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An integrated MCDM model for improving airline operational and financial performance

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ABSTRACT

The development of better methods for the improvement of airline performance is crucial, but this type of problem is difficult to solve because of the large number of complex factors involved making this inherently a multiple criteria decision making (MCDM) problem. In current studies, the factors to be evaluated are considered based upon a literature review or expert opinions. This study proposes an integrated model that combines data mining and MCDM to extract the critical factors for the improvement of airline performance. We apply the dominance-based rough set approach to extract the essential factors. The decision-making trial and evaluation laboratory method with the concepts of the analytic network process (DANP) is then used to construct the complex evaluation system. Finally, the VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian, meaning multicriteria optimization and compromise solution) method is applied to select the suitable improvement alternative goals with the corresponding weights provided by the DANP method. The results show that the current model can be used as the basis for a benchmark industry improvement index which can be used to evaluate each airline individually with defined planning goals to achieve financial efficiency by improving operational efficiency.

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1. Introduction

The past 10 years have seen large fluctuations and extreme changes in airline companies' financial and operational performance. The reasons for these are numerous, including problems caused by management and government regulators, as well as company mergers, restructuring and financial interventions and changes in the markets. For example, inappropriate financial and operational management decisions can affect internal costs, leading to chaotic high-risk situations, which if not dealt with appropriately could result in a declaration of bankruptcy or closing of the airline. Airline managers need a useful tool to identify, diagnose, and evaluate the company's financial and operational performance and rank goals for improvement. An airline's business performance depends upon customer service and internal operations to maximize financial efficiency. How to improve operational and financial performance and overcome problems is a particularly critical challenge for airline managers. The improvement of an airline's financial and operational performance involves a complex decision-making process requiring a systematic approach. Making such decisions entails dealing with a large number of conflicting criteria, which may not be clearly defined, as well as the consideration of interrelated criteria, mixing quantitative and qualitative criteria with subjective judgments (Gomes et al., 2014). All of these factors make airline performance improvement an inherently multiple criteria decision making (MCDM) problem. These multiple dimensions and criteria have motivated several scholars to search other fields to find advanced quantitative methods which can be adapted to create feasible approaches for performance optimization (Fethi and Pasiouras, 2010). Decisions for improving an airline's operational and financial performance, regardless of whether problems have been caused by external (e.g., fuel cost and consumption) or internal (e.g., net income) factors, are critical and unavoidable challenges which must be dealt with by management in order to survive in the air transportation industry. Any alterations in the criteria (factors) for operational efficiency can cause a number of reactions which impact financial efficiency especially because of the interrelationship between the criteria.

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Only a limited number of studies have appeared in the literature which are directly or indirectly related to airline efficiency (for examples see Lu et al., 2014; Lee and Worthington, 2014; Chang et al., 2014; Wu and Liao, 2014; Tavassoli et al., 2014; Arjomandi and Seufert, 2014; Chiu et al., 2013; Barros et al., 2013; Barros and Couto, 2013; Assaf and Josiassen, 2012; Delbari et al., 2016; Min and Joo, 2016; Duygun et al., 2016; Li et al., 2015b). Some have used statistical methods while others have applied data envelopment analysis (DEA) based models to deal with the problem. For example, Mallikarjun (2015) used network DEA (NDEA), Li et al. (2015a) used slack-based measure (SBM) DEA, and Tavassoli et al. (2014) combined the SBM and NDEA methods. The major limitation of previous studies has been that they have mainly focused on past quantitative data alone. Airline performance improvement is a complex system problem requiring qualitative judgements. However, depending upon qualitative analysis alone may provide overly superficial outcomes, while the results of quantitative analysis alone may easily lose their authenticity. A combination of these two approaches is needed to fully integrate various considerations, objectively based on the laws of science that would provide results with increased validity and reliability. The objective of this study is thus to produce an integrated model for improving airline performance that combines a data mining technique (quantitative data analysis) and multiple criteria decision-making (MCDM) models utilizing managers' qualitative judgements. Most MCDM models consider evaluating criteria derived from a literature review or expert opinions, opinions which might be subjective due to the vagueness of human judgments and preferences. Different experts will also generate different evaluation criteria. In today's big data era, interest in systematically exploring historical data with different methods to find new information has been increasing worldwide. Data mining techniques can be combined with MCDM methods to provide an excellent platform for such exploration, in this case, combining the factors to generate acceptable solutions. Thus, data mining techniques are used to extract objective evaluation criteria and the MCDM method is used to provide directions for improvement for airlines.

The integrated MCDM model proposed in this paper is divided into four stages: (1) the dominance-based rough set approach (DRSA) is used to identify the critical criteria in each dimension; (2) an evaluation system is constructed with the decision-making trial and evaluation laboratory (DEMATEL) method; (3) the influential weights of the criteria are analyzed through a DEMATEL-based analytic network process (DANP) method; and (4) the optimal airline performance and improvement goals for airlines are identified and ranked using VIKOR (i.e., VlseKriterijumska Optimizacija I Kompromisno Resenje in Serbian, meaning multicriteria optimization and compromise solution). The proposed model is capable of a facilitating the financial and operational improvement decision-making process and minimizing possible biases during the ranking and goal improvement prioritizing process for each airline. The usefulness and effectiveness of the proposed method is demonstrated in an empirical example, using 10 years of historical data provided by the Office of the Assistant Secretary for Research and Technology of the US Department of Transportation. This integrated model for operational and financial performance improvement can assist airline management to (1) understand the systematic influential network relation structure among the criteria, (2) find the essential factors and priorities in all dimensions, (3) select the most critical financial and operational performance factors with precision in a short period of time, and (4) improve the performance of the financial and operational dimensions by ranking and benchmarking the best practices. The empirical example demonstrates that this managerial tool can facilitate the decision-making process and the benchmarking ranking accurately, minimizing the time required and consequently reducing the costs involved in bad decision-making. The method and the final ranking table may be adapted to multiple cases, thereby helping airlines to improve their decision-making ability. Thus, companies can enhance the use of their resources and improve their financial and operational performance. Managers can pay more attention to the customer service by controlling the operational dimensions, minimizing the financial negative effects of critical operations mismanagement, and consequently, enhancing their overall competitiveness.

Prior works related to financial and operational performance in the airline industry have been mainly relied upon quantitative data and DEA models. However, airline performance improvement involves complex factors and needs managers' qualitative judgement. The evaluating systems constructed with traditional MCDM models might be too subjective due to the uncertainty of expert opinions. This study contributes to the literature by providing an integrated model that can objectively extract the essential criteria which can then be used to build an evaluation system that also consider managers' qualitative judgements, with the aim of improving airline performance. The remainder of this paper is structured as follows: Section 2 offers a brief review of the existing literature related to this topic. Section 3 describes the proposed decision rule-based soft computing model. Section 4 demonstrates the effectiveness of this proposed decision rule-based soft computing model by evaluating 10 years of historical data for the US airline industry. Section 5 presents some conclusions and closing remarks.

2. Literature review

Over the past decades, various methods have been proposed to address airline performance problems. These can be categorized into two major types of approaches: (1) DEA and mathematical programming models, and (2) MCDM approaches.

2.1. DEA and mathematical programming models

DEA and network DEA models have been used in a number of studies related to the operating and financial efficiency approaches for airlines. Lu et al. (2014) used a two-stage network DEA method to examine production and marketing efficiency in 30 US airlines. Lee and Worthington (2014) performed DEA and simultaneously estimated scores with a bootstrapped truncated regression model to explain the efficiency drivers for 42 US and European airlines. A virtual frontier network SBM was proposed by Li et al. (2015a) to evaluate the efficiency of 22 airlines from 2008 to 2012. Chang et al. (2014) analyzed trade-offs between labor and capital measures among 27 international airlines. The DEA results reported that fuel consumption and revenue structure are the major causes of inefficiency in airlines.

Arjomandi and Seufert (2014) applied a bootstrapped DEA method to evaluate performance among 48 international airlines finding that low-cost carriers are operating under increasing returns to scale. Choi et al. (2015) analyzed 12 US airlines. They evaluated service quality as a factor related to service productivity by applying a service quality-adjusted DEA and Mann–Whitney test to illustrate the tradeoff between quality and productivity. Barros et al. (2013) proposed a B-convex model which data from 10 US airlines to prove that airline efficiency is influenced by the size of the airline, mergers, and acquisitions. Barros and Couto (2013) applied the Luenberger productivity index and Malmquist productivity index as they reported on the managerial causes of technical efficiency and the variations in strategies adopted by 23 European airlines. Moreover, Mallikarjun (2015) developed an unoriented DEA network method to measure the performance of

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