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An analytic hierarchy process for ranking operating costs of low cost and full service airlines

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A B S T R A C T

This paper develops an application of the analytic hierarchy process to rank the operating cost components of full service and low cost airlines. It takes into account the financial balance sheets and answers to a questionnaire submitted to the managers of selected airlines. The results suggest that the analytic hierarchy process can be appropriately used to obtain the ranking of the costs taking into account different views: financial, management and operative. Rental, office equipment and other supplies costs show the highest importance in the cost ranking, both for full services and low cost airlines. The robustness of the results is tested by Monte Carlo analysis.

1. Introduction

Airline competition has increased considerably since deregulation in the US in the late 1970s. Subsequently, intra-EU traffic was liberalized in the late 1990s and any airline with a valid Air Operators Certificate can operate within the Union's borders. This has facilitated entry into the airline market and led to an increase in the number of low cost airlines (LCAs), mainly in Europe, but also in other parts of the world, such as Australia (Virgin Blue), Canada (West Jet) and Malaysia (Air Asia). Unlike a full service airline (FSA), an LCA focuses its strategy on cost minimization. Thus, an FSA bears much heavier overheads deriving from the hub and spoke modus operandi, which is based on the primary need to increase the load factor and to optimize aircraft capacity using feeder routes at the hubs.

Alliances have allowed sharing of overheads and capacity more effectively. Promotional fares have been introduced to increase capacity (Lijesen et al., 2002). FSA alliances and code sharing have been put in place to face LCA competitiveness. Furthermore, high fixed costs combined with decreasing demand yield cyclical profits. The reduction in capacity during off peak periods is considered a crucial factor for cost control. A decrease in capacity also reduces associated variable costs – labour, fuel and maintenance (Gillen and Lall, 2004).

Business passengers, who often seek frequent scheduling, inter-flight flexibility and ground service linkages, are the most important customers of the FSAs. They are willing to pay a premium for personal space and comfort on board, in-flight entertainment, free food and alcoholic drinks, frequent flier programmes, free airport lounges and use of major city airports, typically, with higher landing charges. By contrast, the LCA cuts costs by reducing overheads, providing no frills service and often using secondary or regional airports with lower landing charges. Inventory management is simplified by the absence of feeder routes, direct or online booking and ticketless operation. Moreover, LCAs have opened up a wider range of point to point routes, many of them not served by FSAs. LCAs have attracted their share of passengers, often young and leisure travellers, who are more sensitive to fare levels (Morrell, 2005).

Passengers travelling on LCAs place great importance on price and appear to arrange their itineraries using the cheapest fares. Travellers are willing to connect through secondary airports and to accept no frills in exchange for low fares. Instead, passengers travelling on FSAs place strong emphasis on reliability, quality, flight schedule, connections, frequent flier programmes and comfort (O'Connell and Williams, 2005). For these reasons, LCAs usually fly point to point between European cities, and they may have difficulty getting suitable slots at large hub airports. Thus secondary airports are more attractive for these carriers. The arrival of an LCA leads to a permanent increase in traffic, so even if there are no differences in attributes of passengers that prefer LCAs, there is an increase in revenue from concessions and parking due to the number of flights. As Barbot (2006) argues, LCAs have important advantages through using secondary airports: no problem with the availability of slots, absence of congestion and low aeronautical charges. All this allows on schedule departures and arrivals and quick services.

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In the US, Southwest was the first example of an LCA, whose business model was followed by many other including Ryanair in Europe that has taken Southwest's operational effectiveness a step further by providing virtually no services; no food, jet ways, frequent flier programme, refunds, non-electronic booking, tickets, or connections. Food, drinks and what used to be duty free items are sold on board. All tickets sold directly, either on the internet or call centres. Ryanair has also avoided head to head competition; there are few network overlaps involving it and other large LCA such as, easyJet and Virgin Express.

Comparison between Southwest and Virgin Express shows the variations that exist in LCA models. Both provide short haul point to point service and some have a unified fleet, but the similarities end there. The service levels provided by Virgin Express are lower than those provided by Southwest. The latter is very conservative about growth, whereas European carriers have grown more aggressively (Gillen and Lall, 2004; Gudmundsson, 1997).

The main LCA strategy aims to outsource everything except cabin crew, pilots, reservation agents, head office functions and some maintenance activities. Moreover, they have generated new revenue flows by advertising on seatback trays and headrests, and on the exterior of some of their aircrafts. Other sources of revenue include car rentals, travel insurance and travel reservation services.

In this context, we compare the operating costs of FSAs with those of LCAs for the evaluation of the strategic choice behaviour in the allocation of these costs. To compare the airline operating costs, various quantitative approaches have been developed (Oum and Yu, 1998; Swan and Adler, 2006). Furthermore, Tsoukalas et al. (2008) analyse airline costs to understand the different behaviour between FSAs and LCAs, showing a convergence in some categories of costs, such as labour costs. Differently to them, we have used the analytic hierarchy process (AHP), a decision-making method never applied to the problem faced here. Traditional cost accounting may fail to provide useful information for decision-making, because it is based on comparison of the value of the costs, and gives greater importance to costs that have higher value, thus adopting a single criterion. The AHP makes it possible to split the analysis into levels, defined goal, criteria, sub-criteria and alternatives. Moreover, it is based on pair-wise comparisons between different items belonging to the same level. In this way, as the comparison of the costs is made for different levels and with respect to different criteria and sub-criteria, the cost ranking will be less biased than the traditional cost accounting.

2. The operating costs components

Many aircraft costs are proportional to the hours flown, which are linear in distance. Operating costs for individual aircraft and flights are divided into direct and indirect (overheads) costs, whereas direct costs are divided into variable and fixed costs. The direct variable costs are those that can be directly traced to aircraft or flights that vary with the degree of utilization. Even direct fixed costs can be directly traced to aircraft or flights, but do not change according to the degree of utilization.

Salaries of direct maintenance employees, part and component costs, outsourcing maintenance costs, and aircraft insurance, leasing and depreciation costs are initially linked to specific aircraft, and then allocated to individual flights based on the ratio of flight length to the length of all flights. Fuel costs, pilot salaries and direct costs associated with using airports are directly linked to flights. Pilot salaries contribute roughly 12% to airplane costs. Flight crew costs differ across airlines, depending on the union contract and the base country of each airline. Fuel account for 12–20% of aircraft costs, depending on weight, distance flown and seating capacity. The aircraft itself is about 32% costs, and it is allocated to trips per year. In general, maintenance costs, including direct overheads associated with the upkeep of maintenance facilities and tools, of airplanes comprise 13% of operating costs. Cabin crew costs amount to about 10% operating costs, depending on seats, a typical ratio is one crew to every 40 seats. Landing fees are usually based on the maximum take-off weight by aircraft type. They amount to 8–14% of costs, depending on the length of the haul. En route air traffic control charges are based on the size of an airplane approximated by its weight and the distance flown, and range from 2 to 6% of operating costs. Insurance represents less than 1% of the costs and is traditionally computed on an annual basis. Moreover, the salaries of the cabin crew, and direct costs of passenger service (in-flight catering) are directly traced to flight costs.

Overhead costs are divided into four main activities: pool maintenance and repair (M&R), flight planning and management (P&M), marketing and service activities. The main costs relating to M&R activity pool are the salaries of the indirect maintenance employees, machine equipment costs, quality checking costs and hangar costs. The P&M activity pool includes costs of flight dispatching, monitoring and coordination, and the costs of rental, office equipment and other supplies relating to flight activity planning and management. The main components of the marketing activity pool are promotion costs, salaries of financial planning and cabin allocation employees, and the costs of rental, office equipment and other marketing related supplies. Service activity pool components include the salaries of ground staff and the costs of rental, office equipment and other supplies associated with related service activities.

The selected LCAs are Ryan Air, Easy Jet, Virgin Express and Transavia. They have been chosen because operate intra-European routes are completely private companies, and are not controlled by an FSA. Second, because the first two have operated for nearly 20 years and the others are young and aggressive start-ups. There are differences seen, however, as seen in the managers' answers to the questionnaire, detailed analysis of financial balances and Association of European Airline (2004, 2005, 2006) reports, Table 1. For an LCA the costs to be controlled and, eventually, reduced, in order of importance are: landing fees and en route charges, fuel and oil costs and direct employee costs.

For FSAs Alitalia, Iberia, KLM, British Airways and Lufthansa are selected. They operate inside the EU and were formally controlled by their national governments. Except for British Airways, a public company, they are controlled by national groups and they all have a similar route structure. As for the LCAs, it was possible to build a typical FSA cost structure to represent this category (Table 2). It should be noted that for an FSA, the cost areas to be reduced are, in order of importance, indirect employee costs, landing fees and en route charges, fuel and oil costs.

3. Methodology

The AHP (Saaty, 1980), is a method for formulating and analyzing decisions. AHP is a decision support tool that can be used to solve complex decision problems taking into account tangible and intangible aspects. Therefore it helps decision-makers to make decisions involving their experience, knowledge and intuition.

Table 1
LCAs operating component costs.

Direct costs	50%	Overheads	42%	Other costs	8%
Engineering, Spare Parts and other A/C costs	9%	Landing fees and en route charges	35%		
Fuel and oil costs	20%	Selling costs	5%		
Depreciation and amortization	9%	Indirect employee costs	2%		
Direct employee costs	12%				

Table 2
FSAs operating component costs.

Direct costs	41%	Overheads	47%	Other costs	5%	Various services	7%
Engineering and other A/C costs	4%	Landing fees and en route charges	15%				
Fuel and oil costs	13.5%	Selling costs	7%				
Depreciation and amortization	6%	Indirect employee costs	21%				
Direct employee costs amortization	9%	Intangible property lock up	1.5%				
A/C operating lease costs	5%	Handling and catering charges	2.50%				
Spare parts	3.5%						

The AHP breaks the decision problem down according to common characteristics, and levels, which correspond to the common characteristic of the elements. The top level is the "focus" of the problem or ultimate goal; the intermediate levels correspond to criteria and sub-criteria, while the lowest level contains the "decision alternatives". If each element of each level depends on all the elements of the upper level, then the hierarchy is complete; otherwise, it is said to be incomplete. The elements of each level are compared pair-wise with respect to a specific element in the level immediately above.

Table 3 shows the pair-wise comparison scale used in Saaty's (1977). AHP that allows the conversion of qualitative judgments into cardinal values.

For prioritising elements, a judgment matrix is used;

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \quad (1)$$

where a_{ij} represents the pair-wise comparison rating between element i and element j in a level with respect to an element in the upper level. Entries a_{ij} are governed by the following rules: $a_{ij} > 0;\ a_{ij} = 1/a_{ij};\ a_{ii} > 1\ \forall i$.

Following Saaty (1980, 2000), the priorities of the elements can be estimated by finding the principal eigenvector w of the matrix A,

$$AW = \lambda_{\max} W \quad (2)$$

When the vector W is normalized, it becomes the vector of priorities of elements of one level with respect to the element in the upper level. $\lambda_{\max}$ is the largest eigenvalue of the matrix A. The pair-wise comparisons matrix is consistent if it satisfies:

$$a_{ij} = a_{ik}a_{kj}, \quad \forall i, j, k \quad (3)$$

Saaty (1980) showed that to maintain reasonable consistency when deriving priorities from paired comparisons, more than seven factors need to be considered. The AHP allows inconsistency, but provides a measure of the inconsistency in each set of judgments. The consistency of the judgmental matrix can be determined by a measure called the consistency ratio (CR), defined as:

$$CR = \frac{CI}{RI} \quad (4)$$

where CI is called the consistency index and RI is the random index. Furthermore, Saaty provided average consistencies (RI values) of randomly generated matrices (Table 4). CI for a matrix of order n is defined as:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (5)$$

In general, a consistency ratio of 0.1 or less is considered acceptable. If the value is higher, the judgments may not be reliable and should be elicited again (Table 4).

Once the local priorities of elements of different levels are available, to obtain the final priorities of the alternatives a_i, the priorities are aggregated as follows:

$$S(a_i) = \sum_k w_k S_k(a_i) \quad (6)$$

where w_k is the local priority of element k and $S_k(a_i)$ is the priority of alternative a_i with respect to element k of the upper level(Fig. 1).

4. Assessment of cost assignment

For the case study, a four-level analytic hierarchy process is applied; Fig. 1. The first level is composed of the final goal: to identify the best allocation of the operating costs. The second level presents the criteria on the basis of which the operating costs can be divided: direct costs and indirect costs. The third level presents the sub-criteria, defined on the basis of the cost classification, which differs amongst the criteria. The fourth level presents the alternatives. The cost structure reported in Fig. 1 follows the lead of Tsai and Kuo (2004).

Direct costs are divided into variable costs and fixed costs. On the one hand, the direct variable cost involve those costs that change with the degree of utilization of costs of airplanes and embrace salaries of M&R employees, part and component costs, outsourcing maintenance costs, fuel costs, pilot salaries, direct costs using airports, salaries of cabin crew and direct costs for passenger services. On the other hand, the direct fixed costs involve those alternatives whose costs do not change according to the degree of utilization of cost objects, that is, insurance costs, leasing costs and depreciation costs of airplanes.

Further, indirect costs are divided into:

- maintenance and repair activity, involving the alternatives on salaries of indirect M&R employees, machine equipment costs, quality checking costs and hangar costs;
- flight planning and management activity, involving two alternatives, the costs of dispatching and monitoring flights and the costs of rental, office equipment and other supplies;

Table 3
The AHP pair-wise comparison scale.

Numerical values	Verbal scale	Explanation
1	Equal importance of both elements	Two elements contribute equally
3	Moderate importance of one element over another	Experience and judgment favour one element over another
5	Strong importance of one element over another	An element is strongly favoured
7	Very strong importance of one element over another	An element is very strongly dominant
9	Extreme importance of one element over another	An element is favoured by at least an order of magnitude
2,4,6,8	Intermediate values	Used to compromise between two judgments
1.1–1.9	When two elements are very close but often one would be guessing	Better, the elements are compared with other contrasting elements using 1–9 and good answers are obtained

Table 4
The average consistencies of random matrices (RI values).

Size	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

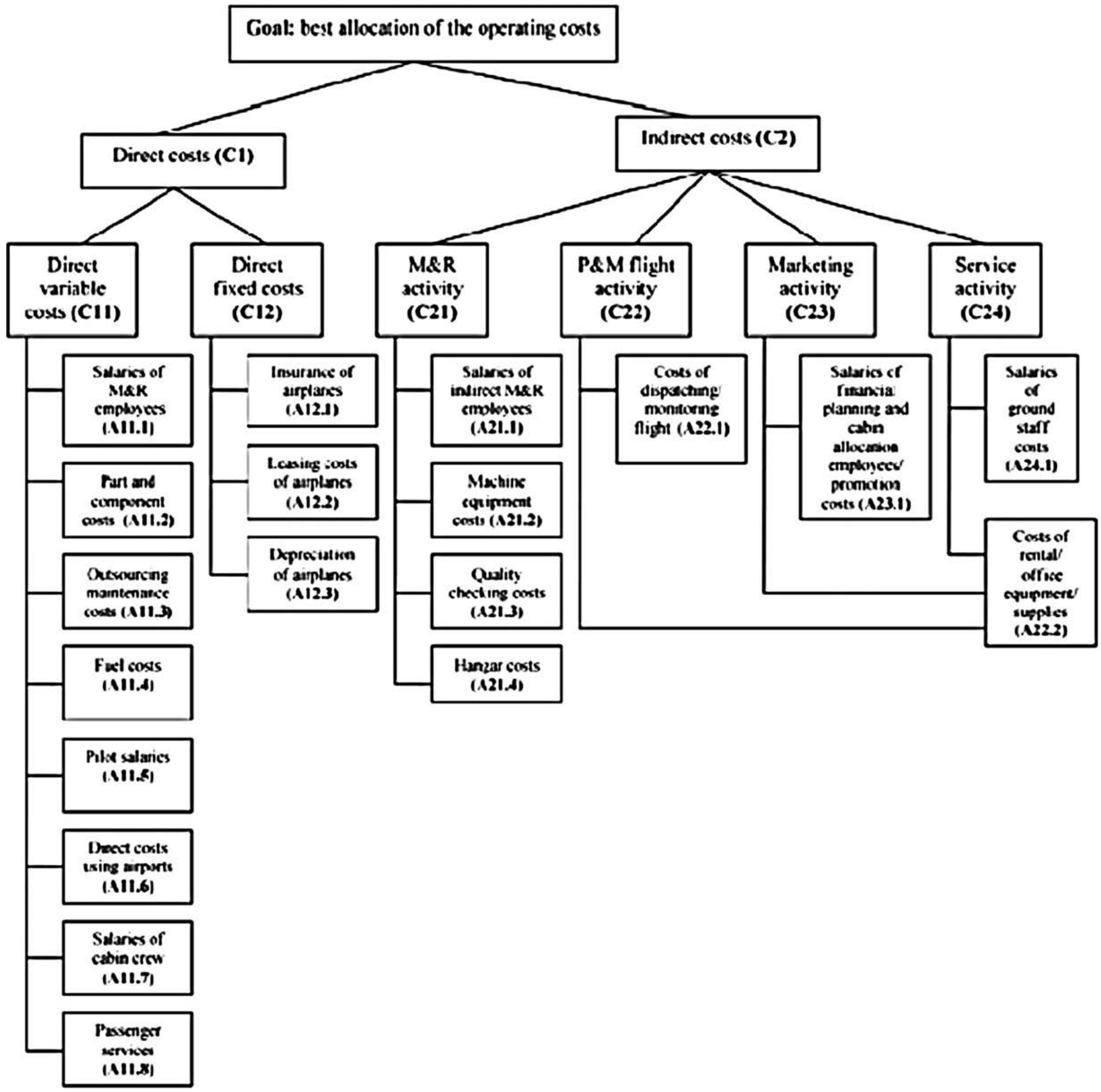

Fig. 1. Analytic hierarchy structure.

- marketing involving two alternatives, salaries of financial planning and cabin allocation employees and the costs of rental, office equipment and other supplies;
- service activity involving two alternatives, the salaries of ground staff and the costs of rental, office equipment and other supplies.

The weights of pair-wise comparisons between different items (criteria, sub-criteria and alternatives) are chosen to give most importance, and hence greater weight, to the cost that are more strategic both in financial, management and operative terms. The weights have been assigned taking into account both the financial sheets, the AEA reports and the answers of the managers to the submitted questionnaire.

Any item was analysed and compared with ones of same level of the cost structure.

At the second level, operating costs for aircraft are divided into direct costs and overheads (indirect costs), considering the former more important than the latter for LCAs (Table 5); conversely for FSAs indirect costs are more important than direct ones. This crucial difference is due to the fact that an LCA has a more flexible and simple financial structure and management than an FSA (Morrell, 2005).

At the third level, independently of the airline type under analysis, direct fixed costs are tightly linked to insurance,

Table 5
Comparison of criteria with respect to the overall objective (LCAs).

	Direct costs	Indirect costs	Local priorities
Direct costs (C1)	1	2	0.67
Indirect costs (C2)	1/2	1	0.33
$\lambda_{max} = 2$ CI = 0 CR = 0			

Table 6
Comparison of sub-criteria with respect to the direct costs (LCAs).

	Variable costs (C11)	Fixed costs (C12)	Local priorities
Variable costs (C11)	1	4	0.8
Fixed costs (C12)	1/4	1	0.2
$\lambda_{max} = 2$ CI = 0 CR = 0			

Table 7
Comparison of sub-criteria with respect to the indirect costs (LCAs).

	M&R activity (C21)	P&M flight activity (C22)	Marketing activity (C23)	Service activity (C24)	Local priorities
M&R Activity (C21)	1	1/2	1/2	1/2	0.14
P&M flight activity (C22)	2	1	1/2	1/2	0.2
Marketing activity (C23)	2	2	1	1	0.33
Service activity (C24)	2	2	1	1	0.33
$\lambda_{max} = 4.05$ CI = 0.018 CR = 0.02					

depreciation of aircraft and leasing costs, which cannot easily be reduced, since they include the fleet characteristics, and in particular the age and condition of the aircraft; by contrast, the direct variable costs can be reduced more effectively. For these reasons it is more appropriate to give a greater value to direct variable costs, equal to 4, than to direct fixed costs (Table 6). Related to indirect costs, maintenance and repair activity costs can be reduced by using a single aircraft typology. This choice allows scale economies and reduction of spare parts and maintenance staff training costs. Planning and managing flight activity costs also depend essentially on aircraft typology and on the schedule adopted. Both types of carrier use scheduler software to optimize their networks, which allows them to achieve savings in terms of time and rationalization of route choices. Marketing and service activities costs are more important than previous ones. They can be cut in order to reduce the indirect costs particularly for an LCA; whereas this is not true for an FSA. In fact, service activities costs are mainly related to provided ground services. Some FSAs engage a handling company to market its services to others. For example, Alitalia Airline and was accredited with the major part of Alitalia's debts because it could be helped by Italian government-subsidies; whereas Alitalia itself could not. Thus, for most airlines, service activity costs cannot be reduced, since services are regulated by contracts between airlines and handling companies. Furthermore for an FSA, marketing activities costs cannot easily be cut, since they have a complex financial structure. Thus higher weight are given components for an LCA and lower weight for an FSA (Table 7).

Table 8
Final priorities of the alternatives (LCAs).

	Final priorities
Costs of rental, office equipment and other supplies (A22.2)	0.191
Outsourcing maintenance costs (A11.3)	0.147
Direct costs using airports (A11.6)	0.096
Direct costs for passenger services (A11.8)	0.073
Insurance of airplanes (A12.1)	0.066
Part and component costs (A11.2)	0.052
Salaries of cabin crew (A11.7)	0.046
Salaries of M&R employees (A11.1)	0.044
Pilot salaries (A11.5)	0.043
Leasing costs of airplanes (A12.2)	0.041
Salaries of financial planning and cabin allocation employees (A23.1)	0.037
Salaries of ground staff (A24.1)	0.037
Fuel costs (A11.4)	0.031
Depreciation of airplanes (A12.3)	0.026
Hangar costs (A21.4)	0.023
Costs of dispatching and monitoring flights (A22.1)	0.022
Machine equipment costs (A21.2)	0.011
Salaries of indirect M&R employees (A21.1)	0.008
Quality checking costs (A21.3)	0.005
Total	1

At the fourth level, related to direct variable costs, salaries of M&R Employees have the same share costs for both LCAs and FSAs; this item, like those relating to other salaries costs, is highly influenced by trade unions, as well as fuel costs that have the same value for both airlines, because there is not a big fuel price difference between them and they also introduce the so-called "Fuel Surcharge Tax" into passengers' tickets. Instead, great importance is given to "outsourcing maintenance costs" for LCAs, that usually outsource this kind of services, while most FSAs have their own maintenance department. Almost all the basic passenger services during LCA flights have been cut out and all others are sold, even with minimal comfort standards and services. On the other hand, all the FSAs give great importance to their comfort standards, so these airlines do not cut these items in order to reduce their operating costs. The direct costs of using airports alternative highlights the big difference between the airline typology. As LCAs search for lower landing fees, usually at secondary airports, the FSAs operate from closer-to-town airports. For these reasons, for an LCA is give a greater value, three, with regard to outsourcing maintenance, the direct costs of using airports and passenger services, with a value of two, for the other cost components. Conversely, for an FSA more importance, a value of three, is given to part and component costs and passenger services.

Related to direct fixed costs, the fleet of most of the LCAs is made up of new aircraft, in order to reduce the costs of maintenance and fuel consumption; so this kind of airline is less influenced by depreciation. Instead, most of the FSAs have old and new aircrafts; thus, the insurance cost is slightly more significant than for the other items. Both the typologies of airlines have to offer the safety standards imposed by the ICAO and FAA, so we decided do not focus on these costs.

A good supply and spare parts management is very important to reduce operating costs. From the view's point of maintenance and repair activity, the cost components related to hangar costs and machine equipment costs are more important than other costs for both kinds of airline, with assigned values, respectively, equal to 3 and 2. This is due to the fact that such costs have a great impact on operative management of an airline, age and type of aircraft, extension and type of airports' network (supply hub and spoke, point to point and/or hybrid) and so on.

Relatively to flight planning and management (P&M), marketing and service activities, we decided to give great importance to rental/office equipment/supplies, with a value equal to 4. In fact, this component is a very significant cost, mostly for FSAs, but also for some LCAs it may be too high. These costs can be reduced by i.e. kiosks or online/web check-in, or by outsourcing that make it possible to reduce costs, as some LCAs are doing (e.g. Ryanair).

5. Results

By applying the procedure previously outlined, the results, reported in Table 5, indicate the higher importance of direct costs.

Table 9
Impacts on alternative' priorities of the Monte Carlo experiments of sub-criteria (LCAs).

Alternatives	Mean %	Standard deviation
Direct variable costs (A11.1–A11.8)	0.06	0.001–0.004
Direct fixed costs (A12.1–A12.3)	−0.23	0.003–0.007
M&R activity (A21.1–A21.4)	0.36	0.001–0.002
Costs of dispatching and monitoring flights (A22.1)	0.61	0.002
Costs of rental, office equipment and other supplies (A22.2)	−0.06	0.003
Salaries of financial planning and cabin allocation employees (A23.1)	−0.45	0.003
Salaries of ground staff (A24.1)	−0.07	0.003

Table 10
Estimated correlation coefficients amongst alternatives (LCAs).

Alternatives	Direct variable costs	Direct fixed costs	M&R activity	Costs of dispatching and monitoring flights	Costs of rental, office equipment and other supplies	Salaries of financial planning and cabin allocation employees	Salaries of ground staff
Direct variable costs	1						
Direct fixed costs	−1	1					
M&R activity	−0.02	0.02	1				
Costs of dispatching and monitoring flights	0.04	−0.04	−0.08	1			
Costs of rental, office equipment and other supplies	0.02	−0.02	−1	0.08	1		
Salaries of financial planning and cabin allocation employees	−0.07	0.07	0.14	−0.37	0.14	1	
Salaries of ground staff	0.05	−0.05	−0.34	−0.29	0.34	−0.63	1

Table 11
Impacts on alternative priorities of the Monte Carlo experiments of criteria (LCAs).

Alternatives	Mean %	Standard deviation
Direct costs	39.15	0.003–0.015
Indirect costs	−79.5	0.001–0.04

This result is consistent because CR = 0. Furthermore, from the comparison of the sub-criteria with respect to the direct costs, we see that the priority of the variable costs is higher than that of the fixed costs (Table 6); by contrast, from the comparison of the sub-criteria with respect to the indirect costs, reported in Table 7, both marketing and service activities have the highest priorities, and P&M flight activity is slightly preferred to M&R activity. These results are consistent, as shown by the values of the CR.

Ranking the alternatives with respect to the goal shows the highest importance of rental and office equipment supplies costs (Table 8). Outsourcing maintenance costs is the second-best alternative. The other direct costs have an importance between 7% and about 10%. The other indirect costs have an importance of less than 3.7%, with salaries of indirect M&R employees and quality checking costs amounting to less than 1%.

Furthermore, we ran Monte Carlo experiments to test under what conditions the ranking of the alternatives may change. The method involves specifying a *priori* distributions for the parameters and sets of parameter values drawn at random from these distributions. In particular, we applied this procedure to two cases: local priorities of sub-criteria and criteria. To calculate the final sample size, we specified a 95% probability that the percentage changes for all 19 alternatives is estimated with a margin of error of not more than 0.1. The necessary sample sizes turned out to be 400 for both cases. Furthermore, the local priorities, w_i, were assumed to evolve according to the stochastic differential equation:

$$dw_i = \mu w_i dt + \sigma w_i dz \quad \forall i \tag{7}$$

This equation implies that w_i change according to a process of *geometric Brownian motion* (GBM). The term μdt is the mean or expected percentage change in w_i for the increment dt, and μ is called the *mean drift rate*. The term σdz introduces a random component to the drift, because $dz = \varepsilon(t)\sqrt{dt}$, where $\varepsilon(t)$ is a normally distributed random variable with 0 mean and standard deviation of 1. A discrete approximation of equation (7) is given by the stochastic difference equation:

$$w_{i,t+1} = (1+\mu)w_{i,t} + \sigma w_{i,t}\varepsilon_{t+1} \tag{8}$$

where the ε_{t+1} is the standard normal variates and the implied increment is $dt = 1$.

Table 9, which reports the mean percentage change in each alternative's priority and the standard deviation across the 400 random samples for the first case, suggests that the results are robust to different combinations of the values of the local priorities. Indeed, the mean percentage change is very low, just as the standard deviation is quite small. The Monte Carlo procedure also makes it possible to estimate correlation coefficients between the percentage change in the alternatives' priorities. Very few of the

Table 12
Final priorities of the alternatives (FSAs).

	Final priorities	Final priorities (% change w.r.t. LCAs)
Costs of rental, office equipment and other supplies (A22.2)	0.377	97
Hangar costs (A21.4)	0.11	378
Direct costs for passenger services (A11.8)	0.075	3
Salaries of financial planning and cabin allocation employees (A23.1)	0.055	49
Part and component costs (A11.2)	0.041	−21
Machine equipment costs (A21.2)	0.039	255
Salaries of M&R employees (A11.1)	0.034	−23
Insurance of airplanes (A12.1)	0.033	−50
Outsourcing maintenance costs (A11.3)	0.031	−79
Direct costs using airports (A11.6)	0.031	−68
Salaries of indirect M&R employees (A21.1)	0.027	238
Salaries of cabin crew (A11.7)	0.025	−46
Salaries of ground staff (A24.1)	0.025	−32
Depreciation of airplanes (A12.3)	0.021	−19
Quality checking costs (A21.3)	0.019	280
Pilot salaries (A11.5)	0.016	−63
Fuel costs (A11.4)	0.014	−55
Costs of dispatching and monitoring flights (A22.1)	0.014	−36
Leasing costs of airplanes (A12.2)	0.013	−68
Total	1	

estimated correlation coefficients in Table 10 are large in magnitude: only 3 estimated correlation coefficients are greater than 0.5 (in absolute value). Thus, with some exceptions, the magnitude of the change in one type of costs provides little information about the magnitude of changes in other costs. This suggests that using only one or two costs could provide misleading information. Monte Carlo experiments for the second case show substantial variability in the mean percentage change (Table 11).

Finally, from comparison of the ranking of the alternatives between LCAs and FSAs, we see that costs relating to M&R activity (hangar costs, quality checking costs, salaries of indirect M&R employees and machine equipment costs) substantially increase their importance in FSAs (Table 12).

6. Conclusions

The aim of this paper was to compare operating cost allocation of LCA versus FSA using the analytic hierarchy process. We assigned values of all the comparisons for any level by means of a questionnaire submitted to the managers, an analysis of the airlines' financial sheets for selected FSAs and LCAs and AEA reports. Furthermore, a sensitivity analysis was carried out using Monte Carlo simulation, validating the robustness of the results. The results show that, differently to the traditional approaches, AHP could be appropriately used to obtain the ranking of the costs taking into account different views: financial, management and operative.

Costs of rental, office equipment and other supplies costs were found to be the best alternative for both carriers. This is due to the complexity of the financial structure and management of these companies, and suggests that the best way to reduce the operating costs is to simplify the airlines' organization (for instance by kiosks or online/web check-in).

The second-best alternative is the hangar costs for FSAs. This is justified by the fact that FSAs have a large number of grounded aircrafts, causing substantial loss of earnings. FSAs are still working to fix this problem by re-planning the schedules of their flights in order to better utilize their fleet capacity. For LCAs, the second-best alternative is outsourcing maintenance costs, which are only in the ninth position for FSAs. This is because many of the FSAs have their own maintenance department.

It should be noted that salaries play a crucial role in costs reduction, since these costs allow high cost savings. LCAs have higher aircraft and crew productivity than FSAs. This is possible in part because of a single type fleet, but also because of the shorter turnaround times achieved through less catering and absence of seat allocation. Pilot contracts encourage high productivity by reducing the fixed salary part, and increasing the variable part relating to flight hours. This advantage is due to the different business model of an LCA compared to an FSA one. The real cost savings of an LCA are achieved by staff cuts and economies in subcontracts.

The most significant contribution to the lower cost of an LCA business model comes from its labour productivity. In recruitment and deployment of labour Ryanair, for example, faces a trade-off between providing inputs from within the airline and outsourcing. The latter leads to flexibility in choosing between different suppliers of service, such as aircraft maintenance, handling at airports, catering and in-flight magazines, since the company can choose whether or not to renew contracts.

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