



## APPLYING FUZZY MCDM FOR FINANCIAL PERFORMANCE EVALUATION OF IRANIAN COMPANIES

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Received 02 July 2013; accepted 13 July 2013

**Abstract.** Financial performance evaluation is very important in a highly competitive business environment. Accordingly, an accurate and appropriate performance evaluation is critical. Financial performance indicators reflect the competitiveness of a company and they must be carefully identified in the evaluation process. Generally, accounting measures are used for performance evaluation. However, these measures are not sufficient for performance evaluation in the today's competitive economy. Therefore, value based measures have recently been introduced to express the company value. In this study, a hybrid approach is proposed for financial performance evaluation of automotive companies of Tehran stock exchange (TSE). For this purpose, a hierarchical financial performance evaluation model is structured based on the accounting measures and economic value measures. In this approach Fuzzy Analytic Hierarchy Process (FAHP) is applied to determine weights of criteria. Then the companies are ranked by using Fuzzy VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje (in Serbian), Fuzzy Additive Ratio Assessment (ARAS-F) and Fuzzy Complex Proportional Assessment (Fuzzy COPRAS), simultaneously. Also results of three outranking methods are combined by using the mean ranks. The results represented the highest importance of economic value measures than accounting measures in financial performance evaluation of companies. Six companies were ranked applying the proposed approach.

**Keywords:** financial performance, accounting measures, economic value measures, Fuzzy Analytic Hierarchy Process (FAHP), Fuzzy VlseKriterijumska Optimizacija I Kompromisno Resenje (Fuzzy VIKOR), Fuzzy Additive Ratio Assessment (ARAS-F), Fuzzy Complex Proportional Assessment (Fuzzy COPRAS).

**Reference** to this paper should be made as follows: Safaei Ghadikolaei, A.; Khalili Esbouei, S.; Antucheviciene, J. 2014. Applying fuzzy MCDM for financial performance evaluation of Iranian companies, *Journal of Technological and Economic Development of Economy* 20(2): 274–291.

**JEL Classification:** C02, C44, C81, D46, D81, M41.

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## Introduction

In a competitive environment, characterized by the scarcity of resources, performance measurement and management play a crucial role (Amado *et al.* 2012). Accordingly, an accurate and appropriate performance evaluation is very crucial.

Financial aspect is one of the main aspects of the organization performance. Traditionally it should be attractive. Seeing that profit is the main goal of many companies, financial performance and proper evaluation is very important. As financial performance indicators reflect the competitiveness of a company, they must be carefully identified in the evaluation process (Yalcin *et al.* 2012).

Most of the economical, industrial, financial or political decision problems are multi attribute. Multiple Criteria Decision Making (MCDM) is an advanced field of operation research. It provides decision makers and analysts with a wide range of methodologies, which are overviewed and well-suited to the complexity of economical decision problems (Zavadskas, Turskis 2011). The application of multi-criteria decision making methods significantly improves the robustness of financial analysis and business decisions in general (Balezentis *et al.* 2012).

In the current research a new multiple criteria model, consisting of Accounting measures and Economic value measures is presented, also a hybrid approach of MCDM methods in fuzzy environment for financial performance evaluation of companies is provided. At first FAHP (Fuzzy Analytic Hierarchy Process) is used to determine the weights of the main criteria and sub criteria. Then fuzzy VIKOR (Fuzzy VlseKriterijumska Optimizacija I Kompromisno Resenje), ARAS-F (Fuzzy Additive Ratio Assessment) and fuzzy COPRAS (Fuzzy Complex Proportional Assessment) are applied simultaneously for ranking the automotive companies traded on Tehran stock exchange in 2002–2011. Final ranking of companies is provided by using mean ranks.

## 1. Literature review

Several studies on financial performance evaluation are focused on ranking the alternatives according to their financial performance measures, included in their comparison environments. Kung *et al.* (2011) applied fuzzy MCDM methods for selecting the best company, based on financial report analysis. The approach used FAHP to select weighting indicators and fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) for outranking the five major airlines. Balezentis *et al.* (2012) used fuzzy TOPSIS, fuzzy VIKOR and ARAS-F methods for integrated assessment of Lithuanian economy in 2007–2010 periods, based on financial ratios. Ergul and Seyfullahogullari (2012) applied ELECTRE III for ranking of retail companies trading in Istanbul stock exchange (ISE), based on their financial performance in 2008–2010. Lee *et al.* (2012) performed a comparative study on financial positions of shipping companies in Taiwan and Korea. At first the study applied Entropy to find the relative weights of financial ratios of four companies, and then it used grey relation analysis to rank the companies. Yalcin *et al.* (2012) constructed a hierarchical structure of the financial performance model for ISE's manufacturing company. The approach used FAHP, VIKOR and

TOPSIS. Bayrakdaroglu and Yalcin (2012) proposed to use MCDM for strategic financial performance evaluation of ISE. The research applied FAHP for determining the relative significances of criteria and used VIKOR for best company selection. Ignatius *et al.* (2012) surveyed financial performance of Iran's Automotive Sector based on PROMETHEE II in the study. Cheng *et al.* (2012) developed an approach combining fuzzy integral with Order Weight Average (OWA) method for evaluating financial performance in the semiconductor industry of Taiwan in 2008. Cement firms are evaluated by taking into consideration only some of the traditional financial performance measures.

Recent studies on the subject are summarized in Table 1.

Table 1. Comparison of the previous studies that have used MCDM methods for financial performance evaluation

| Study                              | Objectives  | Methods used                          | Approach used  |
|------------------------------------|---|---------------------------------------|--|
| Kung <i>et al.</i> (2011)          | Select the best company, based on financial report analysis                 | FAHP, fuzzy TOPSIS                    | Used FAHP to determine indicators' weights and the fuzzy TOPSIS method for outranking the five major airlines    |
| Balezentis <i>et al.</i> (2012)    | Integrated assessment of Lithuanian economy                                 | Fuzzy TOPSIS, fuzzy VIKOR, ARAS-F     | Applied fuzzy TOPSIS, fuzzy VIKOR and ARAS-F together for evaluation of economic sector                          |
| Ergul and Seyfullahogullari (2012) | Ranking of retail companies trading in ISE                                  | ELECTRE III                           | Used ELECTRE III for ranking five retail companies in Turkey   |
| Yalcin <i>et al.</i> (2012)        | Financial performance evaluation of Turkish manufacturing company           | FAHP, VIKOR, TOPSIS                   | Combined FAHP to determine the weights of criteria, also VIKOR and TOPSIS for comparatively ranking of companies |
| Bayrakdaroglu and Yalcin (2012)    | Strategic financial performance evaluation of ISE                           | FAHP, VIKOR                           | Used FAHP for calculate the relative importance measures and VIKOR to select the best company                    |
| Ignatius <i>et al.</i> (2012)      | Financial performance of Iran's automotive sector                           | PROMETHEE II                          | PROMETHEE II was used to select the best company   |
| Cheng <i>et al.</i> (2012)         | Evaluating of financial performance in the semiconductor industry of Taiwan | Fuzzy Integral, OWA                   | Combined fuzzy integral with Order Weight Average for financial evaluation                                       |
| Lee <i>et al.</i> (2012)           | Survey of financial positions of shipping companies in Taiwan and Korea     | Entropy, Grey Relation Analysis (GRA) | Used Entropy for determining the weights of criteria and GRA to rank the company                                 |

## 2. Proposed model

A new multi criteria model, consisting of Accounting measures and Economic value measures is developed with help of the financial experts and presented in the current study. A combinative approach of MCDM methods in Fuzzy environment for financial performance evaluation of companies also provided.

Yalcin *et al.* (2012) constructed hierarchal structure for financial evaluation of manufacturing company on the ground of value based financial performance and accounting based financial performance as main criteria and each having four sub criteria. The model proposed by the Authors differs from Yalcin *et al.* (2012) model. The proposed model is shown in Figure 1. In this model, four Accounting measures are determined by the finance and Tehran stock exchange expert as the sub-criteria. These measures are Return On Assets (ROA), Return On Equity (ROE), Operating Profit Growth (OPG), also ratio of market price and earnings (P/E). Also, seven Economic value measures are determined as the sub-criteria. These measures are Economic Value Added (EVA), Market Value Added (MVA), Refined Economic Value Added (REVA), True Value Added (TVA), Cash Value Added (CVA), Created Shareholder Value (CSV) and Tobin's Q. Formulation of these sub-criteria measures are briefly explained in the Table 2.

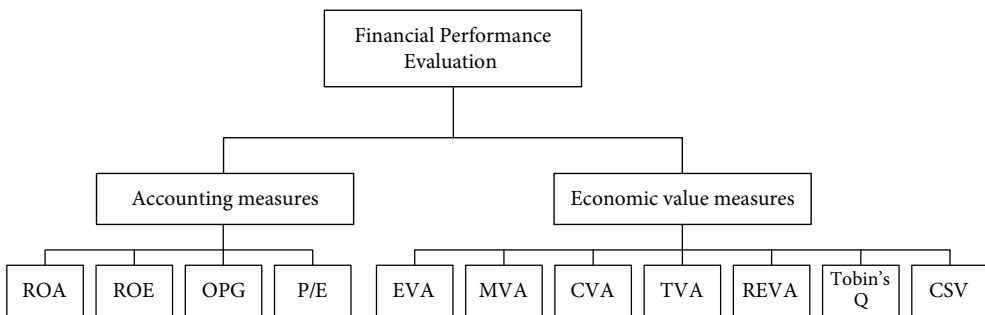


Fig. 1. Hierarchal model for financial performance evaluation of TSE's company

Table 2. Formulation of financial performance evaluation measures

| Financial performance measures | Formula  | Study                              |
|--------------------------------|--|------------------------------------|
| Return On Assets (ROA)         | $ROA = \frac{\text{Net income available to common stockholder}}{\text{Total assets}}$  | Yalcin <i>et al.</i> (2012)        |
| Return On Equity (ROE)         | $ROE = \frac{\text{Net income available to common stockholder}}{\text{Stockholder's equity}}$  | Yalcin <i>et al.</i> (2012)        |
| Operating Profit Growth (OPG)  | $OPG = \frac{(\text{Operationg profit})_t - (\text{Operationg profit})_{t-1}}{(\text{Operationg profit})_{t-1}}$                     | Ergul and Seyfullahogullari (2012) |
| P/E                            | $\frac{P}{E} = \frac{\text{Market price per share}}{\text{Earning per share}}$   | Yalcin <i>et al.</i> (2012)        |
| Economic Value Added (EVA)     | $EVA_t = \text{Net operating profit after tax}_t - (\text{Weighted average cost of capital}_t \times \text{Capital employed}_{t-1})$ | Yalcin <i>et al.</i> (2012)        |
| Market Value Added (MVA)       | $MVA = \text{Total market value} - \text{Total capital employed}$  | Bayrakdaroglu and Yalcin (2012)    |
| Cash Value Added (CVA)         | $CVA = \text{Gross Cash flows} - \text{Economic depreciation} - \text{Capital charge}$   | Yalcin <i>et al.</i> (2012)        |

Continued Table 2

| Financial performance measures      | Formula   | Study                           |
|-------------------------------------|---|---------------------------------|
| True Value Added (TVA)              | $TVA = \text{Free cash flow} + \text{Capital gains} - \text{Market value} \times (1 + \text{Weighted average cost of capital})$ | Bayrakdaroglu and Yalcin (2012) |
| Refined Economic Value Added (REVA) | $REVA_t = \text{Net operating profit after tax}_t - \text{Weighted average cost of capital} (M_{\text{capital}_{t-1}})$         | Hajiabasi et al. (2012)         |
| Tobin's Q                           | $Tobin's Q = \frac{\text{Market value} + \text{Book value of Liabilities}}{\text{Book value of assets}}$                        | Jones et al. (2011)             |
| Created Shareholder Value (CSV)     | $CSV = \text{Market value of equity} \times (\text{Shareholder return} - \text{Cost of equity})$                                | Largani et al. (2012)           |

### 3. MCDM methods

MCDM is an advanced field of Operation Research that provides decision makers and analysts with a wide range of methodologies, well-suited to the complexity of economical decision problems. Available methodologies and their application for economic decisions are broadly overviewed by Zavadskas and Turskis (2011).

In the presented study four fuzzy MCDM methods were used and applied for evaluation of TSE's companies. At first FAHP was used to determine weights of main criteria and sub criteria. Next the research used fuzzy VIKOR, ARAS-F and fuzzy COPRAS for ranking the companies according to best financial performance.

#### 3.1. Fuzzy Analytic Hierarchy Process (FAHP)

Analytic Hierarchy Process (AHP) was introduced by Saaty (1971). In the current research the weights of financial performance criteria are obtained by using extent FAHP method. That is because of the computational easiness and efficiency (Yalcin et al. 2012).

Calculation of FAHP can be described as follows.

Assume that  $O = \{o_1, o_2, o_3, \dots, o_n\}$ , be an object set, and  $G = \{g_1, g_2, g_3, \dots, g_m\}$ , be a goal set. Each object is taken and extent analysis for each goal is performed, respectively. Therefore,  $m$  extent analysis values for each object can be obtained, with the following signs:  $\tilde{Q}_{g_i}^1, \dots, \tilde{Q}_{g_i}^2, \dots, \tilde{Q}_{g_i}^m$ ,  $i = 1, 2, \dots, \alpha$ , where all the  $\tilde{Q}_{g_i}^m$  ( $j = 1, 2, \dots, m$ ) are triangular fuzzy numbers (TFNs).

The further steps of extent FAHP can be given as follows.

**Step 1.** The value of fuzzy synthetic extent with respect to the  $i^{\text{th}}$  object is defined as:

$$\tilde{S}_i = \sum_{j=1}^m \tilde{Q}_{g_i}^j \otimes \left[ \sum_{i=1}^n \sum_{j=1}^m \tilde{Q}_{g_i}^j \right]^{-1}, \tag{1}$$

perform the fuzzy addition operation of  $\beta$  extent analysis values for particular matrix such that:

$$\sum_{j=1}^m \tilde{Q}_{g_i}^j = \left( \sum_{j=1}^m l_j, \sum_{j=1}^m m_j, \sum_{j=1}^m u_j \right), \tag{2}$$

and to obtain  $\left[ \sum_{i=1}^n \sum_{j=1}^m \tilde{Q}_{g_i}^j \right]^{-1}$ , perform the fuzzy addition operation of  $\tilde{Q}_{g_i}^j$  ( $j = 1, 2, \dots, \beta$ ) values such that:

$$\sum_{i=1}^{\alpha} \sum_{j=1}^{\beta} \tilde{Q}_{g_i}^j = \left( \sum_{i=1}^{\alpha} l_i, \sum_{i=1}^{\alpha} m_i, \sum_{i=1}^{\alpha} u_i \right). \tag{3}$$

Then the inverse of the vector above is computed:

$$\left[ \sum_{i=1}^{\alpha} \sum_{j=1}^{\beta} \tilde{Q}_{g_i}^j \right]^{-1} = \left( \frac{1}{\sum_{i=1}^{\alpha} u_i}, \frac{1}{\sum_{i=1}^{\alpha} m_i}, \frac{1}{\sum_{i=1}^{\alpha} l_i} \right). \tag{4}$$

**Step 2.** As  $\tilde{Q}_1 = (l_1, m_1, u_1)$  and  $\tilde{Q}_2 = (l_2, m_2, u_2)$  are two triangular fuzzy numbers, the degree of possibility of  $\tilde{Q}_2 \geq \tilde{Q}_1$  defined as:

$$V(\tilde{Q}_2 \geq \tilde{Q}_1) = \sup_{y \geq x} \left[ \min(\mu_{\tilde{Q}_1}(x), \mu_{\tilde{Q}_2}(y)) \right], \tag{5}$$

and can be equivalently expressed as follows:

$$V(\tilde{Q}_2 \geq \tilde{Q}_1) = \text{hgt}(\tilde{Q}_1 \cap \tilde{Q}_2) = \mu_{\tilde{Q}_2}(d) = \begin{cases} 1, & \text{if } m_2 \geq m_1 \\ 0, & \text{if } l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{O.W} \end{cases}, \tag{6}$$

where  $d$  is the ordinate of the highest intersection point  $D$  between  $\mu_{\tilde{Q}_1}$  and  $\mu_{\tilde{Q}_2}$  (Fig. 2).

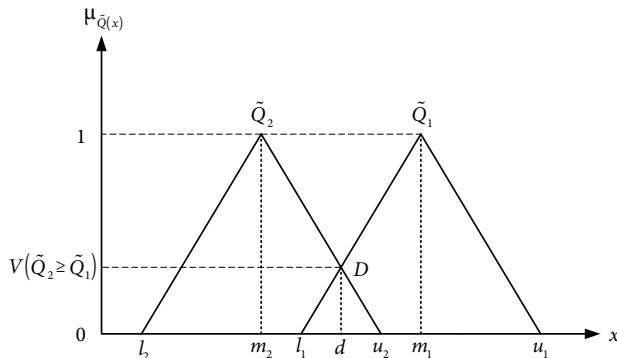


Fig. 2. The intersection between  $\tilde{Q}_1$  and  $\tilde{Q}_2$

To compare  $\tilde{Q}_1$  and  $\tilde{Q}_2$ , we need both values of  $V(\tilde{Q}_1 \geq \tilde{Q}_2)$  and  $V(\tilde{Q}_2 \geq \tilde{Q}_1)$ .

**Step 3.** The degree possibility for a convex fuzzy number to be greater than  $k$  convex fuzzy  $\tilde{Q}_i$  ( $i = 1, 2, \dots, k$ ) numbers can be defined by:

$$V(\tilde{Q} \geq \tilde{Q}_1, \tilde{Q}_2, \dots, \tilde{Q}_k) = V\left[\left(\tilde{Q} \geq \tilde{Q}_1\right) \text{ and } \left(\tilde{Q} \geq \tilde{Q}_2\right) \dots \text{ and } \left(\tilde{Q} \geq \tilde{Q}_k\right)\right] = \min V(\tilde{Q} \geq \tilde{Q}_i), i = 1, 2, 3, \dots, k. \tag{7}$$

Assume that  $d'(P_i) = \min V(S_i \geq S_k)$  for  $k = 1, 2, \dots, n; k \neq i$ . Then the weight vector is given by:

$$W' = \left(d'(P_1), d'(P_2), \dots, d'(P_n)\right)^T, \tag{8}$$

where  $P_i$  ( $i = 1, 2, \dots, n$ ) are  $n$  elements.

**Step 4.** Via normalization, the normalized weight vectors are:

$$W = \left(d(P_1), d(P_2), \dots, d(P_n)\right)^T, \tag{9}$$

where  $W$  is a non-fuzzy number.

### 3.2. Fuzzy MCDM outranking methods

In this study three fuzzy outranking methods are used. Let us assume the fuzzy decision making matrix  $\tilde{D} = \tilde{d}_{ij}$ , where  $i = 1, 2, \dots, m$  and  $j = 1, 2, \dots, n$  represent the number of alternatives and criteria, respectively. In this study  $m = 6$  and  $n = 11$ . The  $j^{\text{th}}$  criterion of the  $i^{\text{th}}$  alternative is represented by triangular fuzzy number  $\tilde{d}_{ij} = (d_{ij_1}, d_{ij_2}, d_{ij_3})$ . Also each  $j^{\text{th}}$  criterion is assigned with respective coefficient of significance  $\tilde{w}_j$ , that it obtained by FAHP. Benefit criteria are members of benefit criteria set  $B$ , while cost criteria are members of respective set  $C$ .

#### 3.2.1. Fuzzy VIKOR

Based on crisp VIKOR that was introduced by Opricovic (1998), also Opricovic and Tzeng (2004), fuzzy VIKOR was developed later and presented in many studies (Antucheviciene et al. 2011, 2012; Chou, Cheng 2012; Vinodh et al. 2013). VIKOR is based on measuring the closeness to the ideal alternative according to separate cases of  $L_p$  metric (Balezentis et al. 2012). Computing of fuzzy VIKOR consists of following steps:

**Step 1.** The fuzzy best values  $\tilde{f}_j^+$  and the fuzzy worst values  $\tilde{f}_j^-$  are found:

$$\begin{aligned} \tilde{f}_j^+ &= \max_i \tilde{d}_{ij}, & \tilde{f}_j^- &= \min_i \tilde{d}_{ij}, \forall j \in B, \\ \tilde{f}_j^+ &= \min_i \tilde{d}_{ij}, & \tilde{f}_j^- &= \max_i \tilde{d}_{ij}, \forall j \in C. \end{aligned} \tag{10}$$

**Step 2.** The distances of each alternative from the ideal one are determined:

$$\tilde{S}_i = \sum_{j=1}^n \tilde{w}_j (\tilde{f}_j^+ - \tilde{d}_{ij}) / (\tilde{f}_j^+ - \tilde{f}_j^-), \forall i; \tag{11}$$

$$\tilde{R}_i = \max \left[ \tilde{w}_j (\tilde{f}_i^+ - \tilde{d}_{ij}) / (\tilde{f}_j^+ - \tilde{f}_j^-) \right], \forall i. \tag{12}$$

**Step 3.** The reference point is defined by computing values of  $\tilde{S}^+$ ,  $\tilde{S}^-$ ,  $\tilde{R}^+$ , and  $\tilde{R}^-$ , which, in turn, enable to obtain the final summarizing ratio  $\tilde{Q}_i$  :

$$\tilde{S}^+ = \min_i \tilde{S}_i, \tilde{S}^- = \max_i \tilde{S}_i, \tilde{R}^+ = \min_i \tilde{R}_i, \tilde{R}^- = \max_i \tilde{R}_i; \tag{13}$$

$$\tilde{Q}_i = v(\tilde{S}_i - \tilde{S}^+) / (\tilde{S}^- - \tilde{S}^+) + (1 - v)(\tilde{R}_i - \tilde{R}^+) / (\tilde{R}^- - \tilde{R}^+), \forall i. \tag{14}$$

**Step 4.** Defuzzifying triangular fuzzy numbers  $\tilde{S}_i$ ,  $\tilde{R}_i$ , and  $\tilde{Q}_i$  into crisp values. A center of area (COA) defuzzification method is used to determine the best non-fuzzy performance (BNP). The BNP value of the triangular fuzzy number  $(l_i, m_i, u_i)$  can be found by the following equation:

$$BNP_i = \frac{l_i + m_i + u_i}{3}, \forall i. \tag{15}$$

**Step 5.** Ranking the alternatives, sorting by the values  $S_i$ ,  $R_i$  and  $Q_i$ , in decreasing order. The results are three ranking lists.

**Step 6.** Proposing as a compromise solution, for given criteria weights, the alternative ( $a'$ ), which is the best ranked by the measure  $Q$  if the following two conditions are satisfied:

**C1. “Acceptable advantage”:**  $Q(a'') - Q(a') \geq DQ$ , where  $a''$  is the alternative with second position in the ranking list by  $Q$ ;  $DQ = \frac{(\max_i Q_i - \min_i Q_i)}{m - 1}$ ;  $m$  is the number of alternatives (Chou, Cheng 2012).

**C2. “Acceptable stability in decision making”:** Alternative  $a'$  must also be the best ranked by  $S$  or/and  $R$ . This compromise solution is stable within a decision making process, which could be: “voting by majority rule” (when  $v > 0.5$  is needed), or “by consensus”  $v \approx 0.5$ , or “with veto” ( $v < 0.5$ ). Here,  $v$  is the weight of the decision making strategy “the majority of criteria” (or “the maximum group utility”).

If one of the conditions is not satisfied, then the set of compromise solutions is proposed, which consists of:

Alternatives  $a'$  and  $a''$ , if only the condition C2 is not satisfied;

Alternatives  $a', a'', \dots, a^{(k)}$ , if the condition C1 is not satisfied;  $a^{(k)}$  is determined by the relation  $Q(a^{(k)}) - Q(a') \approx DQ$ , the positions of these alternatives are “in closeness”.

### 3.2.2. ARAS-F

The ARAS-F is based on comparing every alternative with the hypothetical ideal one (Turskis, Zavadskas 2010; Kersuliene, Turskis 2011; Balezentis *et al.* 2012). The calculation steps of ARAS-F are as presented below.

**Step 1.** In this method the ideal alternative is described in the following way:

$$\tilde{d}_{0j} = \max_i d_{ij3}, \forall j \in B, \quad \tilde{d}_{0j} = \min_i d_{ij1}, \forall j \in C. \tag{16}$$



**Step 2.** The normalized values  $\bar{d}_{ij}$  are obtained:

$$\begin{aligned} \bar{d}_{ij} &= \frac{\tilde{d}_{ij}}{\sum_{i=0}^m \tilde{d}_{ij}}, \forall j \in B, \\ \bar{d}_{ij} &= \frac{1/\tilde{d}_{ij}}{\sum_{i=0}^m 1/\tilde{d}_{ij}}, \forall j \in C. \end{aligned} \tag{17}$$

**Step 3.** Each  $\bar{d}_{ij}$  is weighted by computing elements of the weighted-normalized matrix:

$$\hat{d}_{ij} = \bar{d}_{ij} \times \tilde{w}_j, \forall j, i, \tag{18}$$

where  $\tilde{w}_j$  is coefficient of significance and  $\hat{d}_{ij}$  is the weighted-normalized value of the  $j^{\text{th}}$  criterion of the  $i^{\text{th}}$  alternative.

The overall utility  $\tilde{S}_i$  of the  $i^{\text{th}}$  alternative is computed in the following way:

$$\tilde{S}_i = \sum_{j=1}^n \hat{d}_{ij}, \forall i. \tag{19}$$

Since  $\tilde{S}_i = (s_{i1}, s_{i2}, s_{i3})$ ,  $i = 0, 1, \dots, m$ , is a fuzzy number, the COA method is applied for defuzzification:

$$S_i = \frac{s_{i1} + s_{i2} + s_{i3}}{3}, \forall i. \tag{20}$$

Finally, the relative utility of the  $i^{\text{th}}$  alternative  $K_i$  is found:

$$K_i = \frac{S_i}{S_0}, \forall i, \tag{21}$$

where  $K_i \in [0,1]$ . The best alternative is found by maximizing value of  $K_i$ .

### 3.2.3. Fuzzy COPRAS

COPRAS method was first put forward by Zavadskas and Kaklauskas (1996). Fuzzified COPRAS was presented by Zavadskas and Antucheviciene (2007). It is used to prioritize the alternatives on the basis of several criteria along with the associated criteria weights. This method works on a stepwise ranking and evaluation procedure of the alternatives in terms of their significance and utility degree. Crisp or modified method for uncertain environment has been successfully applied in for maintenance strategy or performance evaluation, for selection of effective decisions in construction or management (Yazdani et al. 2011; Kanapeckiene et al. 2011; Fouladgar et al. 2012; Tamosaitiene, Gaudutis 2013; Das et al. 2012; Mulliner et al. 2013; Staniunas et al. 2013; Palevicius et al. 2013).

Calculations of fuzzy COPRAS can be described as follows:

**Step 1.** Normalize the values of  $\tilde{d}_{ij}$  by using the following formula:

$$\bar{d}_{ij} = \frac{\tilde{d}_{ij}}{\sum_{i=1}^m \tilde{d}_{ij}}, \forall j. \tag{22}$$

**Step 2.** Determine the weighted normalized decision matrix:

$$\hat{d}_{ij} = \bar{d}_{ij} \times \tilde{w}_j, \forall j, i, \tag{23}$$

where  $\bar{d}_{ij}$  is the normalized performance value of  $i^{\text{th}}$  alternative on  $j^{\text{th}}$  criteria and  $w_j$  is the associated weight of the  $j^{\text{th}}$  criteria.

**Step 3.** The sums  $S_i^+$  and  $S_i^-$  of weighted normalized values are calculated for both beneficial and non-beneficial criteria, respectively. For benefit criteria, higher value is better and for cost criteria, lower value is better for the attainment of goal.  $S_i^+$  and  $S_i^-$  are calculated using the following equations:

$$\begin{aligned} \tilde{S}_i^+ &= \sum_{j=1}^k \hat{d}_{ij}, \forall j \in B, \\ \tilde{S}_i^- &= \sum_{j=K+1}^k \hat{d}_{ij}, \forall j \in C. \end{aligned} \tag{24}$$

**Step 4.** Determine the relative importance or priorities of the candidate alternative by the following equation:

$$\tilde{H}_i = \tilde{S}_i^+ + \frac{\sum_{i=1}^m \tilde{S}_i^-}{\tilde{S}_i^- \sum_{i=1}^m \frac{1}{\tilde{S}_i^-}}, \forall i. \tag{25}$$

**Step 5.** Since  $\tilde{H}_i = (h_{i1}, h_{i2}, h_{i3}), i = 0, 1, \dots, m$ , is a fuzzy number, the COA method is applied for defuzzification:

$$H_i = \frac{h_{i1} + h_{i2} + h_{i3}}{3}, \forall i, \tag{26}$$

where the relative importance  $H_i$  of an alternative shows the extent of satisfaction attained by that alternative. Among the alternatives, one with the highest  $H_i$  value is the best alternative.

**Step 6.** Calculate the performance index ( $PI_i$ ) of each alternative as:

$$PI_i = \frac{H_i}{H_{\max}} \cdot 100\%. \tag{27}$$

Here  $H_{\max}$  is the maximum value of relative importance.  $PI_i$  value is utilized to get complete ranking of the alternatives.

#### 4. Applications of the proposed approach

The aim of this study is to present a fuzzy approach to evaluate the financial performance of the companies in the Iran, traded on TSE, by using both Accounting measures and Economic value measures together and in a fuzzy environment. This approach was applied for evaluation of automotive companies of TSE in 2002–2011, i.e. in a period of ten years. Six companies were selected for this study. For this period of the research, annual financial statements of companies which passed independent external auditing are considered. Data was gathered from the TSE’s Database and using Rahavard Novin software.

**4.1. Determining the weights of criteria**

To evaluate the importance of the main criteria and sub-criteria and compose the fuzzy pairwise matrix, expert group (decision makers) utilized the membership function of linguistic scale. The scale is presented in Table 3.

Table 3. Membership function of linguistic scale (Chou, Cheng 2012)

| Linguistic scale      | Positive triangular fuzzy numbers | Positive reciprocal triangular fuzzy numbers |
|-----------------------|-----------------------------------|--|
| Absolutely importance | (8, 9, 10)                        | (1/10, 1/9, 1/8)                             |
| Intermediate          | (7, 8, 9)                         | (1/9, 1/8, 1/7)                              |
| Very strongly         | (6, 7, 8)                         | (1/8, 1/7, 1/6)                              |
| Intermediate          | (5, 6, 7)                         | (1/7, 1/6, 1/5)                              |
| Strong                | (4, 5, 6)                         | (1/6, 1/5, 1/4)                              |
| Intermediate          | (3, 4, 5)                         | (1/5, 1/4, 1/3)                              |
| Weakly                | (2, 3, 4)                         | (1/4, 1/3, 1/2)                              |
| Intermediate          | (1, 2, 3)                         | (1/3, 1/2, 1)                                |
| Equally importance    | (1, 1, 1)                         | (1, 1, 1)                                    |

The pairwise comparison scores have been carried out by financial experts. Experts were asked to make pairwise comparisons for all evaluation criteria based on Table 2. In this study for testing the consistency ratio (CR) of fuzzy pairwise matrix, Lin (2010) approach was used. If the CR is greater than 0.1, the result is not consistent, and the pair-wise comparison matrix must be revised by the evaluator. Let  $\tilde{R} = [\tilde{r}_{ij}]$  be a fuzzy judgment matrix with triangular fuzzy number  $\tilde{r}_{ij} = (l_{ij}, m_{ij}, u_{ij})$  and form  $R = [m_{ij}]$ . If  $R$  is consistent, then  $\tilde{R}$  is consistent (Lin 2010).

After computing the result of each evaluator’s assessment, Lin (2010) approach was used to obtain the consistency ratio of each expert’s pare wise matrix. Consistency ratio values are less than the acceptable threshold value (i.e.  $CR < 0.1$ ).

The overall results were obtained by taking the geometric mean of individual evaluations. Combined pairwise matrix of main criteria with their weights from FAHP is shown in Table 4.

Table 4. The fuzzy evaluation matrix with respect to the goal

|                         | Accounting measures      | Economic value measures  | Weights |
|-------------------------|--------------------------|--------------------------|---------|
| Accounting measures     | (1, 1, 1)                | (0.3102, 0.4518, 0.8409) | 0.2332  |
| Economic value measures | (1.1892, 2.2134, 3.2237) | (1, 1, 1)                | 0.7668  |

With respect to the results, Economic value measures are more important than Accounting measures in financial performance evaluation of TSE’s companies. Table 5 shows the weights of the sub criteria were obtained by FAHP. *CVA*, *TVA*, *REVA* have highest weight among sub criteria, respectively, so TSE’s companies should Pay special attention to this measures about their financial performance.

Table 5. Weights of sub criteria obtained from FAHP

| Sub criteria | Local Weights | Total Weights | Rank |
|--------------|---------------|---------------|------|
| ROA          | 0.2431        | 0.0567        | 10   |
| ROE          | 0.2089        | 0.0487        | 11   |
| OPG          | 0.2689        | 0.0627        | 9    |
| P/E          | 0.2791        | 0.0651        | 8    |
| EVA          | 0.1040        | 0.0797        | 6    |
| MVA          | 0.1359        | 0.1042        | 4    |
| CVA          | 0.1823        | 0.1398        | 1    |
| TVA          | 0.1764        | 0.1353        | 2    |
| REVA         | 0.1668        | 0.1279        | 3    |
| Tobin's Q    | 0.1031        | 0.0791        | 7    |
| CSV          | 0.1315        | 0.01008       | 5    |

#### 4.2. Ranking the alternatives

The following approach was used for convert crisp numbers of financial measures into fuzzy numbers. As for time series data, when  $x_{ij}$  is the value of  $j^{\text{th}}$  criterion of  $i^{\text{th}}$  alternative in each year (2002–2011), a fuzzy number can represent the dynamics of certain indicator during past  $t = 10$  periods (Balezentis *et al.* 2012):

$$\left( \text{Min}(x_{ij}), \frac{\sum_{i=1}^{10} x_{ij}}{10}, \text{Max}(x_{ij}) \right), \forall i, \forall j. \tag{28}$$

Let us assume  $\tilde{C}_{ij} = (c_{ij_1}, c_{ij_2}, c_{ij_3})$  are the initial values of each criterion, obtained using Eq. (28). As some of values in each criterion were negative, for preventing of any problem in computation, all the values in each criterion are transformed to positive values by the following equation:

$$\tilde{d}_{ij} = (c_{ij_1} - \min c_{ij_1} + 1, c_{ij_2} - \min c_{ij_2} + 1, c_{ij_3} - \min c_{ij_3} + 1), \forall i, \forall j. \tag{29}$$

Indeed the above equation is the same as  $\tilde{d}_{ij} = (d_{ij_1}, d_{ij_2}, d_{ij_3})$  in the computation steps of methods.

As it was mentioned, six Iranian automotive companies are analysed. Initial data on their financial performance measurements is presented in Annex 1.

At first fuzzy VIKOR is used to rank the companies. Usually in other studies, the value of  $\nu$  is considered 0.5, but in this study different values of  $\nu$  are considered and ranking of Q was obtained from average of different values of Q. Table 6 shows the results of fuzzy VIKOR with different values of  $\nu$ .

Table 6. The results of fuzzy VIKOR

| Company | $\nu = 0$<br>$Q_i$ | $\nu = 0.25$<br>$Q_i$ | $\nu = 0.5$<br>$Q_i$ | $\nu = 0.75$<br>$Q_i$ | $\nu = 1$<br>$Q_i$ | Average Rank |
|---------|--------------------|-----------------------|----------------------|-----------------------|--------------------|--------------|
| IKCO    | 0.8853             | 0.7994                | 0.7134               | 0.6275                | 0.5415             | 2.4          |
| KAV     | 1.3953             | 1.4116                | 1.4279               | 1.4442                | 1.4604             | 6            |
| PKO     | 1.3705             | 1.3155                | 1.2604               | 1.2054                | 1.1503             | 5            |
| SIPA    | 1.1878             | 1.1183                | 1.0488               | 0.9793                | 0.9098             | 4            |
| RENA    | 0.0021             | 0.0022                | 0.0023               | 0.0024                | 0.0026             | 1            |
| BHMN    | 0.7393             | 0.7493                | 0.7593               | 0.7693                | 0.7793             | 2.6          |

| Ranking results |                          |        |      |        |      |
|-----------------|--------------------------|--------|------|--------|------|
| Company         | Rank obtained from $Q_i$ | $S_i$  | Rank | $R_i$  | Rank |
| IKCO            | 2                        | 1.4078 | 2    | 0.8199 | 3    |
| KAV             | 6                        | 1.9485 | 6    | 0.8634 | 4    |
| PKO             | 5                        | 1.7295 | 5    | 0.8780 | 5    |
| SIPA            | 4                        | 1.7112 | 4    | 0.8901 | 6    |
| RENA            | 1                        | 0.8693 | 1    | 0.2764 | 1    |
| BHMN            | 3                        | 1.4827 | 3    | 0.6463 | 2    |

As one can see from the Table 6, RENA has the minimum score with respect to the  $Q$  values, also conditions of Acceptable advantage and Acceptable stability in decision making are satisfied by this alternative. Accordingly, RENA is chosen as the best company in terms of financial performance among other companies.

Table 7 shows the results obtained from ARAS-F and fuzzy COPRAS together. In this proposed model all the criteria are of benefit, while for applying COPRAS a cost criterion is necessary. Hence values of one criterion ( $OPG$ ) for all alternatives have been reversed for feasibility of using fuzzy COPRAS method for this study.

Table 7. The results of ARAS-F and fuzzy COPRAS

| Company | $K_i$  | Rank | $H_i$  | $PI_i$ | Rank |
|---------|--------|------|--------|--------|------|
| IKCO    | 0.3251 | 2    | 0.2384 | 57.05  | 2    |
| KAV     | 0.0760 | 5    | 0.0772 | 18.48  | 5    |
| PKO     | 0.0624 | 6    | 0.0734 | 17.56  | 6    |
| SIPA    | 0.2118 | 3    | 0.1834 | 43.90  | 4    |
| RENA    | 0.4104 | 1    | 0.4178 | 100.00 | 1    |
| BHMN    | 0.1706 | 4    | 0.1930 | 46.19  | 3    |

As it shown, RENA is the best company with respect to the financial performance among automotive companies traded on TSE in 2002–2011.

Finally, for composing the final order of priority among all alternatives, average of obtained ranks of the three methods has been considered. Table 8 shows the final ranks of the companies.

Table 8. Final Rankings of the companies

| Company | Fuzzy VIKOR | ARAS-F | Fuzzy COPRAS | Average Rank | Final Ranks |
|---------|-------------|--------|--------------|--------------|-------------|
| IKCO    | 2           | 2      | 2            | 2            | 2           |
| KAV     | 6           | 5      | 5            | 5.33         | 5           |
| PKO     | 5           | 6      | 6            | 5.67         | 6           |
| SIPA    | 4           | 3      | 4            | 3.67         | 4           |
| RENA    | 1           | 1      | 1            | 1            | 1           |
| BHMN    | 3           | 4      | 3            | 3.33         | 3           |

## Conclusions

Financial ratios provide useful quantitative financial information about performance of a company. In this context, this study displays a fuzzy hybrid approach for the financial performance evaluation of companies.

In the proposed approach, at first FAHP is used to determine the weights of the main-criteria and also sub-criteria. Then fuzzy VIKOR, ARAS-F and fuzzy COPRAS are used for ranking the companies based on financial performance, simultaneously. Finally, by combining the results of these three methods via mean ranks, final ranking of the companies can be presented.

In today's world economy, good financial situations provide company's competitive advantage. Many studies in the literature involving MCDM procedures use only the traditional financial ratios. In this study both of Accounting measures and Economic value measures have been used for financial performance evaluation. Results showed that Economic value measures are more important than Accounting measures for companies' evaluation. Also, to achieve better performance evaluation, companies should pay more attention to CVA, TVA, REVA and other measures in line with calculated their relative significances.

A case study of automotive parts producer companies traded on TSE in 2002–2011 is presented. The proposed approach is applied for measuring financial performance of companies in uncertain environment with respect to multiple criteria.

Further study can include some other Economic value measures like shareholder value added (SVA), equity economic value added (EEVA) and other for performance measures. In addition to the proposed methods in this study, some other MCDM methods can be used in this area.

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**ANNEX 1.**

Initial data for fuzzy MCDM implementation for financial performance measures of companies

| Companies | Economic value measures       |                                |                                 |                    |                     |
|-----------|-------------------------------|--------------------------------|---------------------------------|--------------------|---------------------|
|           | CVA (mln. IRR*)               | EVA (mln. IRR)                 | MVA (mln. IRR)                  | Tobin's Q          |                     |
| IKCO      | (1; 6676345; 19386085)        | (1151005; 5814877; 10735632)   | (2995114; 10991575; 23923765)   | (1.03; 1.21; 1.64) |                     |
| KAV       | (1141978; 2726328; 4233550)   | (649871; 1348592; 2065734)     | (3360439; 4718970; 6528396)     | (1; 1.16; 1.51)    |                     |
| PKO       | (1466459; 3214814; 4296745)   | (704625; 948637; 1215284)      | (3391226; 4489809; 5998817)     | (1.11; 1.34; 1.75) |                     |
| SIPA      | (4011568; 10796070; 17324195) | (438828; 2403779; 4797621)     | (1; 11296067; 25376019)         | (1.22; 1.76; 3.29) |                     |
| RENA      | (2698054; 16835140; 73758751) | (1; 958242; 1455259)           | (3268146; 5332461; 7218471)     | (1.22; 2.43; 5.80) |                     |
| BHMIN     | (727230; 5754355; 26599228)   | (472085; 825119; 1647045)      | (3706467; 2726328; 10928858)    | (1.57; 2.23; 3.76) |                     |
|           |                               |                                |                                 |                    | CSV (mln. IRR)      |
| IKCO      | (7306087; 9610754; 12755448)  | (5423593; 21322844; 27770850)  | (47094486; 63223227; 131121457) |                    |                     |
| KAV       | (6636993; 8610637; 9253876)   | (29576630; 31134860; 33655814) | (56091123; 58005205; 61485912)  |                    |                     |
| PKO       | (8013380; 8896032; 9381532)   | (29109228; 30410458; 32000762) | (52998354; 57440769; 59821396)  |                    |                     |
| SIPA      | (1; 5325172; 9706911)         | (1; 14918929; 31757275)        | (1; 54554376; 119760813)        |                    |                     |
| RENA      | (5798266; 8419043; 9614870)   | (27594800; 29824510; 31821233) | (54197129; 58614863; 64847896)  |                    |                     |
| BHMIN     | (6222600; 8853049; 10683371)  | (19911498; 27440943; 34812535) | (50904915; 59186347; 76083196)  |                    |                     |
|           |                               |                                |                                 |                    | Accounting measures |
|           |                               |                                |                                 |                    | ROE                 |
| IKCO      | (122.11; 143.86; 158.48)      | (9.63; 13.38; 16.89)           | (1.55; 3.72; 8.51)              | (3.40; 4.04; 5.72) |                     |
| KAV       | (1.00; 130.45; 202.82)        | (1.00; 12.16; 17.10)           | (1.00; 3.65; 9.30)              | (2.87; 3.77; 4.41) |                     |
| PKO       | (114.39; 181.40; 382.74)      | (9.54; 16.04; 26.26)           | (1.34; 5.30; 13.71)             | (1.00; 3.62; 4.83) |                     |
| SIPA      | (122.63; 168.24; 363.51)      | (10.34; 26.65; 40.13)          | (1.32; 3.01; 7.16)              | (3.02; 4.09; 6.22) |                     |
| RENA      | (115.26; 142.75; 204.92)      | (15.64; 29.64; 50.75)          | (1.60; 3.74; 7.26)              | (3.27; 3.94; 5.75) |                     |
| BHMIN     | (124.67; 136.57; 176.48)      | (17.39; 22.34; 31.99)          | (1.34; 3.29; 9.65)              | (3.05; 3.90; 6.33) |                     |
|           |                               |                                |                                 |                    | P/E                 |
| IKCO      | (122.11; 143.86; 158.48)      | (9.63; 13.38; 16.89)           | (1.55; 3.72; 8.51)              | (3.40; 4.04; 5.72) |                     |
| KAV       | (1.00; 130.45; 202.82)        | (1.00; 12.16; 17.10)           | (1.00; 3.65; 9.30)              | (2.87; 3.77; 4.41) |                     |
| PKO       | (114.39; 181.40; 382.74)      | (9.54; 16.04; 26.26)           | (1.34; 5.30; 13.71)             | (1.00; 3.62; 4.83) |                     |
| SIPA      | (122.63; 168.24; 363.51)      | (10.34; 26.65; 40.13)          | (1.32; 3.01; 7.16)              | (3.02; 4.09; 6.22) |                     |
| RENA      | (115.26; 142.75; 204.92)      | (15.64; 29.64; 50.75)          | (1.60; 3.74; 7.26)              | (3.27; 3.94; 5.75) |                     |
| BHMIN     | (124.67; 136.57; 176.48)      | (17.39; 22.34; 31.99)          | (1.34; 3.29; 9.65)              | (3.05; 3.90; 6.33) |                     |

\*(1 EUR = 16280 IRR).

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