The evaluation of financial performance for Taiwan container shipping companies by fuzzy TOPSIS

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A B S T R A C T

In this paper, financial performance of Taiwan container shipping companies are evaluated by fuzzy multi-criteria decision-making (FMCDM). In the evaluating problem, we first apply grey relation analysis to partition financial ratios into several clusters and find representative indices from the clusters. Then the representative indices are considered as evaluation criteria on financial performance assessment of Taiwan container shipping companies, and an FMCDM method called fuzzy technique for order preference by similarity to ideal solution (fuzzy TOPSIS) is utilized to evaluate financial performance. By fuzzy TOPSIS, financial performances of container shipping companies are ranked, and thus a container shipping company can realize its finance competitive strength and weakness between container shipping companies.

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1. Introduction

Financial performance is critical in shipping companies, especially for container shipping ones, because they need large capitals to operation. In Taiwan, the main container shipping companies are respectively Evergreen, Yang-Ming and Wan-Hai. The three container shipping companies have to own some containerships and additional equipments for cargo transportation, whereas the machines and tools take them giant capitals. Based on the idea, a container shipping company should evaluate the financial performance which directly influences the survival of the company. To evaluate financial performance of container shipping companies, evaluation criteria are grasped from financial ratios [34]. The financial ratios are usually from balance sheet, income statement and cash flow. However, some of financial ratios are similar on identified patterns. To avoid evaluating similar financial ratios repeatedly, financial ratios will be partitioned into several clusters, and a representative index is selected from a cluster to be as an evaluation criterion [7–11,13,17,19,20,28,31]. Then an proper method will be applied to evaluate the financial performance of container shipping companies.

In Taiwan, there are three major container shipping companies for stock market. Data is little and distribution is unknown on finance for the three companies, so the classical clustering methods are not adequate. To match scarce data and unknown distribution, we utilize grey relation analysis [6] to cluster financial ratios and then find representative indices to be evaluation criteria. The financial performance evaluation problem with some criteria belongs to multi-criteria decision-making (MCDM) ones [15,18]. Additionally, financial performances of container shipping companies are evaluated in recent five periods. These ratios in the five periods are aggregated into fuzzy numbers for reserving messages, and thus the evaluation problem will be a fuzzy multi-criteria decision-making (FMCDM) one [1–3,14,16,21–27,29,30,32,33]. A FMCDM method called fuzzy technique for order preference by similarity to ideal solution (fuzzy TOPSIS) [35] is used to evaluate the financial performance of Taiwan container shipping companies. By fuzzy TOPSIS, the evaluation problem of financial performance of Taiwan container shipping companies is easily solved.

For the sake of clarity, representative indices found by grey relation analysis are presented in Section 2. Notions of fuzzy sets and fuzzy numbers are displayed in Section 3. The FMCDM method is presented in Section 4. Finally, an empirical example of three container shipping companies in Taiwan is illustrated in Section 5.

2. Financial ratios and representative indices for container shipping companies

In accounting aspect, financial ratios are usually classified into some categories [11,34] because accounting experts suppose that financial ratios within a cluster are partially similar. Likewise,
the financial ratios of container shipping companies are originally divided into following categories shown in Table 1.

In addition to fixed assets to stockholder’s equity ratio, debt to total assets ratio and accounts payable turnover belong to cost criteria, the other ratios are benefit criteria for above table.

Based on entries of Table 1, we apply grey relation analysis to partition financial ratios into several clusters and then find representative indices being criteria from clusters to evaluate financial performances of container shipping companies. Grey relation analysis is from grey system theory introduced by Deng [6]. Greyness fundamental definition is the information being incomplete or unknown, and thus an element from an incomplete message is considered as grey elements. Grey relation analysis is a method to measure relation between grey elements, and definitions of clustering financial ratios are stated below.

Assume that m companies financial performances with t periods are evaluated based on s financial ratios. Let \( x_i = (x_i(k)|k=1, 2, \ldots, mt) \in X \) denote sequences of financial ratio \( i \) constructed on m companies in t periods for \( i = 1, 2, \ldots, s \). \( X \) is a set composed of all financial ratios. For being consistent and monotonically increasing [36–38], financial ratios are normalized in two different situations.

As \( x_i (k) \) belongs to benefit items, \( y_i(k) = \frac{x_i(k)}{\sqrt{\sum_{q=1}^{mt}[x(q(k))^2]}}, \) otherwise \( x_i (k) \) belongs cost items, \( y_i(k) = \frac{1}{\sqrt{\sum_{q=1}^{mt}[1/x(q(k))^2]}}, \)

where \( y_i(k) \) is normalized value of financial ratio \( i \) on item \( k \), \( k = 1, 2, \ldots, s \). \( Y \) being a factor set of grey relation is a set consisting of all normalized financial ratios. Let \( y_0 \in Y \) represent referential sequence, and \( y_i \in Y \) represent comparative sequence, \( y_0 (k) \) and \( y_i (k) \) indicate the financial ratio values of \( y_0 \) and \( y_i \) on item \( k \) respectively. Then average relation value \( r(y_0, y_i) \) of a set \( (r(y_0(k), y_i(k))) | k = 1, 2, \ldots, mt \) is a real number and defined by grey relation in the following. Let

\[
r(y_0, y_i) =\frac{1}{mt}\sum_{k=1}^{mt} r(y_0(k), y_i(k)) = \rho_{0i},
\]

where

\[
r(y_0, y_i(k)) = \frac{\min_{j}|y_0(k) - y_i(k)| + \max_{j}|y_0(k) - y_i(k)|}{|y_0(k) - y_i(k)|}
\]

and \( \zeta \in [0,1] \) is a distinguished coefficient.

By grey relation analysis, we obtain a grey relation matrix \( R = (r_{ij}) \), where \( i = 1, 2, \ldots, s \) and \( j = 1, 2, \ldots, s \). Definition of clustering financial ratios through entries of the grey relation matrix is displayed below.

**Definition 2.1.** If \( r_{ij} \geq r \) and \( r_{ji} \geq r \) then \( Y_i \) and \( Y_j \) are within a cluster, where \( r \) is a threshold value of clustering.

**Definition 2.2.** If \( r_{ij} \geq r \), \( r_{ji} \geq r \), \( r_{ik} \geq r \), \( r_{jk} \geq r \), but \( r_{jk} < r \) or \( r_{ik} < r \), in case \( \min \{r_{ik}, r_{jk}\} \geq \min \{r_{ij}, r_{ji}\} \), \( Y_i \) and \( Y_j \) are clustered into a cluster.

After partitioning financial ratios into several clusters through above definitions, finding of representative indices from clusters is presented in following definitions.

**Definition 2.3.** As \( Y_i \) and \( Y_j \) belong to a cluster, representative index of the cluster is found according to the maximum value of \( r_{ij} \) and \( r_{ji} \). If \( r_{ij} \geq r_{ji} \), representative index of the cluster is financial ratio \( i \).

**Definition 2.4.** As \( Y_i \), \( Y_j \) and \( Y_k \) are within a cluster, representative index of the cluster is found according to the maximum value of \( r_{ij} + r_{ji} + r_{ik} \) and \( r_{jk} + r_{kj} \). In case \( r_{jk} + r_{kj} \) is the maximum value, the representative index of the cluster is financial ratio \( i \).

Sometimes, there are four or more financial ratios in a cluster. Thus Definition 2.5 is proposed for this situation.

**Definition 2.5.** \( T \) is a set composed of four or more financial ratios, and \( Y_i \) belongs to a cluster \( T \). Representative index of the cluster is financial ratio \( i \) if \( \sum_{k \neq i} r_{iq} \geq \sum_{k \neq i} r_{iq} \), for all \( k \in T \) and \( k \neq i \).

### 3. Basic notions of fuzzy sets and fuzzy numbers

In this section, we review some basic notions of fuzzy sets and fuzzy numbers [39–41] expressed in the following:

**Definition 3.1.** Let \( U \) be a universe set. A fuzzy set \( A \) of \( U \) is defined by a membership function \( \mu_A(x) \rightarrow [0,1] \), where \( \mu_A(x), \forall x \in U \), indicates the degree of \( x \) in \( A \).

**Definition 3.2.** A fuzzy set \( A \) of universe set \( U \) is normal iff \( \text{sup}_{x \in U} \mu_A(x) = 1 \).

**Definition 3.3.** A fuzzy set \( A \) of universe set \( U \) is convex iff \( \mu_A(\alpha x + (1 - \alpha)y) \geq \mu_A(x) \land \mu_A(y) \), \( \forall x, y \in U \land \forall \alpha \in [0,1] \), where \( \land \) denotes the minimum operator.

**Definition 3.4.** A fuzzy set \( A \) is a fuzzy number iff \( A \) is normal and convex of \( U \).

**Definition 3.5.** A triangular fuzzy number \( A \) shown in Fig. 1 is a fuzzy number with piecewise linear membership function \( \mu_A \) defined by

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