verifies if the judgments are consistent or not; for this first attempt the judgments are considered consistent; so the Bar Chart for this weights is necessarily the one of Table IV.

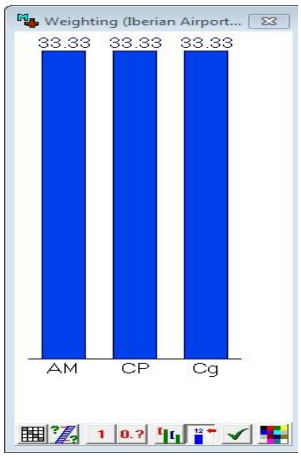


Table IV. Bar Chart for Portuguese Airports (Authors)

Then MacBeth produces a Robustness Analysis as shown in Table V.

	[tudo sup.]	LIS	OPO	FAO	FNC	PDL	HOR	PXO	SMA	FLW	[tudo inf.]
[tudo sup.]	=	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
LIS		=	▲	▲	▲	▲	▲	▲	▲	▲	▲
OPO			=	+	▲	▲	▲	▲	▲	▲	▲
FAO				=	+	+	+	▲	▲	▲	▲
FNC					=	▲	▲	▲	▲	▲	▲
PDL						=	▲	▲	▲	▲	▲
HOR							=	+	▲	▲	▲
PXO								=	+	▲	▲
SMA									=	▲	▲
FLW										=	▲
[tudo inf.]											=

Local information			
	ordinal	MACBETH	cardinal
AM	☑	☑	☑ ±0%
CP	☑	☑	☑ ±0%
Cg	☑	☑	☑ ±0%

Global information		
ordinal	MACBETH	cardinal
☑		☐ ±0%

Diff

Table V. Robustness Analysis for Portuguese Airports (Authors)

Where: ▲ represents the *dominance* - an option dominates other if it is at least as attractive as the other in all criteria and if it is more attractive than the other in at least one criteria; and ✚ represents the *additive dominance* - an option additively dominates other if it is always more attractive than the other through the use of an addictive model under a set of constraints.

From Table V one may conclude that Lisbon Airport (LIS) is the best of all the Portuguese Airports if the three indicators had the same weight; Oporto (OPO) is the second and Faro (FAO) is the third.

In a second step one adds to data of the Portuguese (9) Airports that of the (45) Spanish ones; the Table of Performances is that one of Table VI.

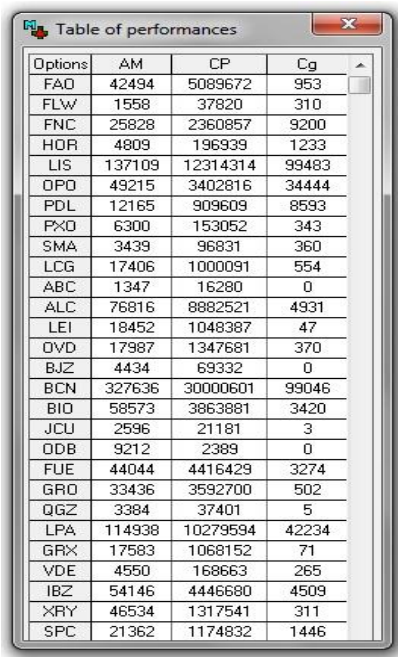


Table of performances

Options	AM	CP	Cg
FAO	42494	5089672	953
FLW	1558	37820	310
FNC	25828	2360857	9200
HOR	4809	196939	1233
LIS	137109	12314314	99483
OPO	49215	3402816	34444
PDL	12165	909609	8593
PXO	6300	153052	343
SMA	3439	96831	360
LCG	17406	1000091	554
ABC	1347	16280	0
ALC	76816	8882521	4931
LEI	18452	1048387	47
OVD	17987	1347681	370
BJZ	4434	69332	0
BCN	327636	30000601	99046
BIO	58573	3863881	3420
JCU	2596	21181	3
ODB	9212	2389	0
FUE	44044	4416429	3274
GRO	33436	3592700	502
QGZ	3384	37401	5
LPA	114938	10279594	42234
GRX	17583	1068152	71
VDE	4550	168663	265
IBZ	54146	4446680	4509
XRY	46534	1317541	311
SPC	21362	1174832	1446

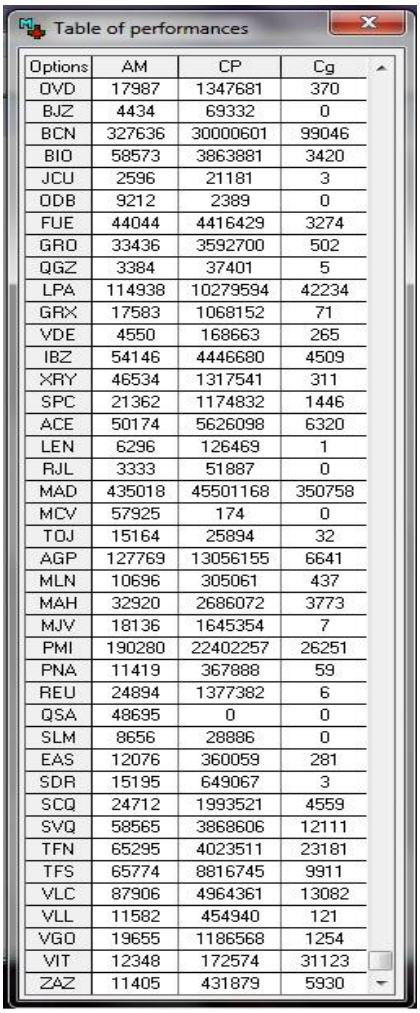


Table of performances

Options	AM	CP	Cg
OVD	17987	1347681	370
BJZ	4434	69332	0
BCN	327636	30000601	99046
BIO	58573	3863881	3420
JCU	2596	21181	3
ODB	9212	2389	0
FUE	44044	4416429	3274
GRO	33436	3592700	502
QGZ	3384	37401	5
LPA	114938	10279594	42234
GRX	17583	1068152	71
VDE	4550	168663	265
IBZ	54146	4446680	4509
XRY	46534	1317541	311
SPC	21362	1174832	1446
ACE	50174	5626098	6320
LEN	6296	126469	1
RJL	3333	51887	0
MAD	435018	45501168	350758
MCV	57925	174	0
TOJ	15164	25894	32
AGP	127769	13056155	6641
MLN	10696	305061	437
MAH	32920	2686072	3773
MJV	18136	1645354	7
PMI	190280	22402257	26251
PNA	11419	367888	59
REU	24894	1377382	6
QSA	48695	0	0
SLM	8656	28886	0
EAS	12076	360059	281
SDR	15195	649067	3
SCQ	24712	1993521	4559
SVQ	58565	3868606	12111
TFN	65295	4023511	23181
TFS	65774	8816745	9911
VLC	87906	4964361	13082
VLL	11582	454940	121
VGO	19655	1186568	1254
VIT	12348	172574	31123
ZAZ	11405	431879	5930

Table VI. Iberian Airports Performances (Authors)

As for the Portuguese Airports in a first attempt one attributes the same importance to every indicator, that is, 33.33%; so MacBeth produces a Robustness Analysis as shown in Table VII.

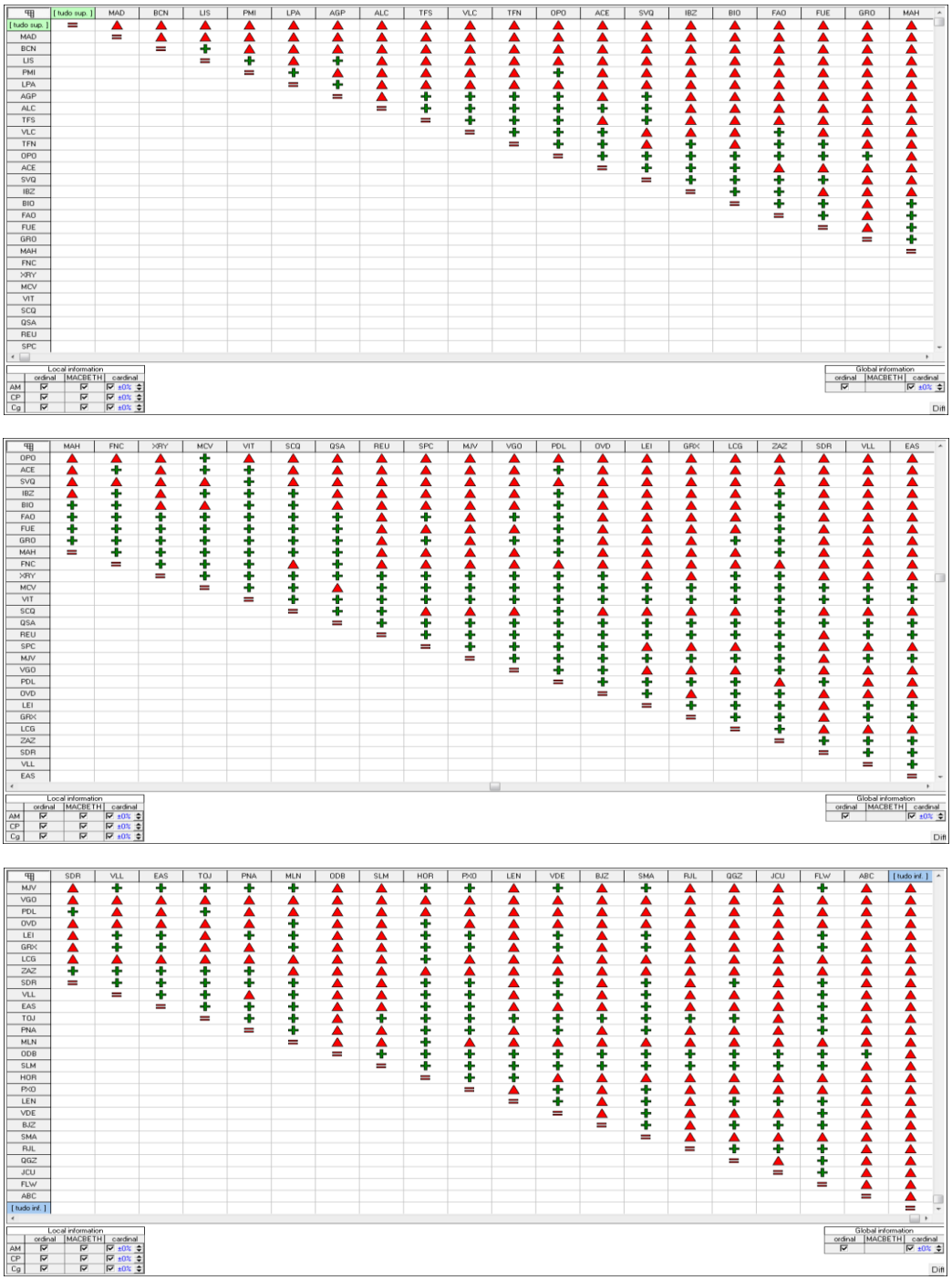


Table VII. Robustness Analysis for Iberian Airports (Authors)

From Table VII one may conclude that Madrid Airport (MAD) is the best of all the Iberian Airports if the three indicators have the same weight; Barcelona (BCN) is the second, Lisbon (LIS) is the third and Palma de Mallorca (PMI) is the fourth.

In the next step one changes the weights/importance of the indicators; for example, thinking about 50% for Movements, 40% for Passengers and 10% for Cargo the results are those of Tables VIII and IX.

Table VIII. Bar Charts for Iberian Airports (Authors)

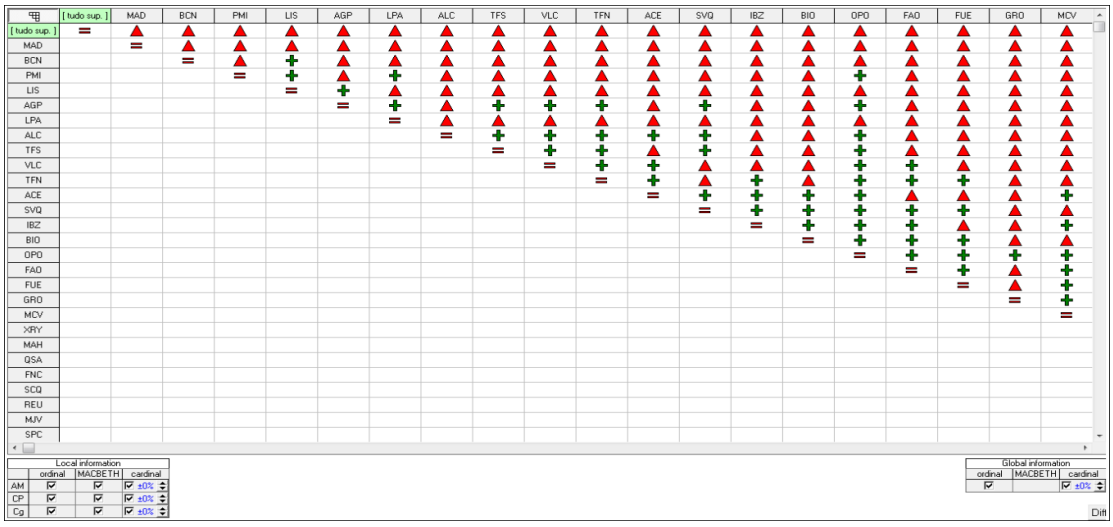


Table IX. Robustness Analysis for Iberian Airports (Authors)

From Table VIII one may conclude that Madrid Airport (MAD) remains the best of all the Iberian Airports if the three indicators have the same weight and Barcelona (BCN) is still the second; but now Palma de Mallorca (PMI) is the third and Lisbon (LIS) is the fourth.

In the next step one maintains the weights/importance of the Movements in 50% but decreases Passengers (to 10%) and increases Cargo (to 40%); the results are those on Tables X and XI.

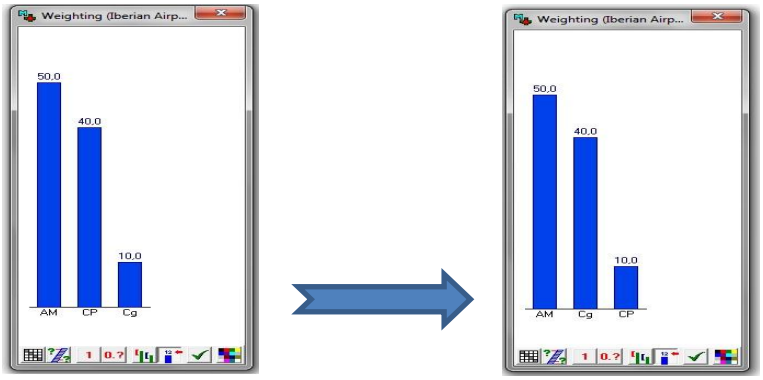
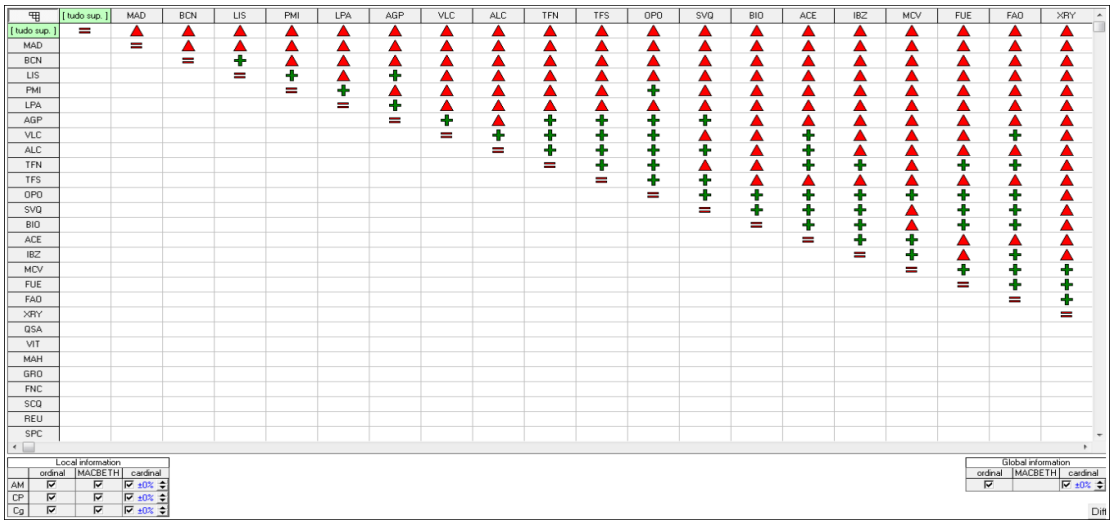
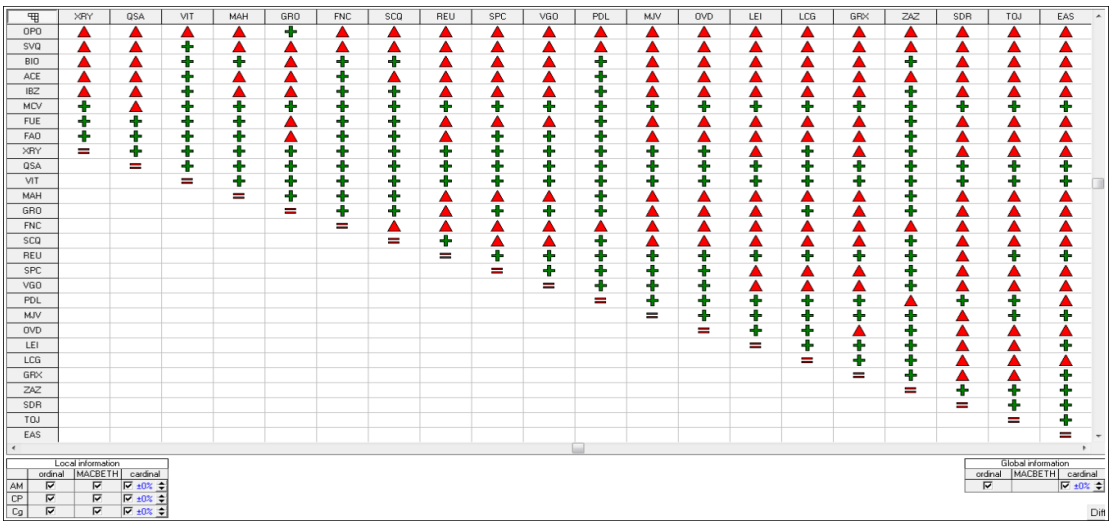


Table X. Bar Charts for Iberian Airports (Authors)





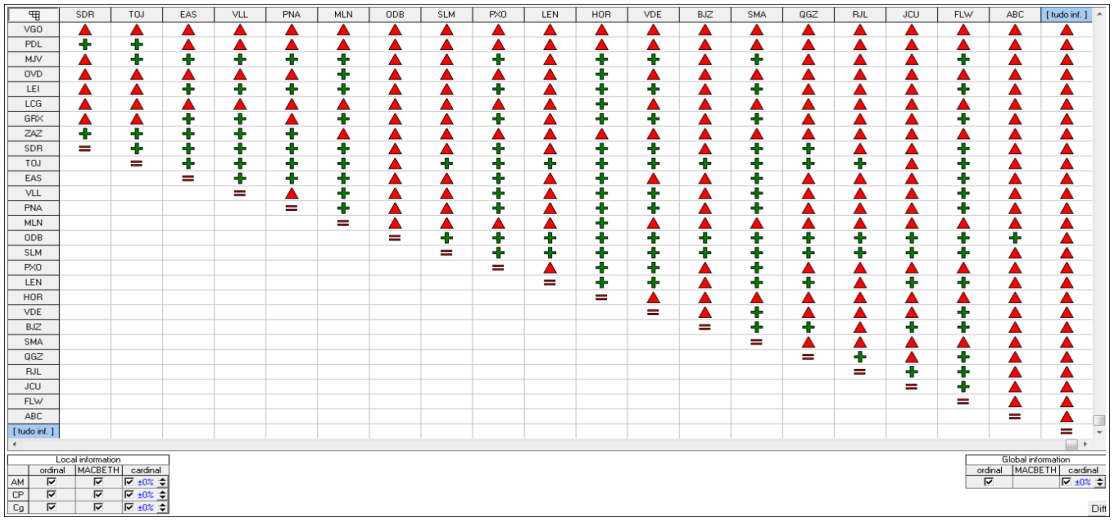


Table XI. Robustness Analysis for Iberian Airports (Authors)

From Table XI one may conclude that Madrid Airport (MAD) also remains the best of all the Iberian Airports if the three indicators have the same weight and Barcelona (BCN) is still the second too; but LIS and PMI change again as Lisbon is the third and Palma de Mallorca is the fourth.

See as positions one (Madrid, MAD) and two (Barcelona, BCN) never change in the ranking because there is a huge difference between the pair Madrid/Barcelona and all the other Iberian Airports.

5. Conclusions

Benchmarking is a self-improvement tool for any organization as it allows: to identify own strengths and weaknesses, to compare itself with others, and to learn more on how to improve efficiency.

There are several works on airport benchmarking each one using different performance indicators; some of them use single indicators as the number of aircraft parking positions, while others consider complex indicators as the number of employees per number of passengers; this work use airside indicators as movements, passengers and cargo, because it was easier to find data for all the 54 airports in the Iberian Peninsula.

The main goal of this work is to understand how important is to airport stakeholders a MCDA approach supporting a decision making process; being a MCDA based one it is necessary to choose the related most appropriate tool that is consistent and simultaneously efficient and functional, and that as easily as the weights of each criteria change the interpretation of the results remains intuitive; so one chose the MacBeth (Measuring Attractiveness by a Categorical Based Evaluation Technique).

The preliminary results show that it is possible to benchmark airports based on different performance indicators and each one with different weights accordingly with the point of view, the expertise, the opinion of each stakeholder. Also MacBeth allows and easy interpretation of the results.

Next steps will be a deeply research on airports qualitative performance indicators as well as on airports self-benchmarking processes related to several indicators along several years.

References

ACI (2006) *Airport Benchmarking to Maximize Efficiency*, Geneve, ACI World Headquarters.

Bana e Costa, C., de Corte, J.-M. and J.-C. Vansnick (2003) MacBeth, *LSE OR Working Paper 03.56, ISBN 0 7539 1529 X*, London School of Economics.

Bana e Costa, C., de Corte, J.-M., Vansnick, J.-C., Costa, J., Chagas, M., Corrêa, É., João, I., Lopes, F., Lourenço, J. and R. Sánchez-López (2005) *MacBeth User´s Guide*, Available: http://www.m-macbeth.com (15/02/2011).

Graham, A. (2005) *Airport Benchmarking: A Review of the Current Situation*, London, University of Westminster.

Humphreys, I. and G. Francis (2002) Performance Measurement: a Review of Airports, *International Journal of Transport Management*, 1(2002: 79–85).

Raposo, B. (2008) *Determinação de Rotas Aéreas com Base em Análise Multicritério de Apoio à Decisão*, Tese de Mestrado em Engenharia Aeronáutica, Covilhã, Universidade da Beira Interior.