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A classification approach based on the outranking model for multiple criteria ABC analysis ☆

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ABSTRACT

The multiple criteria ABC analysis is widely used in inventory management, and it can help organizations to assign inventory items into different classes with respect to several evaluation criteria. Many approaches have been proposed in the literature for addressing such a problem. However, most of these approaches are fully compensatory in multiple criteria aggregation. This means that an item scoring badly on one or more key criteria could be placed in good classes because these bad performances could be compensated by other criteria. Thus, it is necessary to consider the non-compensation in the multiple criteria ABC analysis. To the best of our knowledge, the ABC classification problem with non-compensation among criteria has not been studied sufficiently. We thus propose a new classification approach based on the outranking model to cope with such a problem in this paper. However, the relational nature of the outranking model makes the search for the optimal classification solution a complex combinatorial optimization problem. It is very time-consuming to solve such a problem using mathematical programming techniques when the inventory size is large. Therefore, we combine the clustering analysis and the simulated annealing algorithm to search for the optimal classification. The clustering analysis groups similar inventory items together and builds up the hierarchy of clusters of items. The simulated annealing algorithm searches for the optimal classification on different levels of the hierarchy. The proposed approach is illustrated by a practical example from a Chinese manufacturer. Furthermore, we validate the performance of the approach through experimental investigation on a large set of artificially generated data at the end of the paper.

1. Introduction

The efficient control of inventory can help firms improve their competitiveness [42]. As a basic methodology, the ABC analysis is widely used to manage a number of inventory items in organizations. The ABC analysis helps an inventory manager to divide the inventory items into three classes according to specific criteria. That is, items of high value but small in number are termed as class A, items of low value but large in number are termed as class C, and items that fall between these two classes are termed as class B. The ABC analysis provides a mechanism for identifying items that will have a significant impact on overall inventory cost while providing a method for pinpointing different categories of inventory that will require different management and control policies.

The traditional ABC classification method considers only one criterion, i.e., the annual dollar usage, to classify inventory items. This method is successful only when inventory items are fairly homogeneous and the main difference among items is in their annual dollar usages [36]. In practice, some organizations, such as P&G, Lenovo, and ZTE, have to control thousands of inventory items that are not necessarily homogeneous. Thus, the traditional ABC analysis may be counterproductive in real-world classification of inventory items. It has been recognized that other criteria, such as inventory cost, part criticality, lead time, commonality, obsolescence, substitutability, durability, repairability, and so on, are also important for inventory classification [21,33,36]. To solve such a multiple criteria ABC inventory classification (MCABC) problem, a great variety of methods has been proposed during the past decades. Bhattacharya et al. [3], Rezaei and Dowlatshahi [37], and Torabi et al. [44] have provided comprehensive reviews on the various MCABC approaches in the literature.

Despite the advantages of these approaches, it should be noted that most of them are fully compensatory in multiple criteria aggregation, i.e., a significantly weak criterion value of an item could be directly compensated by other good criteria values. Thus,

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an item scoring badly on one or more key criteria may be placed in good classes. Such classification may not be reasonable in some real-world applications because organizations do not need to manage these items that score badly on key criteria with more efforts and control. Therefore, it is necessary to consider the non-compensation in the multiple criteria ABC analysis. From our point of view, not enough attention has been paid to the MCABC problem with the non-compensation among criteria. Some exceptions include the studies developed by Zhou and Fan [45], Hadi-Vencheh [22], and Lolli et al. [29].

In this paper, we propose an alternative approach based on the outranking relation defined in ELECTRE [15] for the MCABC problem when the non-compensation among criteria should be considered. ELECTRE is a family of multiple criteria decision analysis methods that highlight the limited possibility of compensation through the construction of the outranking relation using tests of concordance and discordance [16]. Concerning the concordance test, the fact that item a outranks or does not outrank item b is only relevant to how much the performances of a are better or worse than the performances of b on the criteria. With regard to the discordance test, the existence of veto thresholds strengthens the non-compensation effect in ELECTRE methods. When the difference between the evaluations of a and b on a certain criterion is greater than the veto threshold, then no improvement of the performance of b or no deterioration of the performance of a, with respect to other criteria, can compensate this veto effect.

In the proposed approach, taking into account the requirement of the ABC analysis, the cardinality limitation of items in each class is specified in advance. We define an inconsistency measure based on the outranking relation and an average distance between items based on the multiple criteria distance to evaluate the classification. We pursue to find a solution that minimizes the two evaluation indices. Due to the relational nature of the outranking model, the search for the optimal classification is a complex combinatorial optimization problem. It is very time-consuming to solve such a problem using mathematical programming techniques, especially for large-size problems. In this paper, we combine the clustering analysis and the simulated annealing algorithm to search for the optimal classification. The clustering analysis aims to identify and group similar items into clusters. An agglomerative hierarchy clustering algorithm is employed to construct the hierarchy of the identified clusters. The hierarchy of clusters permits the search for the optimal classification to proceed on different levels of granularity. In the developed simulated annealing algorithm, the search for the optimal classification is performed according to the hierarchy of clusters from top to bottom. Such a combination of the two basic methods provides a tool to solve the combinatorial optimization problem in an efficient way.

Our work can be regarded as a new method of building the preference order of the identified clusters for the MCABC problem. Over the past few years, several similar techniques have been proposed for the clustering problem. Fernandez et al. [14], De Smet et al. [11], and Meyer and Olteanu [31] all combined an outranking model with a metaheuristic algorithm to explore the preference relation between clusters. Compared with these existing approaches, our work highlights the idea of “progressive refinement”, which is reflected in the hierarchy of clusters and the search strategy. Moreover, our algorithm can escape from a local optimum and avoid premature convergence, which is implemented by accepting a worse solution with a certain probability. Moreover, the cardinality of items in each class is incorporated into our algorithm, and we can specify the cardinality limitation in advance.

The approach presented in this paper is distinguished from the previous MCABC methods by the following new features. First, the non-compensation among criteria is considered in the MCABC problem. We develop an outranking-based classification model that limits the compensation among criteria. Second, the clustering analysis is incorporated into the ABC classification process. The clustering analysis groups similar items together and builds up the hierarchy of clusters. It permits a search for the optimal classification on different levels of granularity, and it contributes to simplifying the complex combinatorial optimization problem. Third, a simulated annealing algorithm is developed to search for the optimal solution according to the constructed hierarchy of clusters. The algorithm solves the combinatorial optimization problem efficiently, especially when the inventory size is large.

The remainder of this paper is organized as follows. In Section 2, we provide a literature review on the MCABC problem. In Section 3, we give a brief introduction to the outranking relation in the ELECTRE method and the multiple criteria distance. In Section 4, we combine the multiple criteria clustering analysis and the simulated annealing algorithm to address the MCABC problem. Section 5 demonstrates the approach using an example. Section 6 compares the approach with another two heuristic algorithms. The paper ends with conclusions and discussion regarding future research.

2. Literature review

The ABC analysis has been a hot topic of numerous studies on inventory management. Since Flores and Whybark [17,18] first stressed the importance of considering multiple criteria in the ABC analysis, various approaches for addressing the MCABC problem have been proposed in the literature. The existing work can be classified into the following six categories: (a) AHP [40], (b) artificial intelligence technique, (c) statistical analysis, (d) Data Envelopment Analysis (DEA)-like approaches [8], (e) weighted Euclidean distance-based approaches, and (f) UTADIS method [12].

Many researchers have applied the analytic hierarchy process (AHP) to the MCABC problem [19,34,35,4,29]. The basic idea is to derive the weights of inventory items by pairwise comparing the criteria and inventory items. However, the most important problem associated with AHP is the subjectivity of the decision maker (DM) involved in the pairwise comparisons. Moreover, when the number of criteria increased, the consistency of judgment will be very sensitive, and reaching a consistent rate will be very difficult.

Several approaches based on artificial intelligence techniques have also been applied to the MCABC problem. Güvenir [20] and Güvenir and Erel [21] proposed an approach based on genetic algorithm to learn criteria weight vector and cut-off points between classes A and B and classes B and C. Güvenir and Erel [21] reported that the approach based on genetic algorithm performed better than that based on the AHP method. Partovi and Anandarajan [33] applied artificial neural networks in the MCABC problem. They used backpropagation (BP) and genetic algorithm in their approach and brought out non-linear relationships and interactions between criteria. The approach was compared with the multiple discriminant analysis technique and the results showed that the approach had a higher predictive accuracy than the discriminant analysis. Tsai and Yeh [43] proposed a particle swarm optimization approach for the MCABC problem. In this approach, inventory items are classified based on a specific objective or on multiple objectives.

Statistical techniques, such as clustering analysis and principle component analysis, are also applied to the MCABC problem. Cluster analysis is to group items with similar characteristics together. Cohen and Ernst [9] and Ernst and Cohen [13] proposed an approach based on cluster analysis for the MCABC problem. The approach uses a full combination of strategic and operational attributes. Lei et al. [28] combined the principle component analysis with artificial neural networks and the BP algorithm to classify inventory items. The hybrid approach can overcome the