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A fuzzy AHP-DEA approach for multiple criteria ABC inventory classification

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ABSTRACT

In order to efficiently control the inventory items and determine the suitable ordering policies for them, multi-criteria ABC inventory classification, which is one of the most common techniques of production and inventory control, is used. In this classification, other criteria in addition to annual dollar usage are taken into account and then the items are classified in three classes with different ordering policies, based on their priority. In this paper, we propose an integrated fuzzy analytic hierarchy process-data envelopment analysis (FAHP-DEA) for multiple criteria ABC inventory classification. The proposed FAHP–DEA methodology uses the FAHP to determine the weights of criteria, linguistic terms such as Very High, High, Medium, Low and Very Low to assess each item under each criterion, the data envelopment analysis (DEA) method to determine the values of the linguistic terms, and the simple additive weighting (SAW) method to aggregate item scores under different criteria into an overall score for each item. The integrated FAHP–DEA methodology is illustrated using a real case study.

1. Introduction

In an organization, even with small size, hundreds of items may be held in a warehouse. Controlling all these items by means of tight ordering policies is not rational in terms of both economy and time limitation and will be resulted in complexity the work of managers and extra costs. In addition, adopting the inexact ordering policies for items with high priority may be faced the stock-out of inventory, thereby losing the market share. On the other hands, the tight ordering policies for items with low priority will generate high inspection costs, and as a consequence, the additional costs will be imposed into the inventory system of organization. Thus, an efficient ordering policy, in view of the priority of item, is always making attempts to solve these two situations in such a way that minimizes the holding and inspection costs of inventory on the one hand, and prevents stock-out caused by lack of inventory on the other hand. To achieve such a success, the classifying items inside the groups with different priority should first be acted and then, suitable ordering policies should be adopted for each group. ABC classification is one of the most common techniques of classification, dividing items into 3 classes, namely, A (very important), B (moderately) and C (least important), based on Pareto principle. Traditional ABC (TABC) only uses the criterion of annual dollar usage, but many papers have mentioned that in addition to this criterion, such other criteria as ordering cost, criticality of part, lead time, commonality, obsolescence, reparability, number of requests, scarcity, durability, perish ability, reparability, demand distribution, stock ability are also needed for classification (Chen, Li, Kilgour, & Hipel, 2008; Cohen & Ernst, 1988; Flores & Whybark, 1986, 1987; Ng, 2007; Partovi & Anandarajan, 2002; Ramanathan, 2006; Zhou & Fan, 2007; Hadi-Vencheh, 2010). Depending on the nature of items and industry, these criteria have different weights. In the real world, prioritizing of the weights of criteria is always as subjective. In other words, depending on the conditions governing on industry and market, inventory managers assign different weights to the criteria. For example, when the suppliers ensure that they will provide the required items in due time, the weight of criterion of lead time is lower than other criteria in their opinion. Also, the importance of criteria differs for different industries. For a perishable item relating to food industry, expiration date is an important criterion, whereas it may not be very important for the vehicle parts manufactures. Thus, we need a model that, on the one hand, meets these needs and, on the other hand, any number of qualitative criteria can be added to that for classification.

A great article has been written on Multiple Criteria ABC (MC-ABC) classification with their points of strenghts and weakness. Flores and Whybark (1986, 1987) proposed the bi-criteria matrix approach, wherein annual dollar usage by a joint-criteria matrix is combined with another criterion. Though this approach is interesting, it accompanies some limitations. Their approach can not use three or more criteria to classify inventory items and also weights of all criteria taken into account equal. Chen et al. (2008) proposed a case-based distance model for multiple criteria ABC

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analysis, which their approach has been arisen from Flores et al. method (Flores & Whybark, 1986, 1987). Advantage of this model is that is easily considered any finite number of criteria for classification. In this model, criteria weights and sorting thresholds are generated mathematically based on the decision maker's assessment of a set the cases. But information cases are very important and if this information is incorrect affect process of classification other items, also its learning may be difficult for the average manager. Partovi and Anandarajan (2002) proposed an artificial neural network (ANN) approach for inventory classification. In their approach two type of learning method, namely back propagation and generic algorithms are used to examine the ANN classification power and then their results are compared with together. Their approach finds and bringing out nonlinear relationships and interactions between criteria. However, as authors have asserted, number of criteria are restricted, also entering many qualitative criteria into model may be difficult and in addition, learning their meta-heuristics approach is difficult for inventory managers. Ramanathan (2006) proposed a weighted linear optimization model for multiple criteria ABC inventory classification, where performance score of each item obtained using a DEA-like model. However his model may result in a position in which an item with a high value in an unimportant criterion is inappropriately classified as class A. This drawback was rectified by Zhou and Fan (2007) via obtaining most favorable and least favorable scores for each item. Ng (2007) proposes a weighted linear model for MC-ABC inventory classification. Via a proper transformation, the Ng-model can obtain the scores of inventory items without a linear optimizer. The Ng-model is simple and easy to understand. Despite its many advantages, Ng-model leads to a situation which the weight of an item may be ignored. To overcome this drawback Hadi-Vencheh (2010) proposed a simple nonlinear programming model which determines a common set of weights for all the items.

Inventory classification is essentially a multiple criteria decision making (MCDM) problem, which involve multiple assessment criteria such as annual dollar usage, average unit cost, lead time and so on. Therefore, MCDM approaches can be used for inventory classification. Of the MCDM approaches, the analytic hierarchy process (AHP) method is particularly suitable for modeling qualitative criteria and has found extensive applications in a wide variety of areas such as selection, evaluation, planning and development, decision making forecasting, and so on. However, due to the fact that there are tenths or hundreds of items to be evaluated and prioritized, while the AHP method can only compare a very limited number of decision alternatives, the pair-wise comparison manner is obviously infeasible in this situation. To overcome this difficulty, we combine the AHP with the data envelopment analysis (DEA) and propose an integrated AHP–DEA methodology in this paper. On the other hand, fuzzy variables are highly suitable for expressing of decision makers' subjective judgments on the issues which have both qualitative and quantitative variables. These variables apply fuzzy numbers for prioritizing and ranking. In this paper, these variables are used to prioritize criteria, and ranking the items, in view of the measures of a portion of items with respect to the criterion, a suitable linguistic variable is selected. For example, for classification of items, if the measure of an item is high for the annual dollar usage (refer to Section 4.4.2), it is said that the measure of this item is high. As we will see, in the discussion of MC-ABC classification, using the fuzzy variable, especially to assert the measure of the qualitative criteria, will contribute to the inventory mangers' decision-making.

This paper is organized as follows. In Section 2, we give a brief description of the fuzzy set theory and provide a ground for the later development of methodology. In Section 3, we develop an integrated FAHP–DEA methodology for the MCDM problems with a large number of decision alternatives. Section 4 presents an application of the proposed FAHP–DEA methodology to a real case study. Section 5 concludes.

2. Fuzzy sets theory

Theory of fuzzy sets is quite similar to man's attitude when facing uncertainties to express inaccurate words, such as "approximately", "very", "nearly", etc. as well as for consistency with subjective judgments of different people due to various interpretations from a subject. Zadeh (1965) introduced fuzzy sets theory for the first time, expressing it in the issue of decision-making. In fuzzy sets, membership degree of an element is between 0 and 1, while in classic sets, there are two states: an element with the degree 1 is inside the set, or it is not with degree 0. In order to elaborate on the said matter, consider the discussion in this paper, in which MC-ABC inventory classification is carried out using inventory managers' subjective judgments and introducing fuzzy concepts of prioritizing the criteria. To achieve these ends, fuzzy set, fuzzy numbers and linguistic variables should first be introduced (Chen, 2000; Kaufmann & Gupta, 1991; Zadeh, 1965; Zimmermann, 1987, 1991).

Definition 2.1. A fuzzy set $\widetilde{A}$ in a universe of discourse X is defined by a membership function $\mu_{\widetilde{A}}(x)$ which associates $\forall x \in X$ a real number in the interval [0,1]. $\mu_{\widetilde{A}}(x)$ express membership degree of x in $\widetilde{A}$.

Definition 2.2. The α-cut of fuzzy set $\widetilde{A}$ is a crisp set $\widetilde{A}_\alpha = \{x|\mu_{\widetilde{A}}(x) \geqslant \alpha\}$. The support $\widetilde{A}$ is the crisp set $Supp(\widetilde{A}) = \{x|\mu_{\widetilde{A}}(x) \geqslant 0\}$. $\widetilde{A}$ is normal if and only if $Supp_{x \in X}\mu_{\widetilde{A}}(x) = 1$.

Definition 2.3. A fuzzy subset $\widetilde{A}$ of universe set X is convex if and only if $\mu_{\widetilde{A}}(\lambda x + (1-\lambda)y) \geqslant \min(\mu_{\widetilde{A}}(x), \mu_{\widetilde{A}}(y)),\ \forall x, y \in X,\ \lambda \in [0,1]$, where min denotes the minimum operator.

Definition 2.4. $\widetilde{A}$ is a fuzzy number if and only if $\widetilde{A}$ is normal and convex fuzzy set of X.

Definition 2.5. A triangular fuzzy number $\widetilde{A}$ is defined with piecewise linear membership function $\mu_{\widetilde{A}}(x)$ as follow:

$$\mu_{\widetilde{A}}(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ \frac{a_3-x}{a_3-a_2}, & a_2 \leqslant x \leqslant a_3, \\ 0, & \text{otherwise}, \end{cases}$$

And as a triplet (a_1,a_2,a_3) is indicated, where a_1, a_3 the lower and upper bounds respectively, and a_2 is the most likely value of $\widetilde{A}$.

Definition 2.6. A positive trapezoidal fuzzy number $\widetilde{C}$ can be defined as (a_1,a_2,a_3,a_4) and its membership function is defined as

$$\mu_{\widetilde{C}}(x) = \begin{cases} 0, & x \leqslant a_1, \\ \frac{x-a_1}{a_2-a_1}, & a_1 \leqslant x \leqslant a_2, \\ 1, & a_2 \leqslant x \leqslant a_3, \\ \frac{a_4-x}{a_4-a_3}, & a_3 \leqslant x \leqslant a_4, \\ 0, & a_4 \geqslant x, \end{cases}$$

Definition 2.7. Let $\widetilde{A} = (a_1, a_2, a_3)$ and $\widetilde{B} = (b_1, b_2, b_3)$ be two positive triangular fuzzy numbers and r be a positive real number. Then, sum, multiplication, subtraction, distance and inversion of these two triangular fuzzy number is defined as follow