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A novel hybrid fuzzy DEA-Fuzzy MADM method for airlines safety evaluation

Sasan Barak[a,c,*], Jalil Heidary Dahooei[b,**]

[a] Faculty of Economics, Technical University of Ostrava, Ostrava, Czech Republic
[b] Faculty of Management, University of Tehran, Tehran, Iran
[c] Department of Management Science, Lancaster University Management School, Lancaster University, UK

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ABSTRACT

Safety is a critical element in the air transport industry. Although fatal air accidents are rare compared to other transport industries, the rapid growth in air travel demands has resulted in a growing aviation risk exposure and new challenges in the aviation sector. Although the issue of airline safety is of serious public concern, notably few studies have investigated the safety efficiency of airlines. This paper aims to propose a novel hybrid method using fuzzy data envelopment analysis (DEA) and fuzzy multi-attribute decision making (F-MADM) for ranking the airlines' safety. In this study, fuzzy DEA is utilized to calculate criteria weights, in contrast to the conventional approach of using DEA for measuring the efficiency of alternatives. A ranking of each airline (DMU) on the basis of obtained weights is then assessed using MADM methods. Six MADM methods including Fuzzy SAW, Fuzzy TOPSIS, Fuzzy VIKOR, ARAS-F, COPRAS-F and Fuzzy MULTIMOORA are implemented to rank the alternatives, and finally, the results are compounded with the utility interval technique. This new hybrid method can efficiently overcome the pitfalls of traditional hybrid DEA-MADM models. The method proposed in this study is used to evaluate the safety levels of seven Iranian airlines and to select the safest one.

1. Introduction

Safety has always been a key factor in the airline industry that leads to an airline's survival, reputation, international prestige, and passengers' confidence (Chang and Yeh, 2004; Cui and Li, 2015). Therefore, the continuous improvement in air safety has been a critical undertaking for the airline industry (Chen and Chen, 2012).

Due to the importance of having an acceptable air safety record for each airline, improving safety has been the top priority for this industry (Hsu et al., 2010; Liou et al., 2008); and as such, the aviation industry must make efforts to establish and implent high safety standards to reduce accident and incident rates (Liao, 2015).

The first thing that is required to manage airline safety is an evaluation mechanism for measuring the overall safety which could assist managers in comparing safety efficiency among airlines and to analyse changes in airline safety performance over time (Chang and Yeh, 2004; Deng et al., 2007). Concerning the vital role of safety levels in airlines, different approaches, e.g. statistical modeling, trend extrapolation, Bayesian belief networks, data envelopment analysis and multi-attribute decision making, have been proposed to evaluate airline safety efficiency and performance (Cui and Li, 2015). With consideration of the literature, multi-attribute decision making (MADM) methods are more strongly underlined by researchers than other methods due to their relative characteristics. However, there are a number of concerns regarding the use of MADM type methods that we try to address in this research. Below, these concerns and potential solutions are addressed:

First concern: MADM suggests choosing the best alternative from a finite set of decision alternatives regarding multiple (and usually conflicting) attributes/criteria. The weights of these attributes play a very significant role in the process of decision-making. Therefore, how to determine the weights of attributes is crucial to MADM (Wang and Luo, 2010).

Based on literature, criteria importance weights can be calculated based on two categories: subjective methods and objective methods (Wang and Lee, 2009). While subjective methods determine weights solely based on the preference or judgments of decision-makers, objective methods determine the weights of attributes using objective decision matrix information and mathematical models (such as entropy,

* Corresponding author. Faculty of Economics, Sokolská třída 33, Ostrava, Czech Republic.
** Corresponding author. Faculty of management, University of Tehran, Jalal-e-Al-e-Ahmad Highway, Tehran, 14155-6311, Iran.
E-mail addresses: sasan.barak@vsb.cz (S. Barak), heidaryd@ut.ac.ir (J.H. Dahooei).

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CCSD,[1] QSPM[2]). Therefore, weights are not affected by the subjective judgment or intuition of the decision-maker, especially with regard to any lack of knowledge and experience.

Regarding this issue, data envelopment analysis (DEA) can be considered to be a powerful method for calculating objective weights. DEA is a mathematical programming approach in evaluating the efficiency scores of a set of decision-making units (DMUs). This evaluation approach is based on identifying the optimal weights of several DMU's criteria that are categorized as inputs and outputs. The input and output weights related to each DMU defers from other DMUs, and reveals the strength and weakness points of each DMU. These weights are assigned by DEA to make each DMU look as efficient as possible. DMUs select smaller and larger values for their weak and strength points respectively. Here, we consider the weight of inputs and outputs as the indicator of criteria importance.

Both DEA and MADM are used in this area, but both have limitations (Sinuany-Stern et al., 2000). Previous studies have tried to combine these two powerful methods simultaneously, calculating weights with MADM methods and then using DEA for reassuring a DMU's efficiency (Abdollahi et al., 2015). However, in this paper, DEA as an objective method is used to weight the criteria (contrary to previous researches in this area), and the alternatives are ranked by MADM methods. We show that this combination takes the best of each model, by avoiding pitfalls that could occur.

Second Concern: Regarding the literature, different MADM methods such as analytic hierarchy process (AHP), technique for order preference by similarity to ideal solution (TOPSIS), analytical network process (ANP), and decision making trial and evaluation (DEMATEL), are used for evaluating safety levels. It should be noted that results may differ depending on the use of different MADM methods (Antucheviciene et al., 2011). Therefore, finding the appropriate MADM method is very significant in the performance evaluation. The use of a single prioritization method cannot ensure the best result; besides, such a result would not be robust (Akhavan et al., 2015). In this respect, some studies have applied the combination of different MADM methods with voting approaches such as the Borda and Copeland (Favardin et al., 2002); and have found this grouping to be a more efficient technique in enhancing the precision of the final decision. We use the utility interval aggregation method that was proposed by Wang et al. (2005), as a systematic and logical scientific procedure that can help decision-makers to achieve the optimum ranking of alternatives.

Third Concern: Problems regarding safety evaluation have uncertainty at different levels such as information shortage, the indistinctive situation of the environment, and undefined variables which can lead to an unclear future state of the system. Moreover, using linguistics measures such as low, medium, and high are often employed in order to judge an event especially about privacy issues.

Because of the imprecision and vagueness inherent in the subjective assessment by the experts for safety evaluation (Deng et al., 2007), and considering the vital point that safety data is either not available or secure for many of the airlines (Oster et al., 2013), we use the fuzzy set theory. So, all models used in this article are fully fuzzy.

In light of the aforementioned concerns, in the first step, the fuzzy weight for each criterion is obtained using fully fuzzy DEA. In the second step, ranking of the safest airlines using obtained weights from the previous step is applied. Given that we require a robust decision-making method to select the safest airline, we propose to rank them using six MADM methods: Fuzzy SAW,[3] Fuzzy TOPSIS, Fuzzy VIKOR,[4] ARAS-F,[5] COPRAS-F[6] and Fuzzy MULTIMOORA. Then, the utility interval technique is applied to combine the ranking results of these methods. Weighted utility intervals are computed by constructing a correlation matrix between the ranking methods.

The overall contribution of this study is fourfold: (1) Using a fuzzy DEA-based objective weighting method instead of directly implementing experts' idea; (2) Using novel fuzzy DEA modeling for calculating the weights of criteria instead of estimating the alternative efficiency; (3) Using the utility interval technique to consolidate six different MADM rankings and to select the best answer; (4) Using a MADM-DEA combination for evaluating airline safety efficiency.

The remainder of this paper is organized as follows: In section 2, a brief review of the literature on airline safety evaluation is presented. Section 3 presents the mathematical details of the hybrid approach proposed in this study. In section 4, we use the proposed method to rank and analyse the airlines, and finally, conclusions and future research directions are discussed in the last section.

2. Literature survey

Whenever an accident occurs in one country's aviation industry, it draws considerable attention from the government and public, and normally the airline's reputation and international prestige dramatically declines as a result (Liao, 2015).

In the past several years, airline safety has been an essential and popular research topic. Cui and Li (2015) classified this research into two categories: (1) Evaluation of civil aviation safety; (2) Analysis of factors influencing civil aviation safety (Cui and Li, 2015).

Several scientific methods have been applied to evaluate airline safety, for example, statistical modeling based on the Poisson process (Janic, 2000), Trend extrapolation models (Li et al., 2009), Bayesian belief networks (BBN) (Brooker, 2011), Data envelopment analysis (DEA) (Cui and Li, 2015), and multi-attribute decision making (MADM) methods (Chang and Yeh, 2004; Deng et al., 2007; Hsu et al., 2010; Liou et al., 2007, 2008).

We use a combination of Fuzzy DEA and Fuzzy MADM methods for measuring the safety efficiency of airlines in this article. In the next section, a brief review of the literature on MADM, DEA and their combination applications in the airline safety field are discussed.

2.1. Airline safety measurement using MADM

Multi-attribute decision making (MADM) is regarded as a practical approach for ranking a finite number of alternatives involving multiple conflicting criteria (Hwang and Yoon, 2012). With respect to the importance of decision-making in usual human tasks and MADM efficiency, different methods are developed and used in many research areas (Tzeng and Huang, 2011a; Zavadskas et al., 2014). Since different dimensions and measures are used for evaluating safety levels (Chang and Yeh, 2004), MADM is a popular method for measuring airline safety performance. MADM methods such as AHP (Chen and Chen, 2012; Yang and Deyi, 2000); Fuzzy TOPSIS (Deng et al., 2007); DEMATEL (Liou et al., 2008); and DANP (Hybrid DEMATEL and ANP) (Hsu et al., 2010; Liou et al., 2007), were used for this purpose. Keshavarz Ghorabaee et al. (2017), integrated a simulation-based assignment approach with a hybrid decision-making approach, to evaluate the performance of five various airline centres based on twenty-eight predefined criteria and the ideas of fifty-eight experts. They employed a combination of TOPSIS, COPRAS, WASPAS[7] and EDAS[8] methods to prioritize alternatives based on a predefined simulation

[1] CCSD: Correlation coefficient (CC) and standard deviation (SD).
[2] QSPM: Quantitative Strategic Planning Matrix.
[3] Simple additive weighting (SAW).
[4] VIšekriterijumsko kOmpromisno rangiranje (VIKOR).
[5] Fuzzy additive ratio assessment (ARAS-F).
[6] Fuzzy complex proportional assessment (COPRAS_F).
[7] Weighted Aggregated Sum Product Assessment (WASPAS).
[8] Evaluation Based on Distance from Average Solution (EDAS).