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A model for aircraft evaluation to support strategic decisions

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ABSTRACT

In the contemporary air transport industry, many factors, such as environmental impact, service quality and comfort are becoming increasingly crucial. In this context, airlines and manufacturing companies can no longer consider air transport exclusively as a cost-oriented problem; thus, for airlines, the choice concerning the purchase of the aircraft is no longer a simple matter of minimizing operative costs, but rather a multi-attribute problem, characterized by a high complexity level in which a variety of factors play a pivotal role. Given this scenario, the aim of this paper is to propose a novel model for aircraft evaluation, based on the investigation of airlines' needs. The model is based on the two main approaches proposed in literature to address generic evaluation problems, Analytic Hierarchy Process and Fuzzy Set Theory, proposing a hybrid approach which combines some the strengths of the two methodologies. The usability of the hybrid model for the stakeholders of the air transport industry is investigated through an empirical study.

1. Introduction

In the contemporary global market, the civil aviation industry is characterized by an ever increasing attention towards passengers' needs, service quality, comfort and environmental issues (Brindisi & Concilio, 2008; Hope, 2005; ICAO, 2013; Miyoshi & Mason, 2009; Newson & Cairns, 2006). In this context, industry stakeholders (including airlines and aircraft manufacturing companies) can no longer consider the provision of air transport exclusively as a cost-oriented problem; consequently, airlines should select aircraft in such a way that they assure the best combination among costs, technical characteristics, passenger comfort, and environmental impact. On the other hand, large manufacturing companies, prior to the launch of capital intensive production programmes, have to clearly identify the set of characteristics that better satisfy airlines' requirements (Esposito & Passaro, 1997; Esposito & Raffa, 1994). The misalignment with respect to airlines requirements could jeopardize the success of new programmes and generate relevant financial losses (Esposito & Raffa, 2007; Ferreri, 2003).

Unsurprisingly, in recent years, the academic literature has been focusing on many aspects in terms of aircraft performances, besides the traditional ones. Several papers analyze environmental impact from different points of views, by highlighting:

- the environmental impact of emissions and noise due to air traffic (Abeyratne, 2003; Armstrong, Allen, & Denning, 1997; Borken-Kleefeld, Berntsen, & Fuglestvedt, 2010; Price & Probert, 1995; Sen, 1997; Tsilingiridis, 2009);
- the social costs of aircraft noise and emissions (Brueckner & Zhang, 2010; Lu & Morrell, 2006; Schipper, 2004);
- strategies and goals of national and international organizations in reducing noise and emissions from air transport (Abeyratne, 2002; Girvin, 2010; Koblen, Szabo, & Krnáčová, 2013; Ott, 2007) and the economic impact and ecological effects of such strategies (Brueckner & Girvin, 2008; Vespermann & Wald, 2011);
- the proposal of new products, new technologies and new materials (such as new engines, alternative fuel, etc.) in order to reduce the negative environmental impact of the aviation industry (Dray, 2013; Frota, 2010; Haddad & Fawaz, 2013).

Also, the amount of papers dealing with comfort and service quality issues is increasing, focusing on:

- the impact of airline service quality and comfort on passenger choices (Balcombe, Fraser, & Harris, 2009; Jiang, 2013; Martin, Roman, & Espino, 2008; Park, Robertson, & Wu, 2004, 2006; Pennig, Quehl, & Rolny, 2012; Wojahn, 2002; Yang, Hsieh, Li, & Yang, 2012; Zhang, 2012);
- the attributes of the airline service quality (Babbar & Koufteros, 2008; Curry & Gao, 2012; De Jager, Van Zyl, & Toriola, 2012; Kim & Lee, 2009; Martin, Roman, & Espino, 2011; Wen & Yeh, 2010) and the customer-value drivers (Boetsch, Bieger, & Wittmer, 2011; Park, Robertson, & Wu, 2009);

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- the evaluation of airline service quality (Chen & Chang, 2005; Cheng & Chang, 2006; Chou, Liu, Huang, Yih, & Han, 2011; Higgins, Lawphongpanich, Mahoney, & Yin, 2008; Liou & Tzeng, 2007; Pakdil & Aydin, 2007; Tsaur, Chang, & Yen, 2002);
- the effect of service quality on airlines' performance (Sim, Koh, & Shetty, 2006), the proposal of methods and strategies for improving airline service quality (Liou, Tsai, Lin, & Tzeng, 2011; Liou, Yen, & Tzeng, 2010; Maji, 2012);
- the important role of comfort in the interior design of airplanes (Brindisi & Concilio, 2008; Lee & Luengo-Prado, 2004; Vink, Bazley, Kamp, & Blok, 2012).

The extant literature suggests that, in the air transport industry, aircraft selection and evaluation issues have become a multi-attribute problem, characterized by a high complexity level in which a variety of quantitative and qualitative factors play a crucial role.

In this context, the aim of this paper is to propose a novel model for aircraft evaluation, based on the investigation of airlines' needs. This model considers not only traditional characteristics (operating costs and technical performance, such as cruise speed) but also a variety of features whose importance is strikingly increasing, such as environmental impact and aircraft interior quality. The proposed model can be useful both for airlines, in their process of selecting the most suitable aircraft for their fleet, and for manufacturing companies in their process of designing future aircraft.

The model is based on two popular approaches proposed in literature to address evaluation problems, the Analytic Hierarchy Process (AHP) (Saaty, 1980, 2001) and the Fuzzy Set Theory (FST) (Zadeh, 1965), proposing a hybrid approach combining the main strengths of the two methodologies.

The usability of the model for the stakeholders of the air transport industry and its adaptability to contexts characterized by complexity, high technological level, and increasing requirements in terms of sustainability and environmental regulations, are investigated through an empirical study focused on regional transport aircraft.

The paper is organized in the following sections. Section 2 provides further information about the extant literature on evaluation models in the aviation industry. Then, in Section 3, the hybrid model is introduced and described. In Section 4, the proposed model is implemented and a case study related to the evaluation of three regional aircraft is analyzed and discussed. Finally, some conclusions are drawn.

2. Background

Since the 1960s, international air transport organizations and large aircraft manufacturing companies have developed accurate methodologies to calculate aircraft direct operating costs (AEA, 1985; Airbus, 1988; ATA, 1964, 1967; Boeing, 1972). For many years direct operating costs (DOCs) and Net Present Value (NPV), that in turn includes DOCs, were the main two indicators being utilized in the aircraft evaluation process and in purchasing decisions.

Under this approach, Gibson and Morrell (2004) proposed the use of a variant of the well-documented adjusted present value (APV) concept and suggested a methodology for aircraft financial evaluation using Monte Carlo simulation and Real Option Analysis. Although this contribution has the merit of proposing a robust methodology, which overcomes the simple analysis based on DOCs or NPV, it addresses the evaluation exclusively from the financial point of view, thus neglecting issues related to quality and environmental impact.

In the early 2000s, a number of airlines introduced empirical multi-criteria procedures that included not only DOCs or NPVs, but also a number of indicators, such as speed, range and passengers' capacity (Ferreri, 2003). The weight of each criterion was identified on the basis of past experience or through heuristic decision-making procedures. Even today, many airlines use simple empirical multi-criteria procedures. In fact, despite the fact that the literature is rich of contributes suggesting a variety of tools to deal with multi-criteria problems, only few papers focus their attention on aircraft evaluation.

Among these, See et al. (2004) presented a multi-attribute methodology for selecting the best aircraft among a set of alternatives. Authors used the method of the hypothetical equivalents and inequivalents (Wu, 1996), basing their choice on three criteria: speed, range and number of passengers. This paper has the undoubted advantage of dealing with the problem of aircraft evaluation through a multi-criteria approach; nevertheless it neglects important criteria such as costs, aircraft interior quality and environmental issues. In addition, when the number of alternatives or the number of criteria increase, the proposed method becomes extremely farraginous and provided results are not easy to be interpreted.

Yeh and Chang (2009) proposed a fuzzy multi-criteria decision making algorithm. The evaluation process is based on three criteria (technological advances, social responsibility and economical efficiency), further articulated into eleven sub-criteria. For each criterion, the performance of each aircraft is evaluated through a fuzzy rating. The authors use a pair-wise comparison process to assess the weights among the three criteria, and between sub-criteria within each criterion. The crisp weights are translated into fuzzy numbers and then aggregated with the fuzzy rating of performances. The result is an overall fuzzy preference value for each aircraft type. The overall fuzzy preference value is then defuzzified to obtain a crisp preference value for each aircraft type. The proposed algorithm appears not easy to use. Nevertheless, it could be partially simplified avoiding the fuzzification of the crisp weights. In fact, the aggregation of the crisp weights with fuzzy performances provides overall fuzzy preference values that are highly correlated with the results of the proposed algorithm, revealing that fuzzification of weights could be an unnecessary complexification.

Gomes, Mattos Fernandes, and Mello (2012) proposed a fuzzy stochastic approach to the multi-criteria selection of aircraft based on the NAIADE method (Novel Approach to Imprecise Assessment and Decision Environments). The process of evaluation is based on three criteria (Financial, Logistics, Quality) further articulated in twelve sub-criteria (Acquisition Cost, Liquidity, Operating Costs, Range, Flexibility, Cruising Speed, Replacement Parts Availability, Landing and take-off distance, Comfort, Avionics, Availability, Safety). The output is the ranking of alternatives by means of an outranking procedure adapted from the PROMÉTHÉE method. The proposed method is conceptually simple. Nevertheless, as also authors underline, in the practical applications the mathematical calculations become complex and the analysis of alternative hard to evaluate and interpret.

In this context this paper proposes a novel model for aircraft evaluation, which aims to overcome the weaknesses of the previous models; specifically, coherently to the above-mentioned nature of the aircraft evaluation problem, the model should be based on a multi-criteria framework, including the most relevant categories for stakeholders in the civil aviation industry. Also, the usability of the model and its applicability to real-world decision-making should be ensured.

3. A hybrid model for aircraft evaluation

The proposed model is based on the two main approaches suggested in literature to address evaluation problems, the Analytic Hierarchy Process (AHP) and the Fuzzy Set Theory (FST). In