ICEUBI 2015* Open Access

Miguel Miranda*, Maria E. Baltazar, and Jorge Silva

Airlines Performance and Efficiency Evaluation using a MCDA Methodology. The Case for Low Cost Carriers vs Legacy Carriers

DOI 10.1515/eng-2016-0059
Received Mar 30, 2016; accepted Jun 16, 2016

Abstract: The air transport has suffered a remarkable transformation over the past decade. The way we travel today is quite different from how we did ten years ago. Due to the rise of low cost carriers, the market of air transportation has been constantly changing and presently witnessing the transformation of legacy carriers in order to manage to continue operating.

The main purpose of this work is to show the differences in efficiency for different performance areas on a case study comprised of six different airline carriers, legacy and low cost, using a Multi Criteria Decision Making (MCDA) tool - Measuring Attractiveness by a Category Based Evaluation Technique (MACBETH).

With the results obtained in this study, it is expected to show the work that is being carried out to obtain a model that would measure the efficiency of one or various airline companies in a defined period of time, using a set of performance indicators, to which specialists in the area previously have given weights.

Keywords: Air Transport; MCDA; MACBETH; Multi Criteria Analysis; Airlines; Efficiency; Competitiveness; Performance Evaluation

1 Introduction

The Global Air Traffic has shown a continuous growth in the last decade. It is expected that by 2030 the number of transported passengers will reach 6.4 billion passengers.

Also the competition between airlines, has been increasing. The Low Cost Carriers (LCCs) have had a major role in this. In Europe, LCCs also put additional pressure on network carriers' operating costs by offering flights at reduced fare [1].

The large-scale market entry of LCCs has increased competition and affected the fares charged by Legacy Carriers (LCs). The relative efficiency of the world's airlines has changed [2].

Increasing the aircraft utilization, the crew productivity, operating from secondary airports, using a young and homogeneous fleet and reducing airport charges allow LCCs to practice cheaper flights. Figure 1 shows the different costs between the low cost and the legacy carriers [3].

Therefore, the aim of this paper is to show the work that is being done to study the performance and efficiency between LCCs and LCs using a robust but flexible methodology, based on strategic key performance areas and related key performance indicators.

In section 2, the adopted methodology is described.

2 Methodology

Contemporary research in airline operational performance frontier models encompasses several scientific methods to analyse quantitatively the relate performance and efficiency [4].

The research began by searching for the current scenario of the air transport market, what is expected in the future, and what will be the most vulnerable aspects. The results led into the choice of a set of Key Performance Indicators (KPIs) for each Key Performance Area (KPA) previously selected. The sets of indicators were chosen accord-

***Corresponding Author: Miguel Miranda:** University of Beira Interior, Aerospace Science Department (DCA-UBI), Rua Marquês d'Ávila e Bolama, 6201 - 001, Covilhã, Portugal; CERIS, CESUR, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais 1, 1049-001, Lisboa, Portugal; Email beirao.miguel@gmail.com; Tel.: +351965046984

Maria E. Baltazar, Jorge Silva: University of Beira Interior, Aerospace Science Department (DCA-UBI), Rua Marquês d'Ávila e Bolama, 6201 - 001, Covilhã, Portugal; CERIS, CESUR, Instituto Superior Técnico, University of Lisbon, Av. Rovisco Pais 1, 1049- 001, Lisboa, Portugal

* International Conference on Engineering 2015 – 2–4 Dec 2015 – University of Beira Interior – Covilhã, Portugal

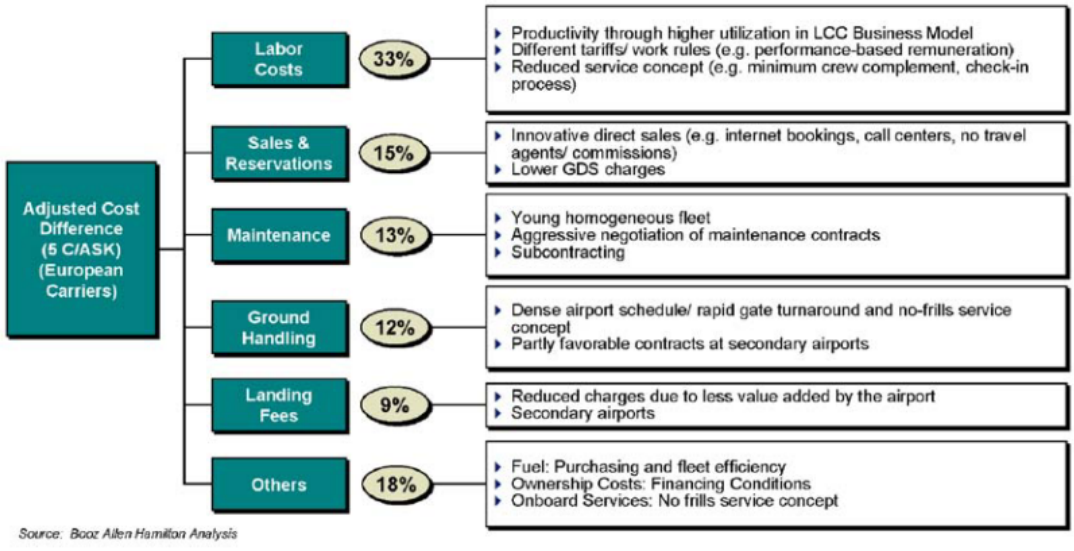

Figure 1: Main drivers of cost differences between LCCs and LCs [3].

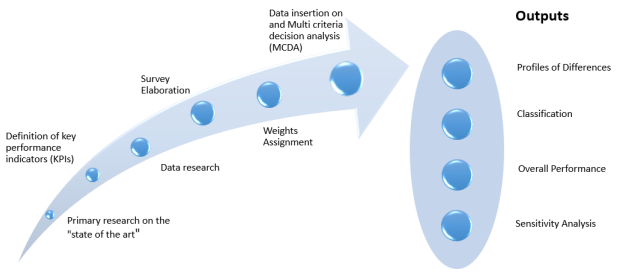

Figure 2: Methodology.

ing to the most referred indicators in the airlines annual reports, and also accordingly with references [5, 6] and [7].

Subsequently the assignment of weights for each indicator were obtained throughout a negotiation (survey and meetings) with experts, all professionals involved in Aircraft Operations, Flight Safety and Air Transport Economics and Management.

Finally, a Multi Criteria Decision Analysis (MCDA) platform called MACBETH (Measuring Attractiveness by a Categorical Based Evaluation technique) was used to obtain the desired outputs (Differences Profile, Thermometer – for each KPI, Classification, Overall Ranking, and Sensibility Analysis), (Figure 2).

The core of this study lies on a MCDA. MACBETH is a MCDA approach that only requires qualitative judgements about differences of value to help an individual or a group of individuals to quantify the relative attractiveness of options [8].

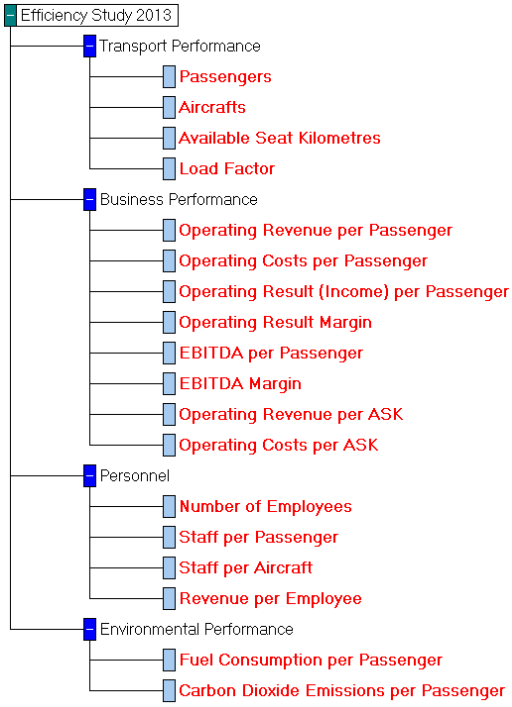

Figure 3: Decision Tree.

3 Key Performance Areas and Key Performance Indicators

Four main areas were chosen: Transport Performance, Business Performance, Personnel Performance and Environmental Performance (Figure 3).

Transport Performance

Passengers are the annual number of passengers. Aircrafts are the number of aircrafts of the fleet. The available seat kilometre, ASK, is a measure of an airline flight's passenger carrying capacity. It corresponds to the number of seats available multiplied by the number of miles or kilometres flown. The Load Factor, LF, is a measure of how much of an airline passenger carrying capacity is used. It means passenger-kilometres flown as a percentage of seat-kilometres available.

Business Performance

This KPA groups eight key performance indicators, namely: Operating Revenue per Passenger; Operating Costs per Passenger; Operating Result (income) per Passenger - where Operating Result is the difference between the Revenues and Operating Costs; Operating Margin - which is the percentage of Operating Result concerning Revenues; EBITDA per Passenger - where EBITDA means earnings before interest, taxes, depreciation, and amortization; EBITDA Margin - which corresponds to the ratio of EBITDA by Revenues; Revenue per Available Seat-Kilometre (RASK); and Operating Cost per Available Seat-Kilometre (CASK).

Personnel

This area, which is related to the sustainability indicators, consists of four Key Performance Indicators: Number of employees, Staff per Passengers - where the Staff refers to the Number of employees, Staff per Aircraft and Revenue per Employee.

	a	b	c	d	e
a	no	very weak	moderate	positive	positive
b		no	weak-mod	moderate	positive
c			no	weak	positive
d				no	no
e				no	no

Figure 4: Example of MACBETH Judgements.

Environmental Performance

Finally, this area is composed of two Key Performance Indicators, namely: Fuel Consumption - in litres per Passenger, and Carbon Dioxide Emissions - in kilograms per Passenger.

4 Multi Criteria Decision Analysis (MCDA)

MCDA, or Multi Criteria Decision Making (MCDM), is a decision-making tool aimed to support decision makers who are faced with numerous and conflicting evaluations [9]. An advantage of MCDA approach is that, it helps decision makers to organise and synthesize such information in a way which leads them to feel comfortable and confident to make a decision, minimizing post-decision regrets by assuring that all criteria or factors have properly been taken into account. Thus, we use the expression MCDA as an umbrella term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups of individuals explore decisions that are really important [10].

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

MACBETH is a decision-aid approach to multi criteria values measurement. The goal behind its conceptualization is to allow measurement of the attractiveness or value of options through a non-numerical pairwise comparison questioning mode, which is based on seven qualitative categories of difference in attractiveness: is there no difference (indifference), or is the difference very weak, weak, moderate, strong, very strong, or extreme (Figure 4). The key distinction from numerical value-measurement procedures, such as the simple multi-attribute rating technique, or SMART approach, is that MACBETH uses only such qualitative judgements of difference in attractiveness in order to generate, by mathematical programming, value scores for options and weights for criteria [11]. According to previous studies, preliminary results evidenced how MACBETH approach seems to be very promising when compared with those (DEA based) traditionally in use [12]. Mainly because not only MACBETH seems to be more user-friendly than DEA but also it can be applied easily in managerial practice involving the stakeholders in the process.

The mathematical foundations of MACBETH are explained in several publications as in [8] and [11].

Figure 4 is an example of a generic MACBETH Judgements Matrix, where a, b, c, d and e could represent any set of indicators, and below are the differences of attractiveness between them. Thus, the difference of attractiveness between a and b is very weak, between a and c is moderate, and between c and d is weak. Between equal descriptors there are no difference in attractiveness, and for the cases where there is no difference of attractiveness assigned, MACBETH assigns a positive difference that guarantees the consistence of judgements, as it can be seen between a and e.

4.2 MACBETH and Airlines Performance and Efficiency Evaluation

A set of six European airlines was chosen among LCs and LCCs, respectively: Aer Lingus, Aeroflot and Turkish Airlines; and Ryanair, EasyJet and Air Berlin (EasyJet and Ryanair are the largest LCCs in Europe followed not far behind by Air Berlin [13]).

In this study two of the four key performance areas mentioned above were used, as well as the related key performance indicators: Transport Performance and Business Performance. All data refers to the year 2013.

The study uses the efficiency of each area separately.

Transport Performance Area

Figure 5 is the decision tree of transport performance area, an extract of the global decision tree as in Figure 3.

Figure 6 shows data available for each KPI of the KPA of Transport Performance.

As stated in section 2, assignment of weights for each indicator were given upon negotiation with experts, all professionals involved in Aircraft Operations, Flight Safety and Air Transport Economics and Management.

Figure 7 is the Ponderation Table, and depicts the weights that were assigned to each indicator as well as the relevance of the relationships among them. The most relevant is PAX indicator and least one is AIRCRAFTS. The column of Current Scale shows the weights assigned for each KPI.

Based on the information of Figures 6 and 7, M-MACBETH software attributed the scores of efficiency relating to the transport performance of each carrier as in Figure 8. It can be seen that the best results are obtained by low cost carriers: RYR (79.03 points) and EZY (78.16 points). This is mainly due to the higher flow of passengers (PAX), greater load factor (LF) and in some cases higher offer (ASK). This is a table of scores, which have by reference the Good value (sup.) with 100 points assigned and Neu-

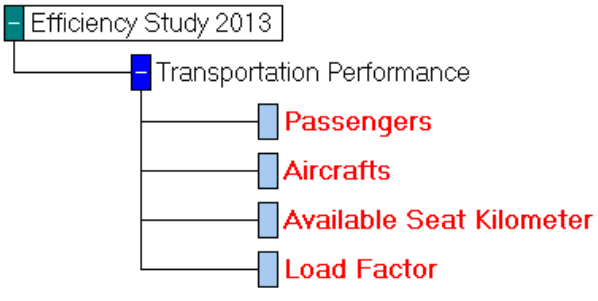

Figure 5: Decision Tree of Transport Performance Area.

Table of performances

Options	PAX	AIRCRAFTS	ASK	LF
RYR	79300000	305	117183.4	82
EZY	60800000	217	74223	89.3
BER	31535867	140	57250	84.85
AFL	31400000	239	109100	78.02
EIN	9625000	47	18898	78.4
THY	48268000	233	116433	79

Figure 6: Transport Performance Data.

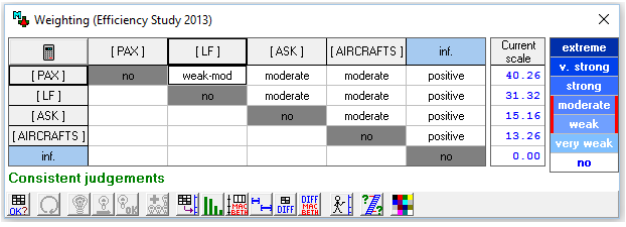

Figure 7: Ponderation (Weighting) Table.

Table of scores

Options	Overall	PAX	AIRCRAFTS	ASK	LF
sup.	100.00	100.00	100.00	100.00	100.00
RYR	79.03	100.00	100.00	100.00	33.05
EZY	78.16	73.45	65.89	56.29	100.00
THY	48.66	55.46	72.10	99.24	5.51
BER	41.88	31.44	36.04	39.02	59.16
AFL	35.27	31.25	74.42	91.78	-3.49
EIN	0.00	0.00	0.00	0.00	0.00
inf.	0.00	0.00	0.00	0.00	0.00
Weights :		0.4026	0.1326	0.1516	0.3132

Figure 8: Table of Scores: Transportation.

Figure 9: Global Thermometer: Transportation.

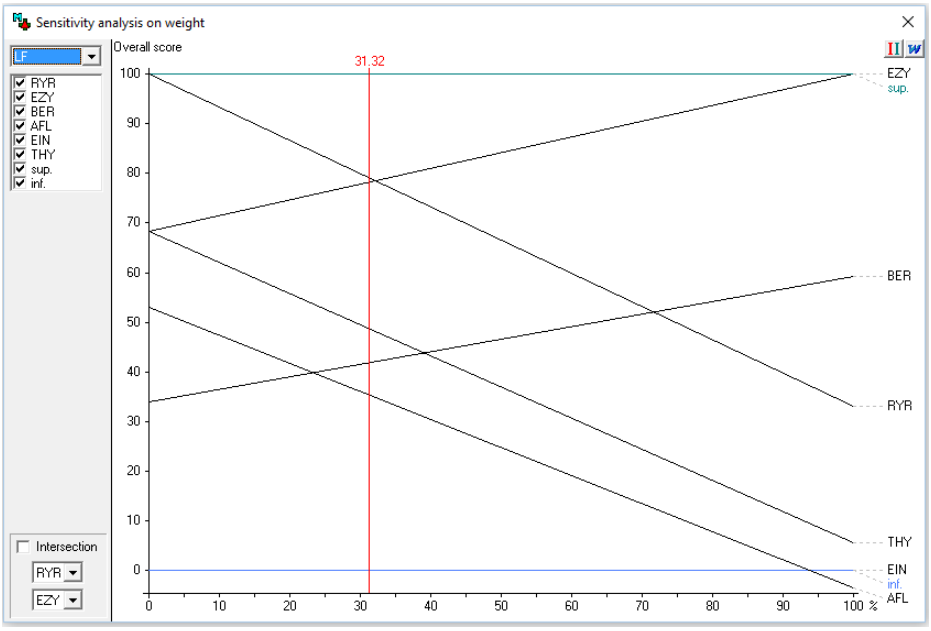

Figure 10: Sensitivity Analysis on Weight: Load-Factor.

tral value (inf.) with 0 (zero) points assigned. Once the two performance references are introduced into the MACBETH model, the Criteria value scales automatically.

A negative score of "–3.49" attributed to the LF of Aeroflot means a worse value than the neutral one. In that dimension is a necessary and sufficient condition for a proposal to be considered negative (worse than neutral) in the set of all dimensions, this means that a determinant dimension has a non-compensatory nature [11].

Further down on the scoreboard is the first LC, the Turkish Airlines, with a score of 48.66 points, followed by the third LCC, the Russian Aeroflot, with 41.88 points. In the last place is the Irish Aer Lingus, with 35.27 points. Irish Aer Lingus position is an obvious result for this KPA as this carrier is the smaller one, with less than half of the number of aircrafts, and therefore less ASK.

Also the M-MACBETH platform allows to obtain a graph with the results of global efficiency similar to that of a thermometer (Figure 9) which shows the ranking position of the 6 carriers.

Figure 10 is the sensitivity analysis on weight of the LF. The left vertical axis represents the overall score, and the right vertical axis represents the LF scores for each carrier. The red line represents the weight (31.32%) assigned to this indicator as explained in Figure 6 above. Air Berlin (BER), for example, has a better score than Aeroflot (AFL). However, if the weight of this indicator was below 20.00%, the score of Aeroflot would be better than that of Air Berlin.

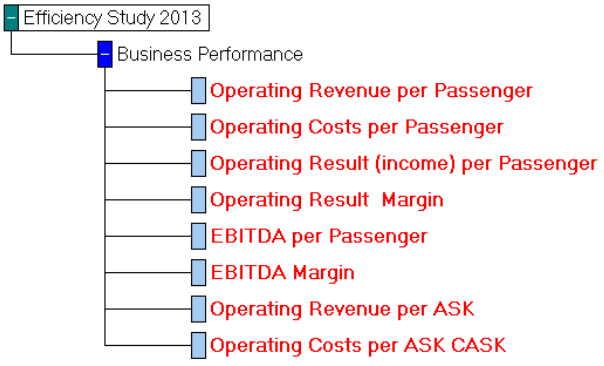

Figure 11: Decision Tree of Business Performance Area.

Otherwise, Air Berlin has a worse score than that of Turkish Airlines (THY), but if the weight of this indicator was above 50.00%, this situation would be inverted. Also it is important to underline that if the LF weight was slightly increased from 31.32% to 33.00% the relative position between RYR and EZY would change.

Business Performance Area

Figure 11 is the decision tree of business performance area, an extract of the global decision tree as in Figure 3.

Figure 12 shows data available for each KPI of the KPA of Business Performance.

Options	REV/PAX	COST/PAX	INC/PAX	INC MARG	EBITDA/PAX	EBITDA MARG	RASK	CASK
RYR	6.16	5.25	0.91	14.71	0.82	13.33	4.17	3.55
EZY	9.86	8.75	1.11	11.23	1.65	16.7	8.08	7.17
BER	13.15	14.07	-0.74	-5.59	1.37	10.43	7.75	7.75
AFL	25.94	24.17	1.76	6.8	2.84	10.95	7.46	6.96
EIN	14.81	14.17	0.63	4.29	1.97	13.28	7.54	7.22
THY	18.31	17.08	1.22	6.69	3.3	18.01	7.59	7.08

Figure 12: Business Performance Data.

Weighting (Efficiency Study 2013)

	[INC MARG]	[INC/PAX]	[EBITDA MARG]	[EBITDA/PAX]	[CASK]	[RASK]	[REV/PAX]	[COST/PAX]	inf.	Current scale
[INC MARG]	no	no	no	no	no	no	no	no	positive	12.5
[INC/PAX]	no	no	no	no	no	no	no	no	positive	12.5
[EBITDA MARG]	no	no	no	no	no	no	no	no	positive	12.5
[EBITDA/PAX]	no	no	no	no	no	no	no	no	positive	12.5
[CASK]	no	no	no	no	no	no	no	no	positive	12.5
[RASK]	no	no	no	no	no	no	no	no	positive	12.5
[REV/PAX]	no	no	no	no	no	no	no	no	positive	12.5
[COST/PAX]	no	no	no	no	no	no	no	no	positive	12.5
inf.									no	0.0

extreme
v. strong
strong
moderate
weak
very weak
no

Consistent judgements

Figure 13: Ponderation (Weighting) Table.

Table of scores

Options	Overall	REV/PAX	COST/PAX	INC/PAX	INC MARG	EBITDA/PAX	EBITDA MARG	RASK	CASK
sup.	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
THY	67.73	61.45	37.45	78.23	61.21	100.08	99.96	87.53	15.95
EZY	60.91	18.71	81.48	73.83	83.30	33.49	82.68	100.00	13.81
AFL	56.62	100.03	0.00	99.84	61.76	81.52	6.80	84.23	18.81
RYR	50.50	0.01	100.00	65.83	100.02	-0.04	38.21	0.00	100.00
EIN	47.89	43.74	52.83	54.64	49.08	46.41	37.55	86.26	12.62
BER	25.28	35.35	53.36	-0.20	0.01	22.18	-0.07	91.60	0.00
inf.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Weights :		0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250	0.1250

Figure 14: Table of Scores: Business.

It is evident how LCCs tend to have a smaller amount of Revenue per Passenger (REV/PAX) mainly because the lower fares they practice. Also it may be concluded that these carriers have lower Costs per Passenger (COST/PAX).

To get a clear picture of these evidences let's look at the Income per Passenger (INC/PAX) and the Income Margin (INC MARG): the LCCs have lower values of Income per Passenger than the Legacy ones; however, concerning the Income Margin - which represents the ratio of Income per Revenues, LCCs clearly have better results than the Legacy ones. The same must be concluded for the Revenue per Available Seat Kilometre (RASK), Cost per Available Seat Kilometre (CASK) and EBITDA per passenger (EBITDA/PAX), which are clearly lower for Low Cost Carriers than for Legacy ones.

As stated in section 2, upon negotiation with specialists it was decided to assign equal weights (12.50) to all KPI of this KPA. Figure 13 is the Ponderation Table, and depicts precisely those weights as well as the relevance of the relationships among them. The most relevant is REV/PAX indicator and less one is CASK. The column of Current Scale shows the weights assigned for each KPI.

Based on the information of Figures 12 and 13 M-MACBETH software attributed the scores of efficiency relating to the business performance of each carrier as in Figure 14. It can be seen that the best overall result is obtained by THY (67.73 points) followed by EZY (60.91 points). The last position belongs to BER (25.28 points). As stated above this is a table of scores, which has by reference the Good value (sup.) with 100 points assigned and Neutral

Figure 15: Global Thermometer: Business.

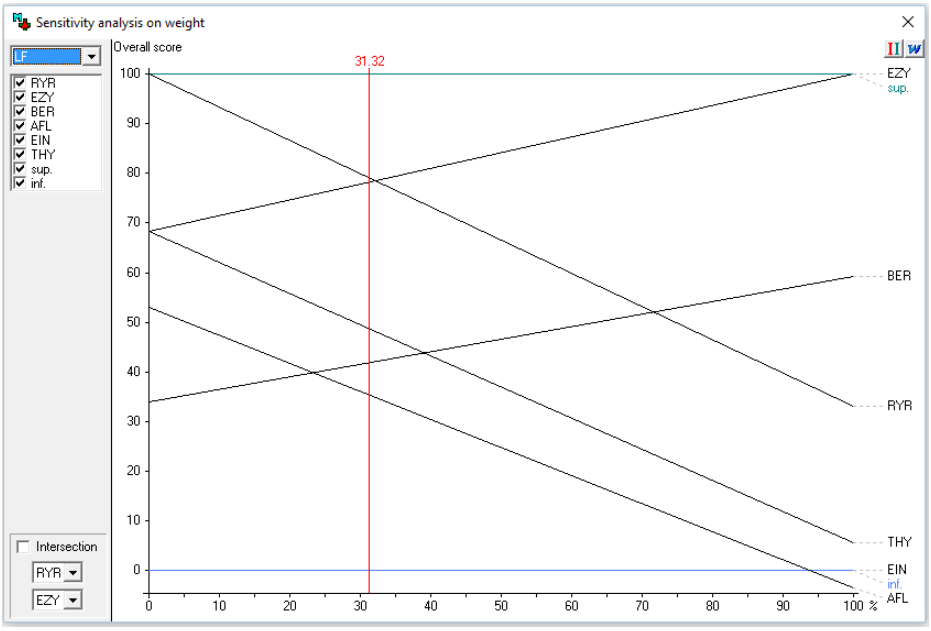

Figure 16: Sensitivity Analysis on Weight: Revenue per Passenger.

value (inf.) with 0 (zero) points assigned. Once the two performance references are introduced into the MACBETH model, the Criteria value scales automatically.

Negative scores of "–0.20" and "–0.07" (BER for INC/PAX and EBITDA Margin, respectively) as well as "–0.04" (RYR for EBITDA per Passenger) mean a worse value than the neutral one. The scores over 100.00 points – the cases like AFL – REV/PAX (100.03 points), RYR – INC MARG (100.02 points), and THY – EBIDTA/PAX (100.08 points) – mean better values than the Good one.

Figure 15 shows the ranking position of the 6 carriers based on this KPA of Business. There is a quite uniform distribution of scores among 5 carriers, with the exception of Air Berlin.

Figure 16 is the sensitivity analysis on weight of the Revenue per Passenger. The red line represents the weight (12.50%) assigned to this indicator as explained in Figure 12 above. Thus, Turkish Airlines (THY) has a better score than Aeroflot (AFL), (see left vertical axis). However, if the weight of this indicator is changed from 12.50% to a value above 40.00% the score of AFL would be better than that of THY. Otherwise, actually Ryanair has a worse score than Aeroflot, but if the weight of this indicator is changed to below 5.00% the situation would reverse.

5 Conclusions and Future Work

Performance of the LCCs and LCs changes depending on the area upon which they are compared: LCCs have higher efficiencies based on Transport Performance KPA while LCs have higher performance efficiencies based on Business Performance KPA. LCCs low prices implies lower revenue per passenger, which necessarily does not mean they have a lower income margin because the cost per passenger is lower too. Still, LCCs need higher flow of passengers as well as greater offer than the LCs to obtain better results.

The main idea of this study was to test this model for the carriers' efficiency, both legacy and low cost. When we simulate different scenarios with two KPAs the results vary dramatically, so that in the future it will be interesting to include all KPAs to understand how these areas may influence the overall performance of a carrier too. Also data collected must be extended to several years in order to evaluate the performance of a single carrier over a set of years (self-benchmarking) or the performance of several carriers with each other (benchmarking).

There is an ongoing survey sent to a wider range of Air Transport experts in order to obtain more robust weights thus to mitigate the subjectivity of the assignment of weights.

Acronyms

AFL	Aeroflot
ASK	Available Seat kilometres
BER	Air Berlin
CASK	Revenue per Available Seat kilometre
COST/PAX	Cost per Passenger
DEA	Data Envelopment Analysis
EBITDA MARG	EBITDA Margin
EBITDA	Earnings Before Interest, Taxes, Depreciation, and Amortization
EIN	Aer Lingus
EZY	EasyJet
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
INC MARG	Income Margin
INC/PAX	Income per Passenger
KPA	Key Performance Area
KPI	Key Performance Indicator
LCC	Low Cost Carrier
LC	Legacy (Flag) Carrier
LF	Load Factor
MACBETH	Measuring Attractiveness by a Category Based Evaluation Technique
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Making
PAX	Passengers
RASK	Revenue per Available Seat kilometre
REV/PAX	Revenue per Passenger
RYR	Ryanair
THY	Turkish Airlines

References

[1] Zuidberg J., Identifying airline cost economies: An econometric analysis of the factors affecting aircraft operating costs, Journal of Air Transport Management, 2014, 40, 86–95

[2] Barbot C., Costa A., Sochirca E., Airlines performance in the new market context: A comparative productivity and efficiency analysis, Journal of Air Transport Management, 2008, 14(5), 270–274

[3] Hansson T., Ringbeck J., Franke M., Flight for survival: a new business model for the airline industry, Strategy + Business, 2003, 31, 78–85

[4] Barros C.P., Peypoch N., An evaluation of European airlines' operational performance, International Journal of Production Economics, 2009, 122(2), 525–533

[5] Arhall J., Cox E., Key Performance Indicators for SAS Flights, Linköping University Electronic Press, 2013, https://www.diva–portal.org/smash/get/diva2:694404/FULLTEXT01.pdf

[6] Demydyuk G., Optimal Financial Key Performance Indicators: Evidence from the Airline Industry, Accounting & Taxation, 2011, 3(2), 39–51

[7] Bittencourt S., Gomes V., The economic and operational analysis of the air transport sector: basic indicators, BNDES Setorial, 2013, 40, 131–162

[8] Bana e Costa C.A., De Corte J.M., Vansnick J.C., On the Mathematical Foundations of MACBETH, The London School of Economics and Political Science, 2004

[9] Marttunen M., Description of Multi–Criteria Decision Analysis (MCDA), Finnish Environment Institute, 2010, http://environment.sal.aalto.fi/MCDA/

[10] Belton V.S., Theodor J., Multiple Criteria Decision Analysis: An Integrated Approach, Springer Science & Business Media, 2002

[11] Bana E Costa C.A., De Corte J.M., Vansnick J.C., Macbeth, International Journal of Information Technology & Decision Making, 2012, 11(2), 359–387

[12] Baltazar M.E., Jardim J., Alves P., Silva J, Air Transport Performance and Efficiency: MCDA vs. DEA Approaches, Proceeding of 16th Meeting the Euro Working Group on Transportation (2013, Porto, Portugal), Procedia – Social and Behavioral Sciences, 2014, 790–799

[13] Alamdari F., Mason K., EU network carriers, low cost carriers and consumer behaviour: A Delphi study of future trends, Proceedings of 10th Anniversary Conference of the Air Transport Research Society (2006, Nagoya, Japan), Journal of Air Transport Management, 2007, 299–310