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Conference Paper

Airports Performance And Efficiency Evaluation Based On Multidimensional Tools

52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Jardim, João Pedro; Baltazar, Maria; Silva, Jorge (2012) : Airports Performance And Efficiency Evaluation Based On Multidimensional Tools, 52nd Congress of the European Regional Science Association: "Regions in Motion - Breaking the Path", 21-25 August 2012, Bratislava, Slovakia, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

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AIRPORTS PERFORMANCE AND EFFICIENCY EVALUATION BASED ON MULTIDIMENSIONAL TOOLS

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ABSTRACT

Airport benchmarking depends on airport operational performance and efficiency indicators, which are important issues for business, operational management, regulatory agencies, airlines and passengers. There are several sets of single and complex indicators to evaluate airports performance and efficiency as well as several techniques to benchmark such infrastructures. The general aim of this work is the development of airport performance and efficiency predictive models using robust but flexible methodologies and incorporating simultaneously traditional indicators (number of movements and passengers, tons of cargo, number of runways and stands, area of terminals both of passenger and cargo) as well as new (emergent) constraints. Specifically this work: firstly shows the performance and efficiency evolution of a set of airports under several constraints based on two multidimensional tools, Multicriteria Decision Analysis (MCDA, by the use of Macbeth - Measuring Attractiveness by a Categorical Based Evaluation Technique) and Data Envelopment Analysis (DEA); and secondly compares the obtained results either with Macbeth or with DEA. Whilst DEA is a linear programming based technique for measuring the relative performance of organizational units in the presence of multiple inputs and outputs, MCDA/Macbeth uses performance and efficiency indicators to support benchmark results, being useful to evaluate not only the real importance of the selected indicators but also its correct weight.

This work is divided as follows: first, a state of the art review concerning airport operational performance and efficiency indicators, and DEA and MCDA tools and techniques; second, the impacts on airports operational performance and efficiency of emergent operational factors (sudden meteorological/natural phenomenon); third, a study on the feasibility of the incorporation of such inputs in airport performance and efficiency predictive models; fourth, the presentation of some case studies concerning a set of selected airports; fifth, some insights and challenges about future research still under development. We believe that new models are needed to benchmark airports simultaneously based on scientific techniques robust but flexible to accommodate new (emerging) constraints and useful for those responsible for airport management in different processes of decision making.

Keywords: airports, performance, efficiency, MCDA, DEA

JEL codes: L93, O18, R11

INTRODUCTION

This work is a part of two MSc and one PhD Thesis in Aeronautical Engineering - developed under the Business Models for Airport Development and Management (AIRDEV) Project, within MIT-Portugal Program – which have aims in two orders: to balance DEA and MCDA tools, and to show how airports benchmarking is also possible using a Multicriteria Decision Analysis (MCDA) tool called Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH). Whilst DEA is a linear programming based technique for measuring the relative performance of organizational units in the presence of multiple inputs and outputs, *MCDA/MACBETH* uses performance and efficiency indicators to support benchmark results, being useful to evaluate not only the real importance of the selected indicators but also its correct weight.

The collected data is related with airports facilities, considered as inputs, particularly: runways, aircraft parking stands, areas of both passenger and cargo terminals, check-in desks, baggage belts and boarding gates; and with airport statistics, namely, passengers, aircraft movements and cargo, which were considered as outputs. An emergent operational factor related to sudden meteorological/natural phenomenon, was taken into account as input for a self-benchmarking study within Madeira (FNC) airport.

This work is divided as follows: first, a state of the art review concerning airport benchmarking and efficiency indicators, and DEA and MCDA tools and techniques; second, the impacts on airports operational performance and efficiency of emergent operational factors (sudden meteorological/natural phenomenon); third, a study on the feasibility of the incorporation of such inputs in airport performance and efficiency predictive models; fourth, the presentation of some case studies concerning a set of worldwide airports; fifth, some insights and challenges about future research still under development.

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 on 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 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 governmental 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), 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.

There are several works on airport benchmarking each one using different performance indicators. Some of them use single indicators as, for example, number of aircraft parking positions (stands), while others consider complex indicators as, for example, number of passengers per area of passenger’s terminal.

The indicators can be divided in two major groups, single and complex, respectively used with DEA and MACBETH tools. The indicators included in our analysis, namely inputs and outputs, were (Table 1):

Table 1: Indicators

Single indicators	DEA	<i>Inputs</i>	Number of Runways Aircraft Parking Stands Passenger Terminal Area Cargo Terminal Area Number of Boarding Gates Number of Check-In Counters Number of Baggage Carousels Natural Phenomenon
		<i>Outputs</i>	Aircraft Movements Processed Passengers Processed Cargo (Ton.)
Complex indicators	MACBETH	<i>PAX/PAX TA</i>	Processed Passengers / Passenger Terminal Area
		<i>CARGO/CARGO TA</i>	Processed Cargo (ton.) / Cargo Terminal Area
		<i>MOVS/STANDS</i>	Aircraft Movements / Aircraft Parking Stands
		<i>MOVS/RWS</i>	Aircraft Movements / Number of Runways
		<i>PAX/GATES</i>	Number of Passengers Processed / Number of Boarding Gates
		<i>PAX/CHK-IN</i>	Number of Passengers Processed / Number of Check-In Counters
		<i>MOVS/GATES</i>	Number of Movements / Number of Boarding Gates
		<i>MOVS/BELTS</i>	Number of Movements / Number of Baggage Belts (arrivals)
		<i>OP TIME</i>	Natural Effects (Operational Time): (24h×365days) – Closure Time per Year

As previously mentioned the main goal of this work is to achieve airport rankings by using a (new) multi-criteria approach allowing the one who is applying it 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 this method is the ability to compare the performance/efficiency either of the airport with other similar infrastructures or the own airport in different years thus offering to airport manager the possibility to be in touch with the evolution of the infrastructure.

DEA AND MACBETH METHODOLOGIES AND TOOLS

As referred before, the aims of this study are in two orders: to balance DEA and MCDA tools, and to show how airports benchmarking is also possible using a Multicriteria Decision Analysis (MCDA) tool called Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH). Whilst DEA is a linear programming based technique for measuring the relative performance of organizational units in the presence of multiple inputs and outputs, MCDA/MACBETH uses performance and efficiency indicators to support benchmark results, being useful to evaluate not only the real importance of the selected indicators but also its correct weight.

DEA – Data Envelopment Analysis

DEA¹ is a non-parametric method designed to measure, in our case, the performance of an airport, using a decision-making unit (DMU). It has several models, and the one chosen for this study was the basic analysis: CCR, as verified in previous study cases. The CCR is related to constant returns and the improvement obtained in the output is proportional to that one observed in the inputs. The name (CCR) is due to its creators (Charnes, Cooper and Rhodes, 1978) and it is also known as CRS (Constant Return to Scale), (Ferreira *et al.*, 2010).

Meza *et al.* (2005), describes the mathematical foundations for SIAD tool, which have been analyzed in order to verify its applicability to our case studies.

As Ferreira *et al.* (2010) underline, the DEA tries to maximize the relationship between the goods produced (outputs) and the material spent in its production (inputs) by defining the weight of each output / input. The only constraint of the model is that the efficiency of all DMUs cannot be greater than the unit if using the weight assigned to the analyzed DMU. The DEA tool is also useful to define benchmark units, which are determined by the projection of the inefficient DMU's on the efficient frontier. The way this projection is

¹ DEA software in use is SIAD (Integrated Decision Support System), Meza *et al.*, (2005), with CCR Model and Input Oriented Analysis (minimizing inputs while keeping output values fixed).

made defines the input/output orientation model: the input oriented model used to minimize inputs while keeping the values of the output constant, or the output oriented model used to maximize the results without decreasing its assets.

Multi-Criteria Decision Analysis approach and MACBETH Tool

Since the beginning of 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 related decisions that are neither easy nor linear to take. When deciding on something generally one takes into account several criteria more or less conflictive. In a stress situation if one must consider just one factor usually the option is the most relevant. So, conflicts could exist between several criteria and so the decision maker has to consider the pros and cons of each one to reach the final (optimal) solution. This is the basis of a multi-criteria decision problem.

After analyzing some MCDA options like *ELimination Et Choix Traduisant la Réalité*, that is, *ELimination and Choice Expressing REality* (ELECTRE), *Preference Ranking Organization Method for Enrichment of Evaluations* (PROMETHEE), *Weighted Sum Model* (WSM), *Weighted Product Model* (WPM) and *Measuring Attractiveness by a Categorical Based Evaluation Technique* (MACBETH), we chose the last one as the tool that fits all the previously 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.

Thus before to develop any model it is necessary to obtain the larger amount of data as possible about what it is to be studied; this step led the decision group to have a global view about decisions to be taken; therefore this will turn the final result more robust. After the collection of data next step is to create a decision tree, that is, a decision model; these nodes correspond to indicators that are going to be taken into account; so the choice of nodes are one of the key questions in the development phase.

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

Within 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 pair of indicators in the model too. 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 (Braz *et al.*, 2011).

THE IMPACTS OF NATURAL FACTORS ON AIRPORTS OPERATIONAL PERFORMANCE AND EFFICIENCY

It is well known that aviation presents a high sensitivity to weather, with major impacts on safety, efficiency and capacity of aviation operations. Consequently, the capacity of airports is highly reduced by the need to increase the separation between aircraft, for additional holdings, or by the closure of one or even all runways, affecting its operational performance. Such weather phenomenon, and from a point of view of airport operations, includes thunderstorms, turbulence and gusts, heavy snowfall and runway icing, low visibility by fog, and most recently, volcanic ashes on airspace, due to volcanic eruptions (Figures 1, 2 and 3).



Figure 1: Heavy rain at Cancun airport



Figure 3: Volcanic ash at San Carlos de Bariloche airport, in Argentina, after wind have carried the ash from Chile's Puyehue volcano in June 2011



Figure 2: Works on snow removal at La Guardia airport, New York City, during December 2010 snowstorms

As a result, the operational capacity of a region’s entire airspace is reduced through delays, diversions and cancellations of flights – all of which have severe effects for travelers. An example is presented in Figure 4 (but see also Figure 5), which presents the arrivals board of London Heathrow airport terminal 5, in 16th April 2010, when Eyjafjallajökull erupted on Iceland; all flights were canceled or highly delayed.



Figure 4: Arrivals board of London Heathrow airport terminal 5, in 16th April 2010



Figure 5: Affected passengers at London Heathrow airport, during December 2010 snowstorms

An airport has an amount of basic characteristics, which all are considered to well combine with specific weather hazards, such as local weather phenomenon and climacteric conditions, topography of the region, orientation of the runways, etc. Due to climate change, these phenomenons will be more common and with highly impacts, therefore, an individual self-benchmarking study has to be done for each airport in order to investigate its susceptibility to adverse weather, since conclusions found for one airport do not automatically hold for others (Sasse and Hauf, 2003).

CASE STUDIES

In the first case study we use airport data from Ferreira *et al.* (2010) adding some more, not only airports, but also performance indicators, both chosen from ATRS 2009 (Air Transport Research Society, 2009) publication, in order to produce an efficiency ranking of a set of worldwide airports, using both DEA and MACBETH tools. In the second case study we use data collected from a Portuguese airport, Madeira (FNC), on Madeira Island, from 2007 to 2011, to self-benchmark such infrastructure using both DEA and MACBETH tools, using the same performance indicators as in the previous case, but now adding the number of closure hours per year due to natural effects.

Efficiency of a set of worldwide airports

Ferreira *et al.* (2010) obtain an efficiency ranking of some worldwide airports, specially focused on Brazilian infrastructures, using a DEA approach (Figure 6).

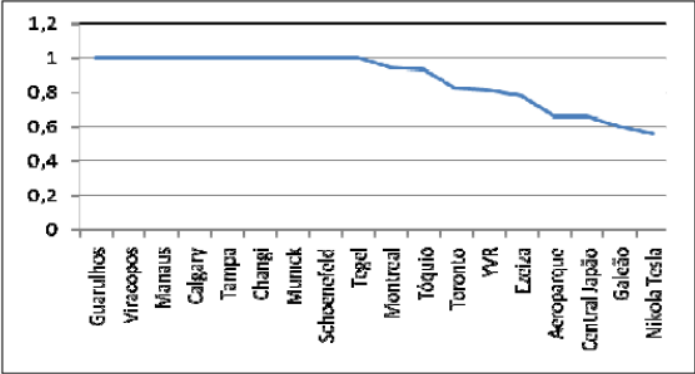


Figure 6: Efficiency ranking for a set of worldwide airports (Ferreira *et al.*, 2010)

The authors use 7 single performance indicators to produce their ranking: 4 Inputs (Number of Runways (RWS), Number of Aircraft Parking Positions (STANDS), Passenger Terminal Area, m^2 , (PAX TA), and Cargo Terminal Area, m^2 , (CARGO TA)) and 3 Outputs (Number of Aircraft Operations (MOVS), Number of Processed Passengers (PAX) and Cargo Volumes, *tons*, (CARGO)). After consulting some literature as well as some experts on airport benchmarking, we decided to add some more inputs to this study, namely, Number of check-in desks (CHK-IN), Number of Boarding Gates (GATES) and Number of Baggage Belts (BELTS). Equally, we used some new airports, with a number of Processed Passengers higher than 19.000.000, as presented at ATRS 2009 (Air Transport Research Society, 2009) report. Thus, it was necessary to get the data.

The collected data is presented in Table 2.

Table 2: Airport data

											Statistics 2011		
											OUTPUTS		
											STATISTICS 2011		
			INPUTS								OUTPUTS		
			IATA	RWS	STANDS	PAX TA	CARGO TA	CHK-IN	GATES	BELTS	MOVS	PAX	CARGO
South America	Brazil	Guarulhos	GRU	2	66	179790	64752	320	61	23	270600	30003428	515175
	Brazil	Galeão	GIG	2	53	280681	41800	150	50	15	139443	14952830	114097
	Brazil	Viracopos	VCP	1	11	8720	67458	70	9	4	99982	7568384	283267
	Brazil	Manaus	MAO	1	15	46266	9300	53	5	4	56298	3019426	179082
	Argentina	Aeroparque ²	AEP	1	68	30000	10000	55	16	9	81675	5320292	13741
	Argentina	Ezeiza ³	EZE	2	42	71000	203827	143	23	11	93346	8786807	248692
North America	Canada	Calgary	YYC	3	45	123000	54812	118	50	9	162000	12844523	116000
	Canada	Vancouver	YVR	3	108	255000	96200	250	95	14	296942	17032780	223878
	Canada	Toronto	YYZ	5	141	251054	84575	370	108	24	428477	33400000	492171
	Canada	Montreal ³	YUL	3	64	72720	135000	208	60	13	217545	13660862	112000
	EUA	Tampa	TPA	3	75	174374	22300	116	59	14	191315	16732051	81822
	EUA	Atlanta	ATL	5	172	340955	130846	124	207	17	923991	84962851	638127
Asia - Pacific	Japan	Tokyo	NRT	2	141	783600	815580	584	67	28	183451	28068714	1898885
	Japan	Central Japan	NGO	1	66	220000	260000	180	28	9	82137	8890683	143134
	Singapore	Changi	SIN	2	85	650000	510000	444	92	15	301711	46543845	1865252
	Australia	Sydney	SYD	3	93	354000	53850	258	56	23	280910	35630549	249159
	China	Hong Kong	HKG	2	120	710000	351600	377	75	12	334000	53904000	3938000
	Dubai	Dubai	DXB	2	144	1444474	78600	400	82	31	326317	50980000	2190000
Europe	Germany	Munich	MUC	2	135	469400	58250	310	200	28	409956	37782256	303655
	Germany	Frankfurt	FRA	4	189	800000	90000	381	120	31	487162	56443657	2169304
	UK	Gatwick	LGW	1	115	258000	20300	348	94	16	244741	33639900	88214
	Serbia	Belgrade	BEG	1	22	40000	7300	47	16	4	44923	3124633	8025
	Italy	Milan	MPX	2	139	142000	45000	313	93	15	186780	19291427	440258
	Spain	Barcelona	BCN	3	168	674759	43692	258	149	28	303054	34398226	96572

Thus we use this data to obtain an efficiency ranking based on MACBETH and DEA approaches. If we introduce these single indicators within MACBETH, as mentioned we would produce not an efficiency ranking but a performance one. Then, it's necessary to create new indicators, which we call complex ones, combining the above inputs and outputs, as presented on Table 1. Movements, includes the number of aircraft landing/take-off on/from the airport; Passengers, includes the number of passengers who arrives and departs into/from the airport; and Cargo, includes the number of cargo tons that arrives and departs on/from the airport being domestic or international, freight or mail flights. Then, we divided this analysis in two different parts, in order to verify the position change in the ranking due to additional performance indicators, as presented on Table 3.

² Statistics data for 2006

³ Statistics data for 2010

Table 3: Cases studies for a set of worldwide airports

1	DEA	Include the same inputs and outputs as used by Ferreira <i>et al.</i> (2010)
	MACBETH	
2	DEA+	Include all the performance indicators as presented in Table 2
	MACBETH+	

In order to use the MACBETH analysis, it was necessary to give a weight to each indicator; thus, we ask for the opinion of 30 (national and international) aeronautical specialists (from research, airports, airlines, regulation, air traffic control, and industry sectors) about the weights (%) to attribute to those complex indicators. The sum of weights necessarily would be 100.00%.

For the first case study (MACBETH), the weights were obtained from a previous one done by Braz (2011); for the second one (MACBETH+) it was necessary to search for them as mentioned above.

So, according to Table 2 we obtained the complex indicators of Table 4 (as explained in Table 1); the respective weights are those of Table 5.

Table 4: Complex indicators for a set of worldwide airports

Options	MOVS/STANDS	MOVS/RWS	PAX/PAX TA	CARGO/CARGO TA	PAX/CHK-IN	PAX/GATES	MOVS/GATES	MOVS/BELTS
ATL	5372.04	184798.2	249.19	4.88	685184.28	410448.56	4463.72	54352.41
FRA	2577.58	121790.5	70.55	24.1	148146.08	470363.81	4059.68	15714.9
HKG	2783.33	167000	75.92	11.2	142981.43	718720	4453.33	27833.33
DUB	2266.09	163158.5	35.29	27.86	127450	621707.32	3979.48	10526.36
SIN	3549.54	150855.5	71.61	3.66	104828.48	505911.36	3279.47	20114.07
MUC	3036.71	204978	80.49	5.21	121878.25	188911.28	2049.78	14641.29
SYD	3020.54	93636.67	100.65	4.63	138102.9	636259.8	5016.25	12213.48
BCN	1803.89	101018	50.98	2.21	133326.46	230860.58	2033.92	10823.36
LGW	2128.18	244741	130.39	4.34	96666.38	357871.28	2603.63	15296.31
GRU	4100	135300	166.89	7.96	93760.71	491859.48	4436.07	11765.22
TPA	2550.87	63771.67	95.95	3.67	144241.82	283594.08	3242.63	13665.36
VCP	9089.27	99982	867.93	4.2	108119.77	840931.56	11109.11	24995.5
AEP	1201.1	81675	177.34	1.37	96732.58	332518.25	5104.69	9075
MAO	3753.2	56298	65.26	19.26	56970.3	603885.2	11259.6	14074.5
MXP	1343.74	93390	135.86	9.78	61633.95	207434.7	2008.39	12452
YYZ	3038.84	85695.4	133.04	5.82	90270.27	309259.26	3967.38	17853.21
BEG	2041.95	44923	78.12	1.1	66481.55	195289.56	2807.69	11230.75
YUL	3399.14	72515	187.86	0.83	65677.22	227681.03	3625.75	16734.23
YYC	3600	54000	104.43	2.12	108851.89	256890.46	3240	18000
YVR	2749.46	98980.67	66.8	2.33	68131.12	179292.42	3125.71	21210.14
GIG	2631	69721.5	53.27	2.73	99685.53	299056.6	2788.86	9296.2
NRT	1301.07	91725.5	35.82	2.33	48062.87	418936.03	2738.07	6551.82
NGO	1244.5	82137	40.41	0.55	49392.68	317524.39	2933.46	9126.33
EZE	2222.52	46673	123.76	1.22	61446.2	382035.09	4058.52	8486

Table 5: Complex indicators weights

Indicators	MACBETH	MACBETH+
MOVS / STANDS	21,60%	16,61%
MOVS/ RWS	27,90%	12,78%
PAX / PAX TA	25,80%	18,01%
CARGO / CARGO TA	24,70%	12,93%
PAX / CHK-IN	-	10,93%
PAX / GATES	-	10,05%
MOVS / GATES	-	9,56%
MOVS / BELTS	-	9,09%
	100%	100%

Then we use MACBETH and DEA tools to get airports efficiency ranking based on a combination of the above mentioned indicators, and its related weights (Tables 6 and Figures 7 to 11).

Table 6: Airports position in the efficiency ranking for the four case studies

DMU	DEA	Rank DEA	DEA+	Rank DEA+	MACBETH	Rank MACBETH	MACBETH+	Rank MACBETH+
Atlanta	1	1	1	1	46,83	3	55,63	3
Frankfurt	1	1	1	1	44,32	4	37,80	5
Hong Kong	1	1	1	1	38,75	6	39,90	8
Dubai	1	1	1	1	50,61	2	40,95	2
Singapore	1	1	1	1	32,29	10	31,42	4
Munich	1	1	1	1	38,6	7	28,74	12
Gatwick	1	1	1	1	41,03	5	31,99	7
Tampa	1	1	1	1	20,15	17	22,42	17
Viracopos	1	1	1	1	62,51	1	67,19	1
Aeroparque	1	1	1	1	18,35	20	22,15	14
Manaus	1	1	1	1	35,77	9	40,14	6
Guarulhos	97,4419	12	1	1	38,26	8	34,83	11
Malpensa	95,6754	13	95,6750	15	26,5	12	21,95	21
Sydney	89,0577	14	1	1	25,85	13	30,76	9
Toronto	76,9192	15	77,0023	16	26,85	11	26,98	18
Barcelona	72,8363	16	1	1	19,86	18	19,08	22
Belgrade	71,8792	17	74,3827	17	13,83	24	15,87	24
Montreal	66,8798	18	66,8798	18	23,32	14	23,93	10
Calgary	63,2856	19	64,4523	19	20,85	16	23,12	13
Galeao	57,0501	20	62,5324	21	19,16	19	19,91	16
Vancouver	53,2939	21	63,4889	20	22,81	15	22,09	15
Toquio Narita	52,7282	22	58,9331	22	17,1	21	18,19	19
Ezeiza	41,3818	23	51,3938	24	15,79	22	20,05	20
Central Japan	40,6819	24	56,9539	23	14,39	23	16,26	23

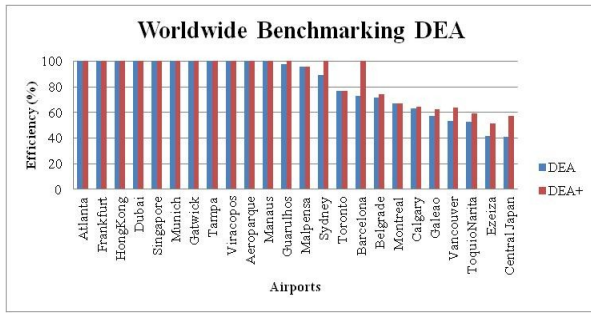


Figure 7: Comparative efficiency between DEA and DEA+

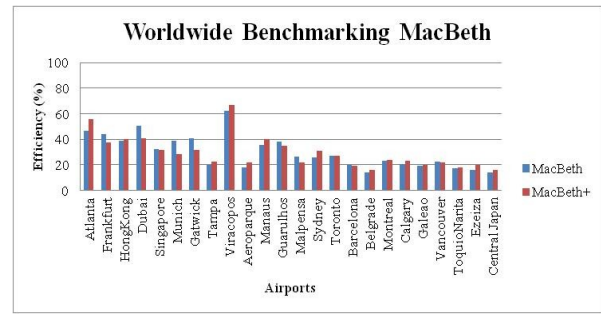


Figure 8: Comparative efficiency between MACBETH and MACBETH+

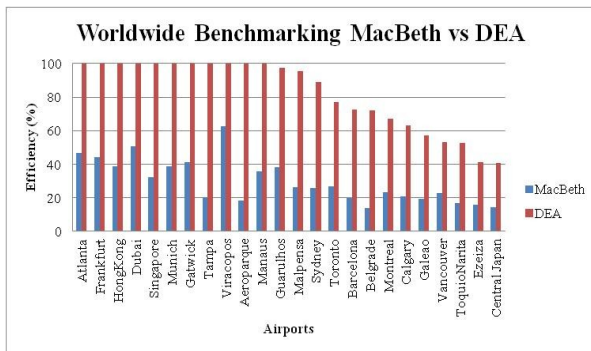


Figure 9: Comparative efficiency between MACBETH and DEA

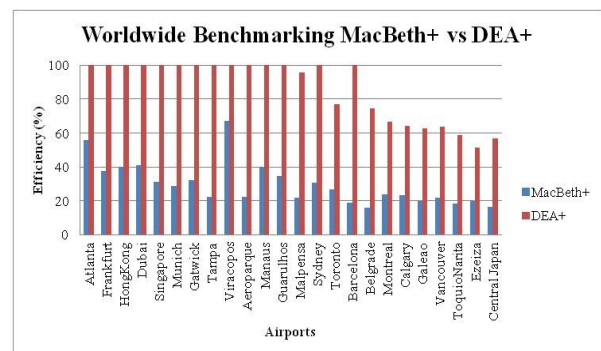


Figure 10: Comparative efficiency between MACBETH+ and DEA+

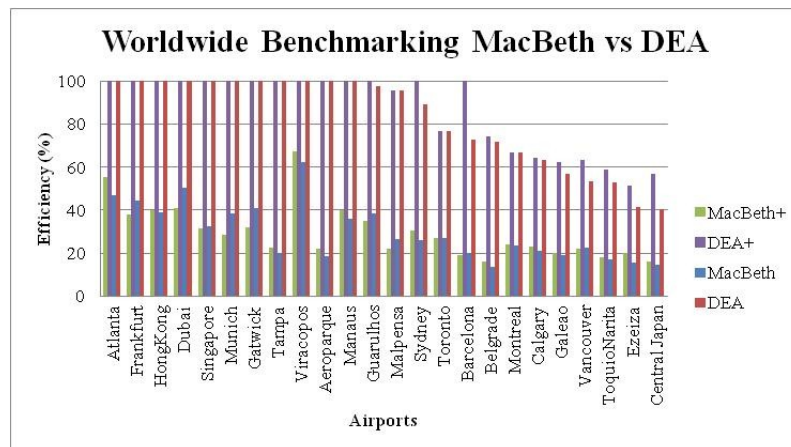


Figure 11: Comparative efficiency for all case studies

The efficiency results obtained with MACBETH and DEA approaches are quite different. From Figure 7 to 10, or from Figure 11 (direct comparison), it's possible to observe the variation on efficiency values, due the use of those two different tools. Some airports have different values between approaches, since MACBETH does a thinner approach and presents a non-convergence approach, and DEA presents more than one airport in first place.

Figures 12 to 19 permit another perspective. Comparing the transition from DEA to DEA+ (i.e., Figures 12 and 13), which represent the adding of new indicators, it's possible to observe that there are some similarities as for Atlanta, Dubai, Tampa, Viracopos, Frankfurt, among others, but also there are great discrepancies as for Sidney and Barcelona.

Comparing the transition from MACBETH to MACBETH+, which represents again the adding of new indicators (ie., Figures 14 and 15), it's possible to observe that there are some similarities as for Atlanta, Dubai, Tampa, Viracopos, Belgrade, Vancouver and Central Japan, but also that there are great discrepancies as for Singapore, Munich, Aeroparque, Malpensa and Toronto.

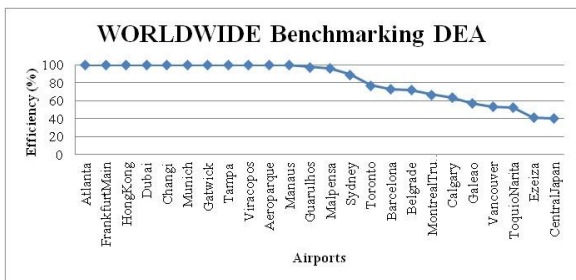


Figure 12: DEA efficiency ranking

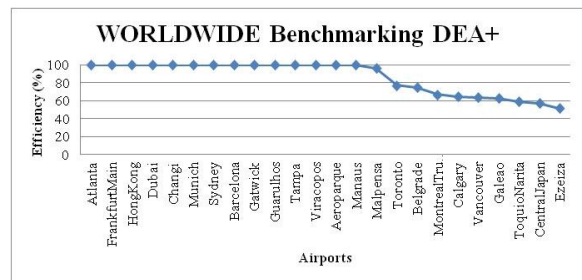


Figure 13: DEA+ efficiency ranking

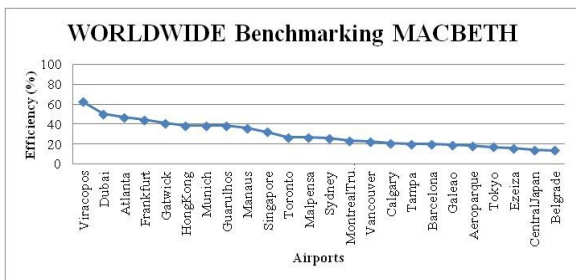


Figure 14: MACBETH efficiency ranking

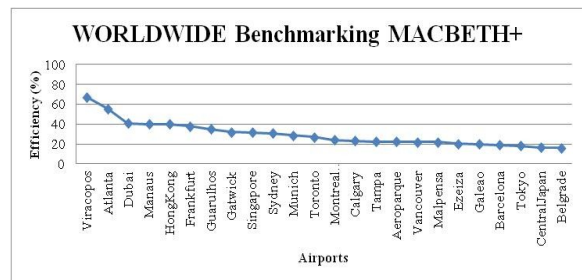


Figure 15: MACBETH+ efficiency ranking

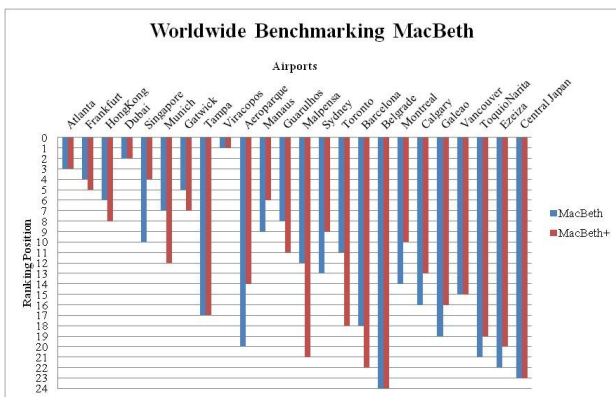


Figure 16: Balance between MACBETH rankings

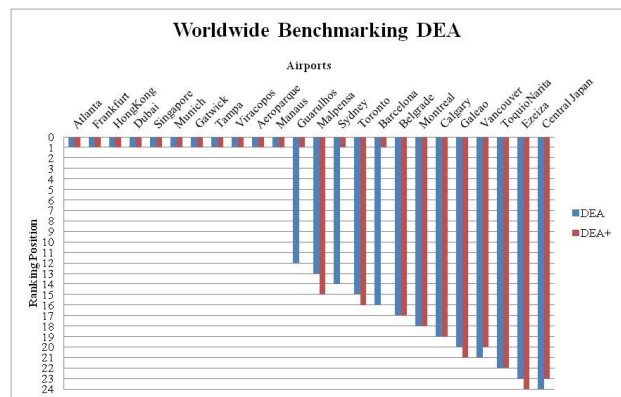


Figure 17: Balance between DEA rankings

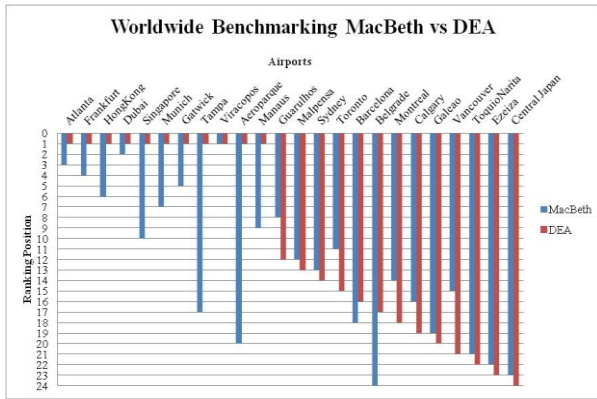


Figure 18: Balance between MACBETH and DEA rankings

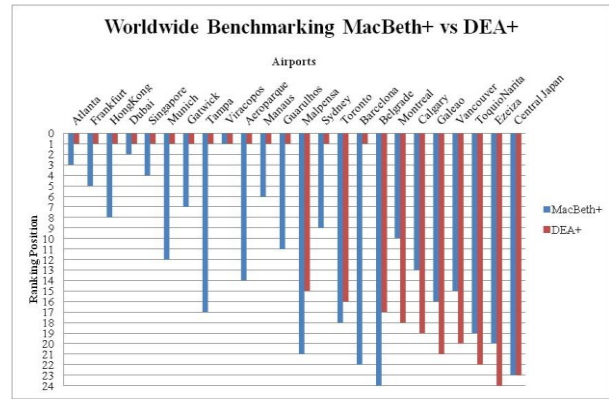


Figure 19: Balance between MACBETH+ and DEA+ rankings

In Figures 16 and 17 a comparison is done between rankings, before and after the addition of new indicators, where is visible the high influence for some airports as Singapore and Malpensa of MACBETH tool (Figure 16), and Guarulhos, Sidney and Barcelona of DEA one (Figure 17). Equally, in Figures 18 and 19, a new comparison is shown, now between tools, where is visible again the high influence for some airports as Aeroparque, Tampa and Singapore (Figure 18), and Barcelona, Tampa, and Aeroparque (Figure 17).

Thus, is possible to conclude that the addition of new indicators, such as check-in desks, boarding gates and baggage belts, in this benchmarking study, has an important, non negligible, influence for some included airports.

Self-Benchmarking for Madeira (FNC) airport

An interesting improvement for benchmarking studies is the possibility of both DEA and MACBETH tools to compare efficiency values of a given airport over several years. This feature is particularly interesting when observing the answer given by the airport whenever there are investments in such infrastructure. If there are no investments, it is always possible to see how effective the airport has become all over the years. Thus, this case study performs specifically the self-benchmarking of a Portuguese airport, Madeira (FNC) one, in Madeira island. We use data of Table 7 for input and output indicators.



Figure 18: Overview of Madeira airport

Table 7: Madeira airport data 2007-2011 (ANAM, 2007 to 2011)

INPUTS									OUTPUTS		
DMU	RWS	STANDS	PAX TA	C TA	CHK-IN	GATES	BELTS	OP TIME	PAX	MOVS	CARGO
FNC2007	1	16	44590	4800	40	16	4	-	2418489	21954	6774,6
FNC2008	1	16	44590	4800	40	16	4	-	2446924	22799	6637,6
FNC2009	1	16	44590	4800	40	16	4	-	2346649	21955	6228,4
FNC2010	1	16	44590	4800	40	16	4	-	2233524	22094	6069,5
FNC2011	1	16	44590	4800	40	16	4	-	2311380	21346	5095

This case study is divided into three parts: in the first and second ones the indicators structure is the same of the previous case study - as presented in Table 3, and the third one will be called MACBETH++ and DEA++ which corresponds to the inclusion of a new indicator related to the number of closure hours per year due to natural effects. As such information is confidential related data cannot be displayed, as requested by the airport authority; nevertheless it will be included in the case study. These three parts/experiences are again to verify possible changes in the ranking between methods, due to additional performance indicators to the analysis.

Table 8 specifies information related to complex indicators, as in the previous case study, where data concerning closure hours per year due to natural effects is, as mentioned, not visible.

Table 8: Complex indicators for Madeira airport

Opções	MOVS/STANDS	MOVS/RWS	PAX/PAX TA	CARGO/CARGO TA	PAX/CHK-IN	PAX/GATES	MOVS/GATES	MOVS/BELTS	OP TIME
FNC2007	1372.13	21954	54.24	1.41	60462.23	151155.56	1372.13	5488.5	
FNC2008	1424.94	22799	54.88	1.38	61173.1	152932.75	1424.94	5699.75	
FNC2009	1372.19	21955	52.63	1.3	58666.23	146665.56	1372.19	5488.75	
FNC2010	1380.88	22094	50.09	1.26	55838.1	139595.25	1380.88	5523.5	
FNC2011	1334.13	21346	51.84	1.06	57784.5	144461.25	1334.13	5336.5	

Then we use MACBETH and DEA tools again to rank this set of years between 2007 and 2011. The weights for MACBETH and MACBETH+ are those of table 5, and for MACBETH++ are those of Table 9, accordingly (again) with the opinion of (the same) 30 (national and international) aeronautic specialists.

Table 9: Complex indicators weights

Indicators	MACBETH++
MOVS/STANDS	15,63%
MOVS/RWS	11,80%
PAX/PAX TA	17,03%
CARGO/CARGO TA	11,96%
PAX/CHK-IN	9,96%
PAX/GATES	9,07%
MOVS/GATES	8,57%
MOVS/BELTS	8,11%
NATURAL EFFECTS	7,88%
	100%

The results are displayed in the following Table 9 and Figures 20 to 24.

Table 9: Airport positions in the efficiency rankings for the six case studies

DMU	DEA	Rank DEA	DEA+	Rank DEA+	DEA++	Rank DEA++	McB	Rank MacB	McB+	Rank MacB+	McB++	Rank MacB++
FNC2007	1	1	1	1	1	1	97,76	2	97,77	2	97,95	2
FNC2008	1	1	1	1	1	1	99,47	1	99,73	1	99,74	1
FNC2009	96,2981	4	96,2981	4	96,6422	4	95,19	3	95,61	3	95,92	3
FNC2010	96,9078	3	96,9078	3	97,6050	3	93,81	4	93,73	4	94,15	4
FNC2011	94,4606	5	94,4606	5	94,5087	5	89,21	5	91,54	5	92,20	5

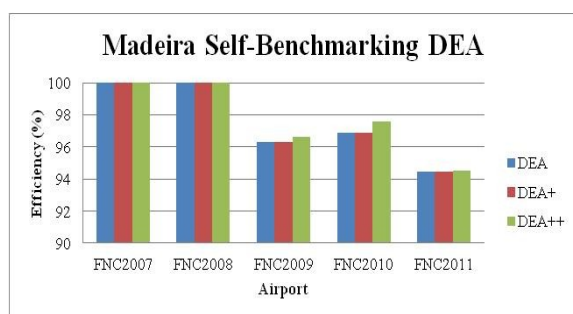


Figure 20: DEA comparative efficiency

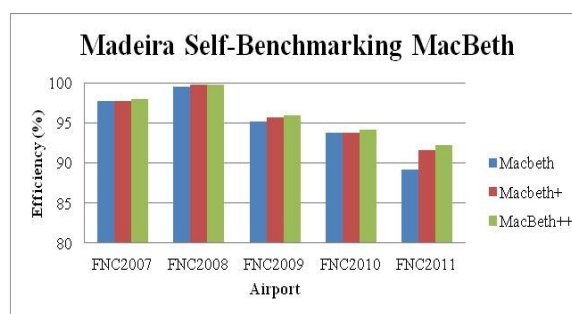


Figure 21: MACBETH comparative efficiency

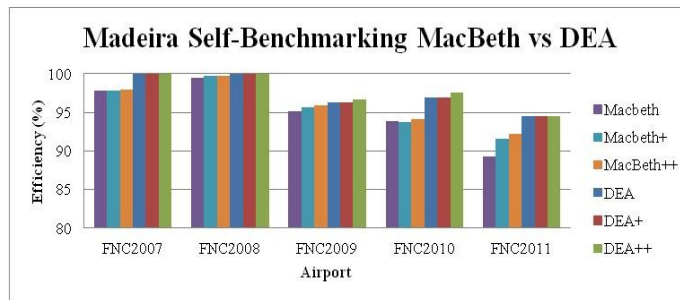


Figure 22: Comparative efficiency for all case studies

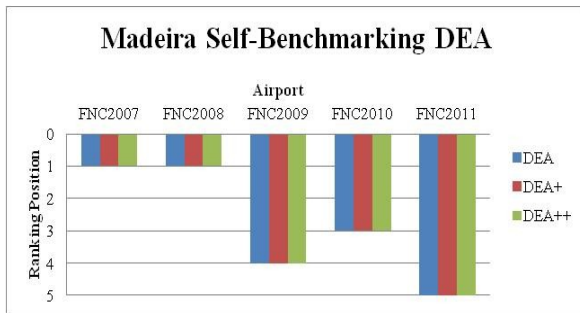


Figure 23: Ranking Balance for DEA case studies

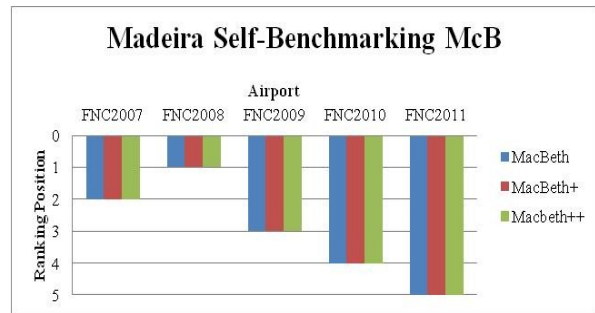


Figure 24: Ranking Balance for MACBETH case studies

Comparing on one hand MACBETH, MACBETH+, MACBETH++ and, on the other hand DEA, DEA+, DEA++ (Figures 20 to 22), it's possible to observe that exist differences in the efficiency values due to the successive addition of new indicators, despite no changing exists in the rankings, for each year and each method (Figures 23 and 24). Figures 25 to 31 evidences the same results in a different way of presentation.

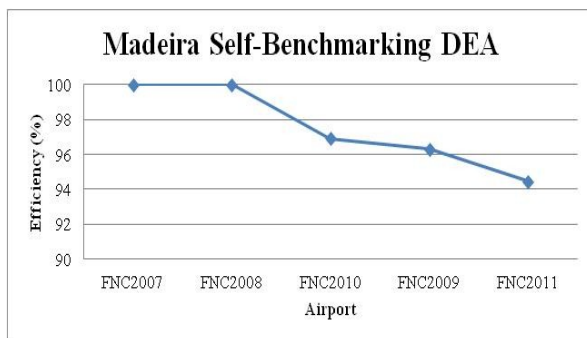


Figure 25: DEA efficiency ranking

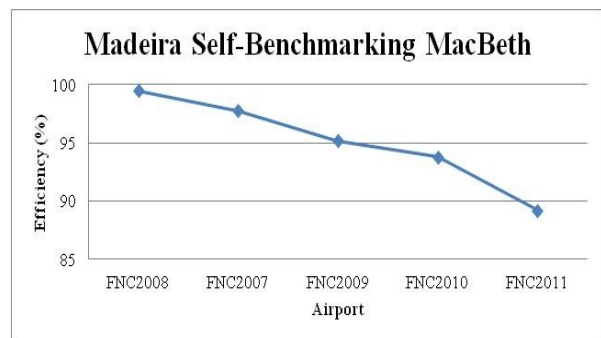


Figure 26: MacBeth efficiency ranking

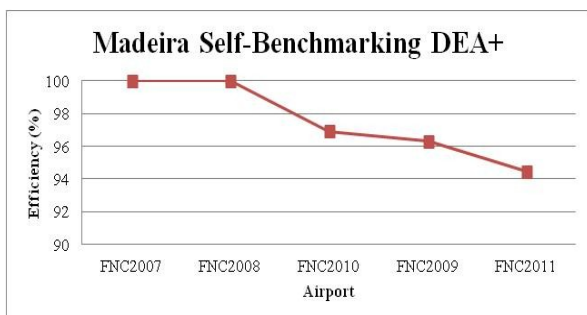


Figure 27: DEA+ efficiency ranking

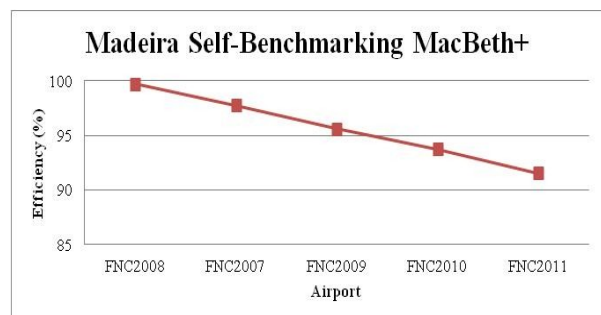


Figure 28: MacBeth+ efficiency ranking

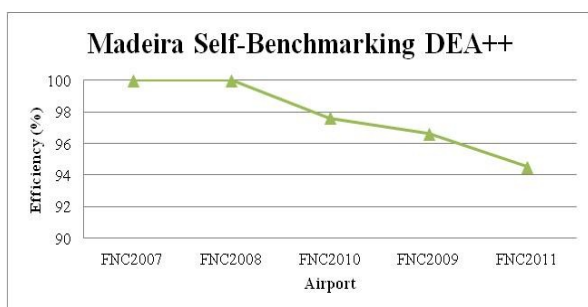


Figure 29: DEA++ efficiency ranking

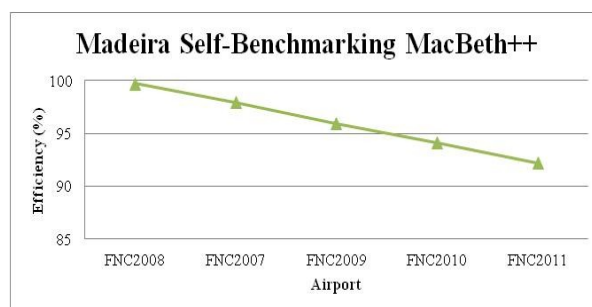


Figure 30: MacBeth++ efficiency ranking

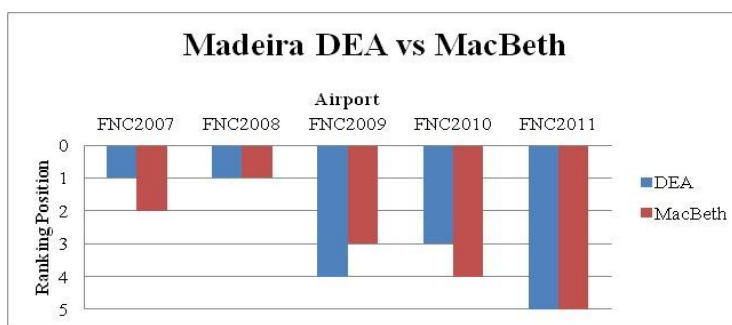


Figure 31: Balance between MACBETH and DEA rankings

As evidenced in Figure 31, the results obtained with MACBETH and DEA approaches are quite different for 2007, 2009 and 2010. For both, MACBETH and DEA, 2008 was the most efficient year for Madeira airport, as 2011 was the less efficient year. Curiously, with the addition of the closure time (MACBETH++ and DEA++) the efficiency values show a slight increase; this fact is not clear for us, and we need further research with other case studies (airports) for better understand such phenomena.

FINAL REMARKS

MACBETH and DEA have the ability to compare either the airport with other similar infrastructures or the own airport in different years, offering to all stakeholders the possibility to be in touch with the evolution of the performance and efficiency of the infrastructure. Results obtained within MACBETH tool are quite different than those obtained within DEA one, since MACBETH does a thinner approach and presents a non-convergence approach against DEA solutions. In our opinion MACBETH allows any stakeholder to analyze more easily the position of any airport within the raking, and to easily understand changes needed within the airport to modify its individual and overall classification. The natural/meteorological conditions under which airports are working seems to be for our experts a not relevant indicator to rank the infrastructure, either with others, or with itself over the years.

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, for example, number of aircraft parking positions, while others consider complex indicators as, for example, number of passengers per area of passenger's terminal. It is easy to understand how important is to airport stakeholders a MCDA approach supporting a decision making process. The main goal of this work is not only to balance DEA and MCDA tools in general, but also to achieve airport rankings by using a (new) multicriteria approach allowing the one who is applying it to choose properly both the indicators and the related weights. Therefore we use MACBETH and to rank airports in two ways thus underlining the versatility of such tool: the efficiency of a set of worldwide airports, and the self-benchmarking of one Portuguese one (Madeira). The disadvantage of MACBETH to benchmark airports is the subjectivity needed to determine the indicator weights which is possible to mitigate in two ways: using the opinions of specialists in the appropriate fields of knowledge, and getting as much answers as possible so that related average (and variance) values are as close as possible with the reality, Braz (2011). The DEA analysis gives the indicator weighting by mathematical approach, leading to some airports getting maximum efficiency, simply because exists one indicator, on that airports, which is much better that the other ones. For this reason, sometimes this approach not allows a clear understanding of the desired efficiency ranking.

Next research steps will be focused on using both, DEA and MACBETH models, and the same efficiency indicators used in the previous (+) cases, as benchmarking studies for (a) the closest airports to the European Union capitals, for (b) the most important Iberian airports (Portugal and Spain), and for (c) the most important Portuguese ones; also is our target the self-benchmarking of some Iberian airports, including in this particular natural effects, and ramp occurrences.

ACKNOWLEDGEMENTS

To FCT (Fundação para a Ciência e Tecnologia, Portugal) by the MSc grant of João Jardim, under AIRDEV (Business Models for Airport Development and Management) Project in partnership with MIT-Portugal Program (Reference: MIT-Pt-TSAAs/0046/2008).

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Image sources:

Figure 1:

<http://www.airliners.net/photo//1997873/L/&sid=59e58578479082447f32436a822ef06b>

Photograph: Mr. Ricardo Morales (last access on 23/6/2012)

Figure 2:

http://www.redrif.com/images/ff/0611/27/bvolcanic_ashis_very_dangerousfor_aircraftbrparticles_of_5.jpg (last access on 23/6/2012)

Figure 3:

http://www.csmonitor.com/var/ezflow_site/storage/images/media/images/2010/0210/010-snowstorm-east-coast-airports-laguardia/7375969-1-eng-US/0210-snowstorm-east-coast-airports-laguardia_full_600.jpg (last access on 23/6/2012)

Figure 4:

http://ga.wikipedia.org/wiki/%C3%8Domh%C3%A1:Arrivals_board,_Heathrow_T5,_April_16_2010.JPG (last access on 23/6/2012)

Figure 5:

http://www.easydestination.net/blog/media/AM/Heathrow_Airport_Terminal.jpg (last access on 23/6/2012)

Figure 18:

<http://english4aviation.pbworks.com/f/Airport%20Madeira%20Airport.jpg> (last access on 23/6/2012)