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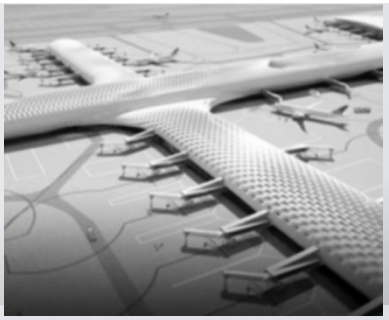

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

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Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Introduction

The air transportation provides to its users a fast net of transports at a global scale that is used annually by about 2.2 thousand million of **passengers**.

Goods carried by this mode of transport represent 35% of the international trade.

About 40% of the international **tourists** travel using air mode.

About 2,000 air companies **in the world** operate a fleet with about 23,000 aircraft connecting about 3,750 airports through a net of routes of some millions of miles managed for about 160 providers of air services.

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Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Introduction

Forecast of the evolution of the air transportation of passengers at a world-wide level, for the period between 2008 and 2027 (ICAO, 2008).

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Introduction

Airport **benchmarking** depends on airport **performance and efficiency** indicators.

There are several sets of indicators to evaluate airports performance and efficiency.

The aims of this work are of two orders: to **balance** DEA and MCDA tools, and to **show** how airports benchmarking is **also possible** using a Multi-criteria Decision Analysis (MCDA) tool – **the MacBeth**.

Thus using MacBeth we evaluate:

Firstly, **the efficiency** of a set of worldwide airports; and
Secondly, **the self-benchmarking** of two Portuguese airports.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Airports Benchmarking and Performance Indicators

The airport sector has in the **Benchmarking a tool** for analysis not only of the **performance and efficiency** of each airport but also for the **definition of objectives** on the basis of the performance and efficiency of its pairs.

There are some works concerning benchmarking of airports each one **using different indicators** of performance; some use **simple indicators** as, for example, the number of slots, while others consider **complex indicators** as, for example, the number of passengers for the area of passengers terminal.

The use of **simple** indicators in the process of benchmarking produces **rankings of performance**, in turn the use of **complex indicators** produces rankings of **efficiency.**

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

The **simple** indicators can be divided in two groups:

Inputs: Runways, Stands, Passenger Terminal Area, Cargo Terminal Area;
Outputs: Aircraft Movements, Passengers, Cargo.

The **complex** indicators are based on both input and output simple indicators:

Passengers / Passenger Terminal Area;
Cargo / Cargo Terminal Area;
Aircraft Movements / Stands;
Aircraft Movements / Runways.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth

The **methodologies** in use to evaluate the performance and efficiency of airports are divided in two groups: single-dimensional and multi-dimensional.

Among **single-dimensional** ones the prominence goes for the Method of the Partial Measure.

The **multi-dimensional** ones are divided in 3 sub-groups:

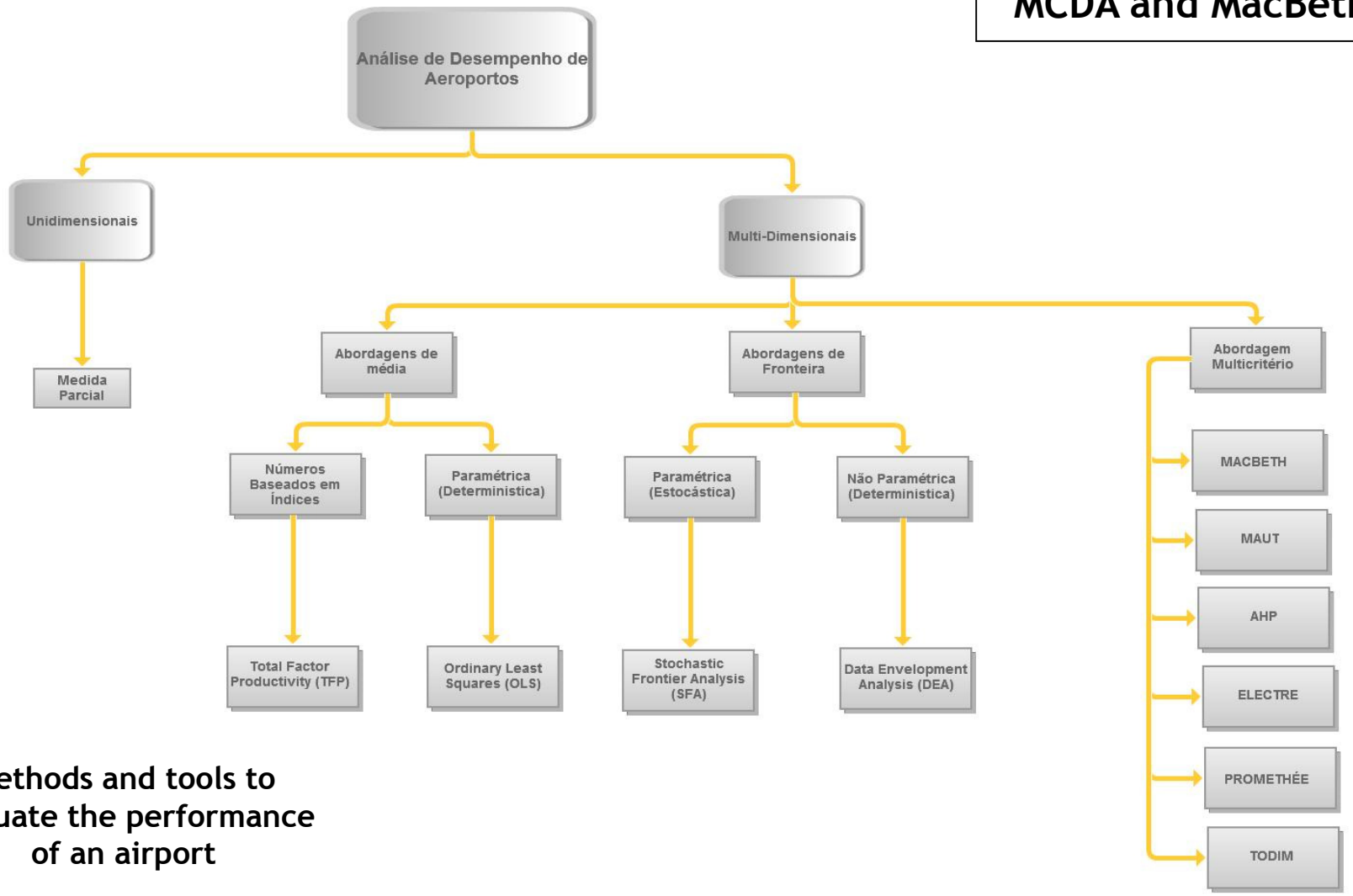
those of Average Approach (Total Factor Productivity - TFP, and Ordinary Least Square - OLS);

those of Frontier Approach (Stochastic Frontier Analysis - SFA, and Data Envelopment Analysis - DEA);

Multi Criteria Decision Analysis (MCDA).

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth



Methods and tools to evaluate the performance of an airport

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth

MCDA is one of the most used methodologies; others, purely mathematical, as the SFA and the DEA, have more complex formulations.

Advantages of the MCDA:

It constructs a base for the dialogue between **analysts and deciders** that makes use of wide range and common points of view;

It **facilitates** the incorporation of **uncertainties** on the data in each point of view;

(…)

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth

Advantages of the MCDA:

It interprets each alternative as a commitment among the objectives in conflict; that is, it **prevents** any situation where may exist a **superior alternative** to the remaining ones on all the points of view;

It produces a **good ordinance** of the alternatives, essential when it is intended **to construct rankings**.

Disadvantages of the MCDA:

In the choice of the performance indicators, but **mainly** in the **attribution** of the respective relative **weights**, which of course **involve some degree of subjectivity**.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth

Tools associated with MCDA:

MAUT (Theory of the *Multivariable* Utility);

AHP (Analytic Hierarchy Process*)*;

MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique);

ELECTRE (Elimination and Choice Expressing Reality);

TODIM (Taking Of Interactive Decision Multi Criteria);

PROMETHÉE (Ranking Organization Method for Enrichment of Evaluations).

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

MCDA and MacBeth

MacBeth **allows** to evaluate options having in **account multiple criteria**.

The basic distinction between MacBeth and other methods of Multi Criteria Decision Analysis is that this **requires only qualitative judgments** on the differences of attractiveness between elements to generate **punctuations** for the options in **each criterion and to ponder the criteria**.

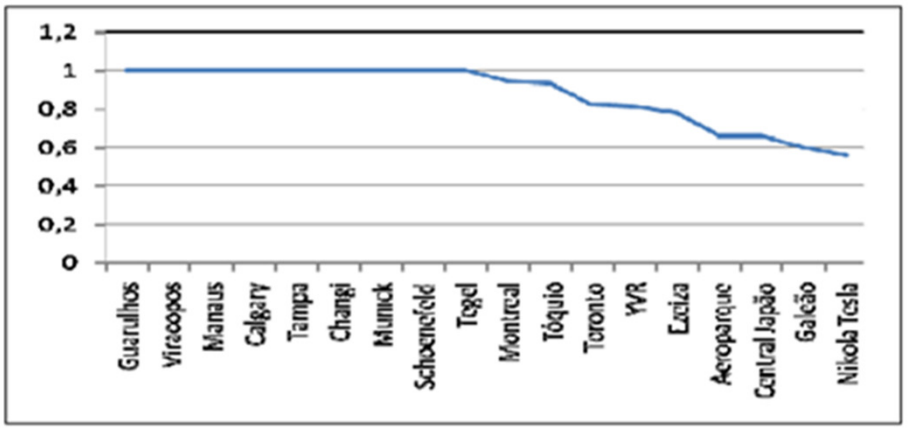
MacBeth **compares** the alternatives **among themselves** but also with **references**, that can be better or worse than the alternatives, being therefore an **ideal tool to produce rankings**.

The main **disadvantage** is the subjectivity that can be **induced** in the determination of the weights of the criteria, but… **can be mitigated**.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: 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.



Efficiency ranking for a set of worldwide airports

The authors use **7 single performance** criteria to produce their ranking: **4 Inputs** (Number of Runways, Number of Aircraft Parking Positions, Area of Passenger Terminal, and Area of Cargo Terminal) and **3 Outputs** (Number of Aircraft Operations, Number of Processed Passengers and Cargo Volumes).

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: efficiency of a set of worldwide airports

Thus we use the **same data** from the same set of airports to obtain an efficiency **ranking based on MacBeth**.

If we introduce those **single** performance criteria within MacBeth we would produce not an efficiency ranking but **a performance one**; so it is necessary to create **new criteria**, which we call **complex ones**, combining the above mentioned inputs and outputs as follows:

A = Number of Processed Passengers / Area of Passenger Terminal;

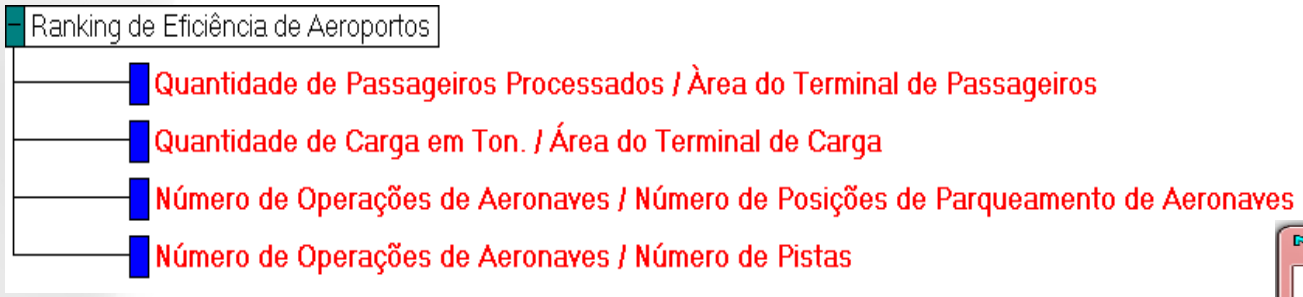
B = Cargo Volumes / Area of Cargo Terminal;

C = Number of Aircraft Operations (Movements) / Number of Aircraft Parking Positions;

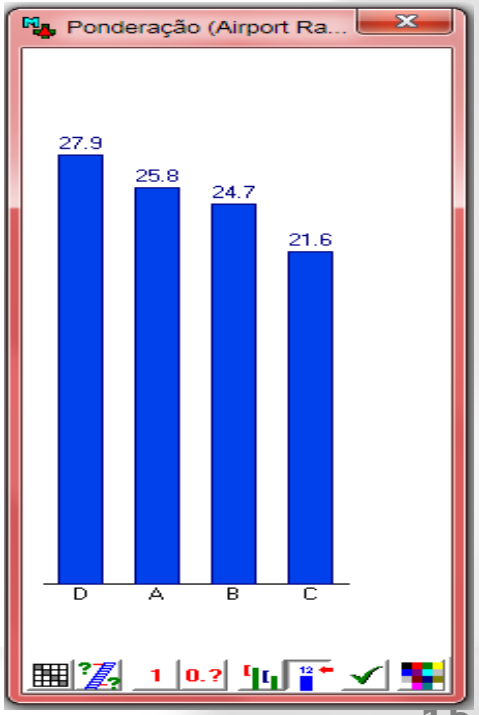
D = Number of Aircraft Operations (Movements) / Number of Runways.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: efficiency of a set of worldwide airports



Decision Tree



Attractiveness (weight) of the indicators based on the opinion of 30 aeronautical specialists

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Case Study 1: efficiency of a set of worldwide airports

Table of performances

Options	A	B	C	D
Guarulhos	87.7	6.5	2347.7	77474
Galeão	31.6	1.9	1903.7	50447.5
Viracopos	94.8	2.7	2282.5	25107
Manaus	36.5	15.8	2252.3	33785
Calgary	74.6	2.1	4768.5	71527.7
YVR	66.4	2.3	2985.1	64479.2
Toronto	114.1	3.4	2861.2	80684.8
Montreal	129.3	1.8	3209.9	68477.3
Aeroparque	177.3	1.3	1201.1	81675
Ezeiza	105.1	0.9	1600.3	33606
Tampa	107.6	5.4	3437.4	85935.7
Tókio	44.7	2.7	1339.1	94410
Central Japão	54.5	1.1	1619.7	106897
Changi	53.9	3.7	2086.4	177348
Munich	67.2	3.4	2760.6	205667.5
Schoenefeld	338.1	2.2	1880.6	33851
Tegel	459.6	2.4	3195.7	140611
Nikola Tesla	55.6	1.4	1925.5	42360

Airports Data And Macbeth Robustness Analysis

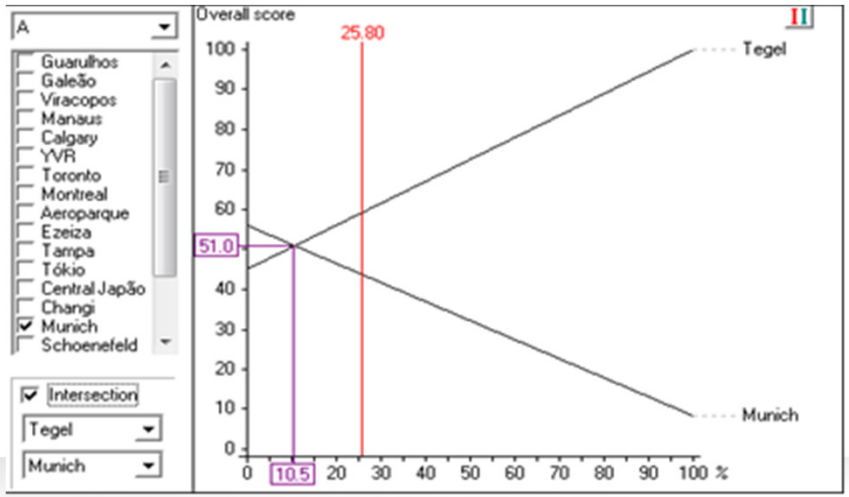
Table of scores

Options	Overall	A	B	C	D
[tudo sup.]	100.00	100.00	100.00	100.00	100.00
Tegel	63.10	100.00	15.19	67.02	68.37
Munich	49.49	14.62	21.52	57.89	100.00
Changi	42.32	11.73	23.42	43.75	86.23
Tampa	41.71	23.41	34.18	72.09	41.78
Manaus	41.53	7.94	100.00	47.23	16.43
Calgary	38.77	16.23	13.29	100.00	34.78
Guarulhos	36.23	19.08	41.14	49.23	37.67
Toronto	35.63	24.83	21.52	60.00	39.23
Schoenefeld	35.53	73.56	13.92	39.44	16.46
Montreal	33.90	28.13	11.39	67.31	33.30
YVR	29.59	14.45	14.56	62.60	31.35
Aeroparque	28.51	38.58	8.23	25.19	39.71
Central Japão	26.62	11.86	6.96	33.97	51.98
Tókio	25.60	9.73	17.09	28.08	45.90
Viracopos	23.29	20.63	17.09	47.87	12.21
Galeão	20.21	6.88	12.03	39.92	24.53
Nikola Tesla	19.78	12.10	8.86	40.38	20.60
Ezeiza	19.11	22.87	5.70	33.56	16.34
[tudo inf.]	0.00	0.00	0.00	0.00	0.00
Weights :		0.2580	0.2470	0.2160	0.2790

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: efficiency of a set of worldwide airports

MacBeth approach also provides a sensitivity analysis tool on possible impacts of each criteria weight changes. The example is for criteria A (25.80%) and involves Munich and Tegel airports. At this stage Tegel has an overall score around 57.50% and Munich around 42.50%. If this criteria weight/importance decreases from 25.80% to less than 10.50% (keeping the proportionality among all other criteria) then Munich will have an overall score higher than Tegel. But it will be necessary a drastic change (around 15.30%) in the specialists opinion.



Macbeth sensitivity analysis on A criteria weight for Tegel and Munich airports.

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Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: efficiency of a set of worldwide airports

Ferreira et al. (2010) put on the top of efficiency 9 Airports. Efficiency starts dropping with Montreal airport (10th position within the ranking) till Nicola Tesla airport (18th position within the ranking).

The results obtained with MacBeth approach are quite different. It is possible a better understanding of each criteria values and how benchmark among airports gets more understandable too:

Individually, Tegel achieves the best position within criteria A, Manaus within criteria B, Calgary within criteria C and Munich within criteria D;

Combining all criteria, Tegel airport is the most efficient and Ezeiza airport is the less efficient; Munich is 2nd, Manus is 6th and Calgary is 7th;

In comparison with the ranking of Ferreira et al. (2010) Guarulhos is now 8th, Viracopos is 15th, Tampa is 4th, Changi is 3rd, and Schoenefeld is 9th.

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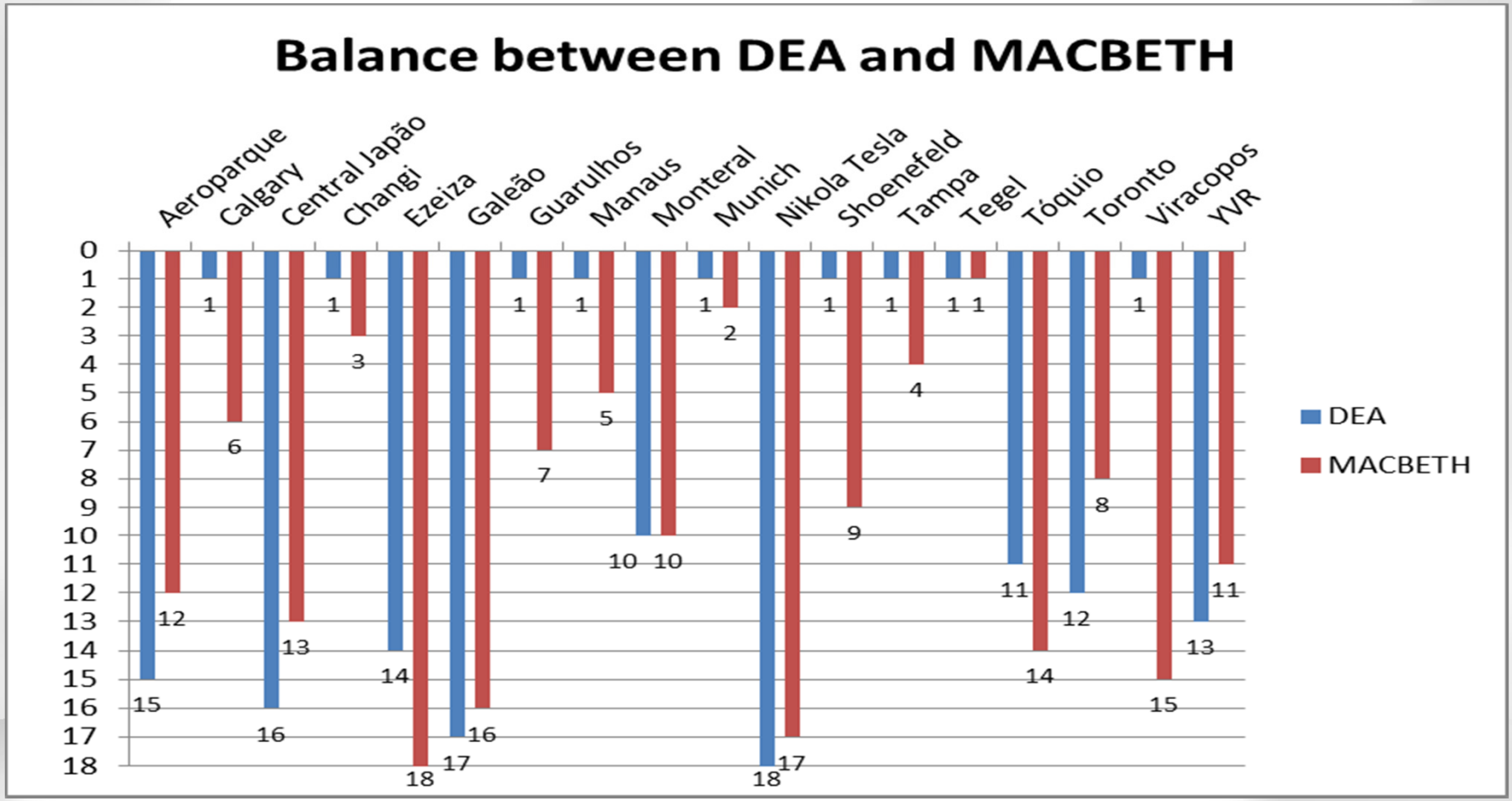
Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 1: efficiency of a set of worldwide airports



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Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

Number of Runways	2006	2007	2008	2009	2010
Porto (OPO)	1	1	1	1	1
Madeira (FNC)	1	1	1	1	1

Passenger T. Area (m^2)	2006	2007	2008	2009	2010
Porto (OPO)	69.112	69.112	69.112	69.112	69.112
Madeira (FNC)	44.590	44.590	44.590	44.590	44.590

Cargo T. Area (m^2)	2006	2007	2008	2009	2010
Porto (OPO)	19.141	19.141	19.141	19.141	19.141
Madeira (FNC)	7.535	7.535	7.535	7.535	7.535

Aircraft Parking Stands	2006	2007	2008	2009	2010
Porto (OPO)	48	48	48	48	48
Madeira (FNC)	17	17	17	17	17

Processed Passengers	2006	2007	2008	2009	2010
Porto (OPO)	3.402.805	3.986.748	4.534.829	4.508.330	5.279.531
Madeira (FNC)	2360857	2.419.697	2.448.574	2.348.040	2.239.353

Aircraft Movements	2006	2007	2008	2009	2010
Porto (OPO)	47.061	50.745	56.095	52.194	55.432
Madeira (FNC)	25.828	25.616	25.961	25.162	25.898

Cargo (ton)	2006	2007	2008	2009	2010
Porto (OPO)	34.444	32.585	32.215	27.375	28.782
Madeira (FNC)	9.368	9.012	9.303	8.732	8.654

Data for the airports of Porto (OPO) and Funchal (FNC), 2006 - 2010

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Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

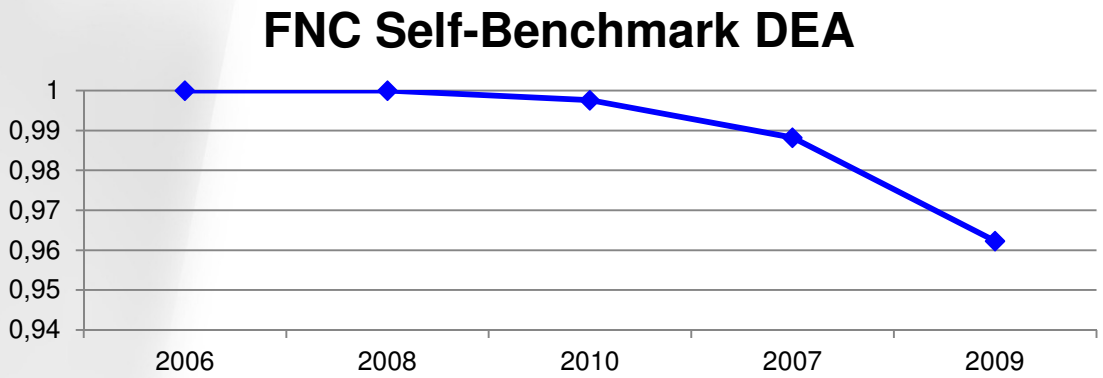
DEA software in use is **SIAD (Integrated Decision Support System)**, with CCR Model and Input oriented analysis (minimizing inputs while keeping output values fixed).

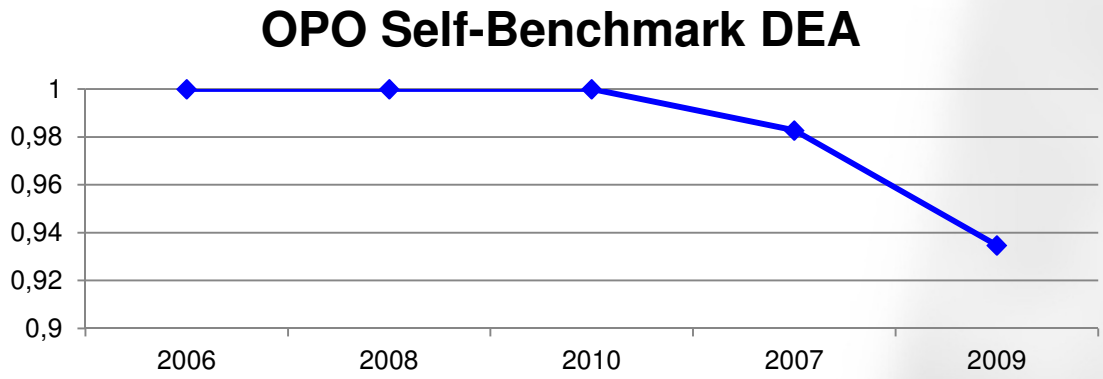
The indicators structure is as follows:

DEA	***Inputs***	Number of runways Aircraft Parking Stands Passenger Terminal Area Cargo Terminal Area
	Outputs	Aircraft Movements Processed Passengers Processed Cargo (Ton.)

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports





Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

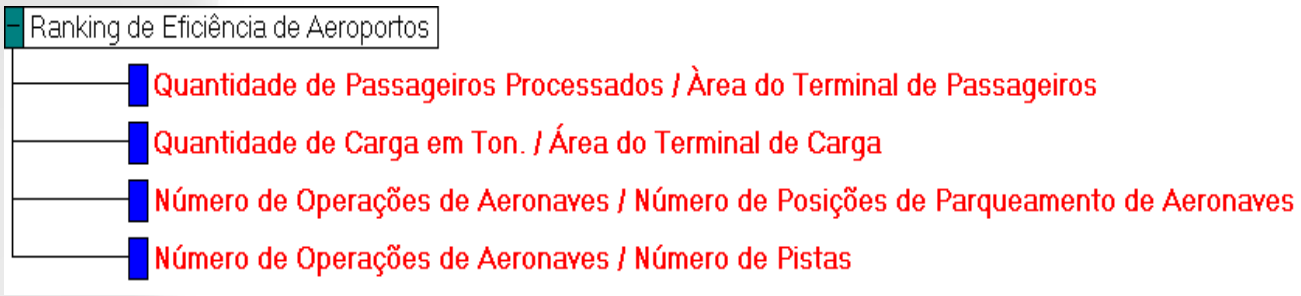
For **Macbeth analysis** we use the information of the **same set of aeronautical specialist** of the previous case study to fixe the weights (importance, attractiveness) of each indicator.

The related weights (importance) values are as follows:

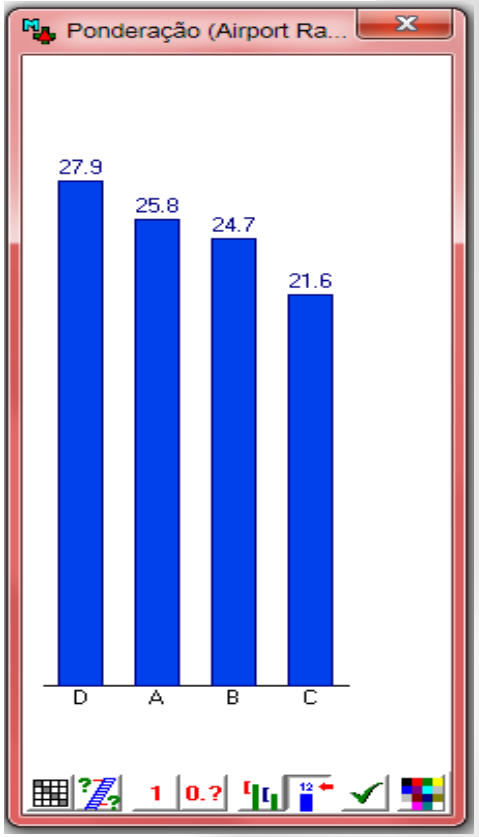
Macbeth	*A*	Processed Passengers / Passenger terminal Area	25,8%
	B	Processed Cargo (ton.) / Cargo Terminal Area	24,7%
	C	Aircraft Movements / Aircraft parking stands	21,6%
	D	Aircraft Movements / Number of Runways	27,9%

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports



Decision tree



Attractiveness (weight) of each indicator based on the opinion of 30 aeronautical specialists

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

Tabela de performances

Opções	A	B	C	D
OPO2006	49.24	1.8	980.44	47061
OPO2007	57.69	1.7	1057.19	50745
OPO2008	65.62	1.68	1168.65	56095
OPO2009	65.23	1.43	1087.38	52194
OPO2010	76.39	1.5	1154.83	55432

Data of the airport of Porto (OPO), (complex indicators)

Tabela de performances

Opções	A	B	C	D
FNC2006	52.95	1.24	1519.29	25828
FNC2007	54.27	1.2	1506.82	25616
FNC2008	54.91	1.23	1527.12	25961
FNC2009	52.66	1.26	1480.12	25162
FNC2010	50.22	1.15	1523.41	25898

Data on the airport of Funchal (FNC), (complex indicators)

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

Tabela de pontuações

Opções	Global	A	B	C	D
[tudo sup.]	100.00	100.00	100.00	100.00	100.00
FNC2008	99.40	100.00	97.58	100.00	100.00
FNC2006	98.43	96.43	98.39	99.49	99.49
FNC2007	97.85	98.83	95.16	98.67	98.67
FNC2009	97.42	95.90	100.00	96.92	96.92
FNC2010	95.49	91.46	91.13	99.76	99.76
[tudo inf.]	0.00	0.00	0.00	0.00	0.00
Pesos :		0.2580	0.2470	0.2160	0.2790

Ranking of efficiency of the airport of Funchal, (2006-2010)

2008 is the more efficient year of Madeira airport, when it reached the best results for the criteria A, C and D.

2010 is the less efficient year, with the lowest results of all the period for the criteria A and B.

Although the efficiency of this airport always presents values above 95.49% between 2006 and 2010, in the really they oscillated from year to year.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports

Tabela de pontuações

Opções	Global	A	B	C	D
[tudo sup.]	100.00	100.00	100.00	100.00	100.00
OPO2010	95.30	100.00	83.33	98.82	98.82
OPO2008	94.72	85.90	93.33	100.00	100.00
OPO2009	87.71	85.39	79.44	93.05	93.05
OPO2007	87.59	75.52	94.44	90.46	90.46
OPO2006	82.86	64.46	100.00	83.90	83.90
[tudo inf.]	0.00	0.00	0.00	0.00	0.00
Pesos :		0.2580	0.2470	0.2160	0.2790

Ranking of efficiency of the airport of Porto, (2006-2010)

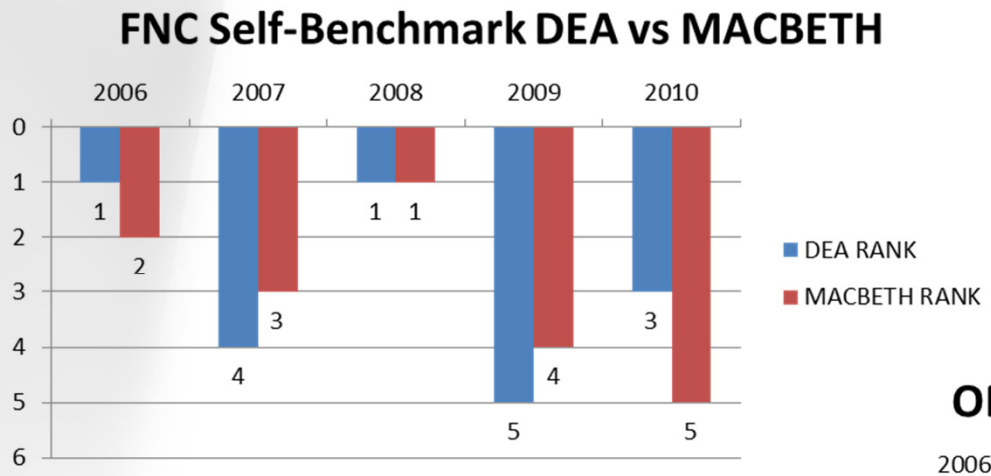
For the **airport of Porto (OPO) the year of 2010 was the most efficient**, for opposition to the year **of 2006 that was the less efficient.**

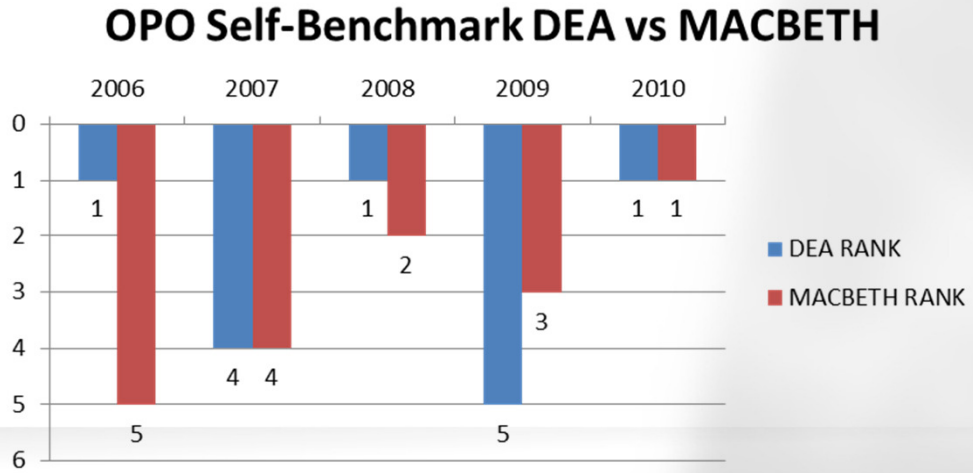
In the perspective of each criterion: 2006 presents the best score for B, 2008 for C and D, and 2010 for A.

It is remarkable the increment in the efficiency of this airport between 2006 (82.86%) and 2010 (95.30%), that is, 12.44% during these 5 years.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Case Study 2: Self Benchmarking of two Portuguese airports





Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Conclusion

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.

The reason is that **DEA** determines the indicator weights by mathematical approach thus **leading to several airports** with **maximum efficiency** simply because exists at least one indicator on those airports which is much better that the others; therefore sometimes this approach does not allow a clear understanding of the efficiency ranking.

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Conclusion

It seems that MacBeth **allows** any stakeholder:

1. to **analyze** more **easily** the **position** of any airport within the raking; and
2. to **understand** easily **changes needed** within the airport to **modify** its individual and/or its overall classification.

The **disadvantage** of MacBeth to benchmark airports is based on the **subjectivity** of the indicators weights, which is possible **to mitigate** in two ways:

1. **using the opinions of specialists in the appropriate fields of knowledge**; and
2. getting as **much answers** as possible so that **related average** (and variance) values are as **close as possible** with the **reality.**

Performance and Efficiency Evaluation of Airports. The Balance Between DEA and MCDA Tools.

Conclusion

Future research:

- ✓ focused on **introducing** on both, DEA and MacBeth models, **new indicators** based on different, but complementary, **operational/technical constraints to improve models robustness;**

- ✓ (…)

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