Original Paper

Comparison of Multi Criteria Decision Making Methods SAW and ARAS: An Application to Performance of Indian Pharmaceutical Companies

Dr. A.Vijayakumar[1*]

[1] Associate Professor and Head, Department of Commerce, Erode Arts and Science College, Erode-638009, Tamilnadu, India

[*] Dr. A.Vijayakumar, Associate Professor and Head, Department of Commerce, Erode Arts and Science College, Erode-638009, Tamilnadu, India

Abstract

While assessing the performances of companies, the decision makers to take not only a single criterion for making the right decisions in to account, but also a number of other relevant criteria that could affect the performance. Because when it is necessary to make the best selection among several option, Multiple-Criteria Decision Making (MCDM) methods are used. This study is to provide insight in to the applicability of method Simple Additive Weightings Method (SAW) and Additive Ratio Assessment (ARAS) method under MCDM techniques to evaluate the performance of Indian Pharmaceutical companies during the study period 2006-2019. The seventeen evaluation criteria's were used in the application. The constructed model was analysed using both SAW and ARAS method. The study results showed that the best performance belongs to Glico Smith Kline Pharma Limited in SAW method and Sun Pharmaceutical Industries Ltd in ARAS method and worst performance belongs to Ranbaxy Laboratories Limited in both methods. By comparison, both methods revealed the similar rankings of companies during the study period.

Keywords

financial performance, mcdm, saw method, aras method, Indian pharmaceutical companies, entropy method, financial soundness and firm's performance

1. Introduction

The Indian industrial sector has undergone regulatory changes as the consequences of the economic reforms between 1988 and 1991. India moved away from 'control' era towards the "open" economy model. It should bring out a dramatic change in Indian Pharmaceutical companies. Firm's performance is dependent on both financial and non-financial conditions of the firm. For this purpose, profitability, assets utilization, liquidity, working capital efficiency, long-term solvency, market value and foreign trade measures are grouped under financial indicators and other indicators such as sales and marketing strategy, consumer satisfaction, technological issues, human resources and growth variables are grouped under non-financial indicators. However, in this study, an attempt has been made to analyse the financial indicators only which help to measure the financial performance of selected Indian Pharmaceutical companies.

In many real world decision problems, a decision maker has set of multiple conflicting objectives. The decision must be compared according to many criteria (Turskis et al., 2009). The problem of a decision maker is to evaluate a finite set of alternatives in order to find the best one, to rank them from the best to worst or to describe how well each alternative meets all the criteria simultaneously (Zavadskas & Turskis, 2010). There are many methods of determining the ranking of a set of alternatives in terms of a set of decision criteria. In a multicriteria approach, the researchers to build several criteria using several views. Multi-Criteria Decision-Making(MCDM) is one of the most widely used decision methodology used in science, business and government and help to improve the quality of decisions by making the decision making process more efficient. The MCDM represents one of the fastest growing fields of operation research. It has over the time bound its application in solving various decision making problems.

2. Method

2.1 Indian Pharmaceutical Industry—Sectorial Background

In the year 1969, Indian pharmaceuticals had a 5 per cent share of the market in India and global pharma had a 95 per cent share. By 2020, Indian pharma having an almost 85 per cent share and global, 15 per cent. Over the last 50 years, Indian pharmaceutical companies have been successful in meeting the domestic needs as well as building a leading position in the global landscape. The pharmaceutical industry in India is worth about $37 billion, with exports accounting for about $18 billion. Indian pharma now ranks 3rd worldwide in volume and 13 in value. The growth rate of the industry is 13 per cent per year. Almost 70 per cent of the domestic demand for bulk drugs is catered by the Indian pharma industry. The Indian pharma industry produces around 20 per cent to 25 per cent of the global generic drugs. It is one of the biggest producers of the Active Pharmaceutical ingredients (API) in the international arena. Around 40 per cent of the total pharmaceutical produce is exported. The Indian pharma industry includes small, medium and large scaled players around 300 different companies.

India is a leading exporter of generic drugs across the globe and as demand expands across the globe, Indian pharmaceutical industry aspires to become the world's largest supplier of drugs by 2030.

Indian pharmaceutical companies played an important role in the global fight against the coronavirus pandemic that had affected over 3 million people across the world. Hydroxychloroquine has been identified by the US Food and Drug Administration as a possible treatment for the Covid-19. India, one of the largest producers of anti-malarial drug Hydroxychloroquine, has seen spurt in demand in recent weeks. India has sent the drug to over 50 countries over the last few weeks including United States. However, in the last couple of years, Indian pharma industry has faced several challenges such as higher level of customer consolidation, increased competition and number of product approvals, increased pricing control, transient impact of demonetisation and continued to face destructions from regulatory bodies. Further, our strong position as a global supplier of high quality and affordable medicines has also been impacted due to recent compliance challenges and low productivities. The profits are under severe pressure. Hence, the continued viability of Indian pharma industry is of strategic concern for the government, industry and stakeholders.

2.2 Justification for the Study

Financial performance of firms is subject to continuous monitoring. Good financial conditions leads to growth and development and guarantee satisfaction to all stakeholders. On the other hand poor performance may lead to negative consequences for the achievement of goals of all the stakeholders involved. An evaluation of financial performance is a multidimensional assessment based on multiple criteria including profitability, asset utilisation, liquidity, working capital efficiency, solvency and market value measures. For this reason, developing a ranking of entities so as to make comparisons among them by using Multiple Criteria Decision Making (MCDM). While taking a decision, there might be many alternatives with distinct criterions. The MCDM is an approach designed for the evaluation of problems with a finite or an infinite number of choices.

2.3 MCDM Methodology

The Multiple Criteria Decision Making is defined as the process of selecting one from set of available alternatives or ranking alternatives based on a set of criteria. The MCDM methods transform multiple criteria optimization in a single criterion decision-making optimization, which is much easier to solve. There are different phases in MCDM process which includes criteria weight determination, normalization, aggregation and selection. A typical MCDM problem can be presented in the following form.

$$\mathbf{D = [x_{ij}]_{mxn}} \qquad\qquad\qquad \textbf{..... (1)}$$

$$\mathbf{W = [w_j]_n} \qquad\qquad\qquad \textbf{..... (2)}$$

Where D is decision matrix, x_{ij} is performance of ith alternative with respect to j^{th} criterion, w is the weight vector, w_j is weight of jth criterion, i=1, 2, ...m; m is the number of compared alternatives, j=1,2, ...n; n is the number of criteria.

Information stored in a decision matrix expressed using different units of measure. Therefore, data should be transformed in to comparable values, using a normalization procedure. For normalization numerous procedures were given by Zavadskas and Turskis (2008). Evaluation criteria involved in the MCDM models can be classified in to two types namely; benefit criteria, i.e., the higher rating is better; and cost criteria, i.e., the lower rating is better. In MCDM, evaluation criteria usually have different importance (weights), and it is also important that weights of criteria often have a large impact on selection of the most acceptable alternative.

2.4 Literature Reviews

Several studies on financial performance evaluation are focussed on ranking the alternatives according to their financial performance measures included in their comparison environments. A number of research studies have approached various MCDM methods such as SAW, ARAS, COPRAS, MOORA, MULTIMOORA, TOPSIS AHP, PROMETHEE and so on. The comparison of above methods is given by Turskis and Zavadskas (2011), Stanujkic et al. (2013), Zavadskas et al. (2014) and Mardani et al. (2015). However in this study the SAW and ARAS method is chosen because of its simplicity compared to other MCDM methods for comparison with respect to Indian Pharmaceutical companies.

Raikar Avinash (2019) used SAW method to analyse financial performance of the selected 24 steel manufacturing firms in India over a period 2014 to 2018. The study uses 17 ratios that broadly cover profitability, solvency, stability, managerial efficiency and liquidity. These ratios are the criteria on which steel companies are evaluated by using three MCDM techniques ARAS, SAW and TOPSIS. Stanujkic et al. (2013) used SAW method in the case of ranking Serbian banks. Dedania et al. (2015) used SAW method to evaluate portfolio management for stock ranking. Zolfani et al. (2012) made an attempt to evaluate the rural ICT centres by applying Fuzzy AHP, SAW and Gand TOPSIS method. Zavadskas et al. (2010) evaluate contractor selection for construction works by applying SAW method of MCDM. Chen (2012) made an attempt for comparison of SAW and TOPSIS based on interval-valued Fuzzy sets.

The ARAS method applied to the selection of the chief accountant (Kersuliene & Turkskis 2014), measuring the quality of faculty website (Stanujkic & Jovanovic, 2012), the analysis of fuzzy multiple criteria in order to select the logistic centers location (Turskis et al. 2010b) multi criteria analysis of foundation instalment alternatives (Zavadskas et al., 2010), decision making problems with interval-valued Triangular Fuzzy numbers (Stanujkic, 2015), evaluation of microclimate in office rooms (Zavadskas & Turskis, 2010), ranking of factoring companies (Asir & Emel, 2017), ranking of Serbian Banks (Dragisa et al., 2013), financial performance of steel companies (Raikar, 2019), for determining inside climate of the premises (Zavadskas & Turskis, 2010), evaluating quality of air transport services (Bakir & Atalik, 2018), personnel selection (Karabasevic et al, 2015), selecting and ranking of the vendors (Chatterjee & Bose, 2013), evaluation of mobile banking services (Ecer, 2018), identify the indicators of corporate social responsibilities (Karabasevic et al., 2016), the status of

26

building (Kutut et al., 2013), selection of chief accountant (Kersuliene & Turskis, 2013), selection of construction project manager assessment (Zavadskas et al., 2012), comparison of different design of building (Saparauskas et al., 2011) and so on.

In literature, various types of MCDM techniques like SAW, ARAS, TOPSIS, VIKOR, GRA, ELECTREE, MOORA and PROMETHEE are used to assess the performance of manufacturing companies by using ratios derived from the information contained in the financial statement. With such an approach one of the simplest and widely used MCDM method for evaluation and ranking of alternative is Simple Additive Weighting (SAW) and Additive Ratio Assessment (ARAS) methods. Hence, in this study an attempt has been made to ranking selected Indian Pharmaceutical companies by using SAW and ARAS method.

2.5 Simple Additive Weighting (SAW) Method

Simple Additive Weighting (SAW) Method probably the simplest, best known and formerly often used MCDM method (Dragisa, 2013). The SAW method uses a simple aggregation procedure, which is presented using the following formula:

$$Q_i = \sum_{j=1}^{n} w_j r_{ij}$$

…… (3)

where Q_i is the overall ranking index of ith alternative; w_j is the weight of jth Criterion, r_{ij} is normalised the performance of ith alternative with respect of jth criterion, i=1, 2, …..m; and j=1,2, …..n.

In SAW method, the alternatives are ranked on the basis of their Q_i in ascending order, and the alternative with the highest value of Q_i is the best ranked. The best ranked, or the most preferable, alternative, based on the SAW method, A_{SAW}^* can be determined using the following formula:

$$A_{saw}^* = \left\{ A_i = \max_i Q_i \right\}$$

…… (4)

The method involves three steps:

Step 1: Construct the decision matrix with m alternative and n criterion as follows

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & & x_{mn} \end{bmatrix}$$

Where x_{ij} represents performance of ith alternative on the jth criteria; i=1,2, ...m and j=1,2, ...n

Step 2: Since the Criteria have different scales, a normalisation process is performed in order to make an evaluation. The normalised decision matrix R= [r_{ij}] $_{mxn}$ should constructed. Some of typical normalisation procedures used in the SAW method are given below.

(a) **Linear Scale Transformation—Max Method**:

$$r_{ij} = \begin{cases} x_{ij}/x_j^+ \; ; j \in \Omega_{max} \\ x_j^-/x_{ij} \; ; j \in \Omega_{min} \end{cases}$$

(b) **Linear Scale Transformation—Sum Method**:

$$r_{ij} = \begin{cases} x_{ij}/\sum_{i=1}^{n} x_{ij} \; ; \quad j \in \Omega_{max} \\ \left(\dfrac{1}{x_{ij}}\right)/\sum_{i=1}^{n} \left(\dfrac{1}{x_{ij}}\right) \; ; j \in \Omega_{min} \end{cases}$$

(c) **Vector Normalisation**:

$$r_{ij} = \begin{cases} x_{ij}/\left(\sum_{i=1}^{n} x_{ij}^2\right)^{\frac{1}{2}} \; ; \qquad j \in \Omega_{max} \\ 1 - \left(x_{ij}/\left(\sum_{i=1}^{n} x_{ij}^2\right)^{\frac{1}{2}}\right) ; \quad j \in \Omega_{min} \end{cases}$$

(d) **Linear Scale Transformation—Max Min Method**:

$$r_{ij} = \begin{cases} \dfrac{x_{ij} - x_j^-}{x_j^+ - x_j^-} \; ; \quad j \in \Omega_{max} \\ \dfrac{x_j^+ - x_{ij}}{x_j^+ - x_j^-} \; ; \quad j \in \Omega_{min} \end{cases}$$

Where x_j^+ is the largest performance ratings and x_j^- is the smallest performance rating of jth criterion, Ω_{max} and Ω_{min} are sets of benefit and cost criteria, respectively.

Step 3: Calculate relative importance of the ith alternative based on Simple Attitude Weighting Method as shown below.

$$Q_i = \sum_{j=1}^{n} w_j r_{ij}$$

2.6 Additive Ratio Assessment (ARAS) Method

ARAS method is a new MCDM procedure which is asserted by Zavadskas and Turskis (Zavadskas & Turskis, 2010). The typical MCDM problem is concerned with the task of ranking a finite number of decision alternatives, each of which is explicitly described in terms of different decision criteria which have to be taken into account simultaneously. According to ARAS method, a utility function value determining the complex relative efficiency of a feasible alternative is directly proportional to the relative effect of values and weights of the main criteria considered in a project (Edumundas, Kazimieras, Zavadskas, & Turskis, 2010).

In this method, the most acceptable alternative is determined on the basis of degree of utility Q_i, which can be calculated using the following formula

$$Q_i = \frac{S_i}{S_o} ; i = 1, 2, \ldots n \qquad\qquad \text{..... (5)}$$

Where S_i is overall performance index of ith alternative, S_o is overall performance index of optimal alternative, and S_o usually has a value which is 1. The alternatives are ranked on the basis their Q_i in

28

ascending order, and the alternative with the highest value of Q_i is the best ranked. The best ranked alternative, based on the ARAS method, A_{ARS}^* can be determined using the following formula.

$$A_{ARS}^* = \left\{ A_i = \max_i Q_i \right\} \; i = 1, 2, \dots m$$

The specificity of ARAS method, compared to other methods, is the introduction of the optimal alternative A_0. The performances of the optimal alternative are determined on the basis of decision maker's preferences. If the decision makers has no preference about some criterion, its optimal performance is determined as follows

$$x_{0j} = \begin{cases} \max_i x_{ij} \; ; & j \in \Omega_{max} \\ \min_i x_{ij} \; ; & j \in \Omega_{min} \end{cases}$$

The stages of ARAS Method can be put and in an order as follows.

Step 1: Decision-Making Matrix (DMM)

Construct the decision matrix with "m" alternative and "n" criteria as follows.

$$D = \begin{matrix} & \begin{matrix} C_1 & C_2 \dots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} x_{11} & x_{12} \dots & x_{1n} \\ x_{21} & x_{22} \dots & x_{2n} \\ \vdots & \vdots & \vdots \\ x_{1n} & x_{2n} & x_{mn} \end{bmatrix} \end{matrix}$$

Where $A_1, A_2,\dots A_m$ are available alternatives, $C_1, C_2\dots C_n$ are criteria, X_{ij} is performance rating of i-[th] alternative with respect to j[th] eth criterion, i= 1,2, ...m and j= 1,2, ...n.

Step 2: Determine optimal performance rating for each criterion

After creating a decision matrix, the next step in the ARAS method is to determine the optimal performance rating for each criterion. If the decision marks do not have preferences, the optimal performance ratings are calculated as

$$x_{0j} = \begin{cases} \max_i x_{ij} \; ; & j \in \Omega_{max} \\ \min_i x_{ij} \; ; & j \in \Omega_{min} \end{cases}$$

Where x_{0j} is optimal performance rating in relation to the jth criterion, Ω max denote a set of benefit type criteria, i.e., optimisation direction is maximization: and Ω min denote a set of cost type criteria, i.e., optimisation direction is minimization.

Step 3: Calculate the normalised decision matrix:

The third step is to calculate normalised decision matrix $R=r_{ij}$ in such that.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^m x_{ij}} \; ; \quad if \, j = benefit \, criteria$$

$$r_{ij} = \frac{\frac{1}{x_{ij}}}{\sum_{i=1}^{m}\left(\frac{1}{x_{ij}}\right)}; \quad if\ j = cost\ criteria$$

Where r_{ij} is the normalised performance rating of the ith alternative on j^{th} criteria.

Step 4:   Calculated the weighted normalised decision matrix.

The weighted normalised performance ratings $[V = \{V_{ij}\}]$ as calculated as follows:

$$V_{ij} = w_j \times r_{ij}; \quad i = 1, 2, \ldots..m$$

Where v_{ij} is weighted normalised performance rating of ith alternative in the relation to j^{th} criterion.

Step 5: Calculate the overall performance index for each alternative:

The overall performance index S_i, for each alternative can be calculated as the sum of weighted normalised performance ratings, using the following formula.

$$S_i = \sum_{j=1}^{n} V_{ij}; \quad i = 1, 2, \ldots…..m \qquad \qquad \text{….. (6)}$$

Step 6: Calculate the degree of utility for each alternative.

In the case of evaluating the alternatives, the degree of utility for each alternatives can be calculated using the following formula.

$$Q_i = \frac{s_i}{s_o}; i = 1, 2, \ldots..m$$

Where Q_1 is degree of utility of ith alternative, and S_o is overall performance index of optimal alternative, and it is usually 1. The largest value of Q_i is the best and the smallest one is the worst.

2.7 Weighting by Entropy Method

Entropy has become an important concept in the social sciences as well as the physical Sciences (Capocelli & De Luca, 1973). In information theory, entropy is a criterion for the amount of uncertainty presented by the discrete probability distribution P_i (Jaynes, 1957). Entropy is one of the most widely used objective waiting methods. If the data of the decision matrix is available then, the entropy method can be very useful to evaluate the weighting (Deng et al., 2000). The entropy concept was defined as a measure of uncertainty by Shannon (1948). This measure of uncertainty is given by Shannon (1948) with the following equation:

$$S(P_1, P_2 ….P_n) = -K \sum_{j}^{n} P_j I_n P_j$$

$$\text{…… (7)}$$

where K is a constant coefficient. Since the entropy expression is first found in statistical mechanics, it is called entropy of P_i probability distribution. When all P_i values take $P_i = \frac{1}{n}$ and S has the greatest uncertainty.

Entropy can be used as the tool for evaluating criteria (Zeleney, 1974; Nijkamp, 1977) if given a decision matrix containing information for a certain amount of alternatives. The basic idea of entropy is particularly useful when examining the contrast between datasets. If the criterion very similar values to its alternatives, then this is the little performance. Even if all the alternatives have the same values, the

criterion is ignored. The entropy method measures the uncertainty in the data set and measures the variance of the data set with this uncertainty value. For each criterion, the value of the variation value in the total variance gives the weight value of the criterion. The decision matrix for a MCDM problem comprises a definite quantity of information; entropy can be utilised as an implement in criteria evaluation.

The process of determining the weighted value for the criteria by the entropy method is summarised as follows:

Let mxn-dimensional decision matrix of a decision-making problem with m alternatives and n criteria be given as follows:

$$
D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_i \\ \vdots \\ A_m \end{array}
\begin{array}{cccccc}
X_1 & X_2 & \dots & X_j & \dots & X_n \\
\begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} & \dots & x_{1n} \\
x_{21} & x_{22} & \dots & x_{2j} & \dots & x_{2n} \\
\vdots & \vdots & & \vdots & & \vdots \\
x_{i1} & x_{i2} & \dots & x_{ij} & \dots & x_{in} \\
\vdots & \vdots & & \vdots & & \vdots \\
x_{m1} & x_{m2} & \dots & x_{mj} & \dots & x_{mn} \end{bmatrix}_{m \times n}
\end{array}
$$

Where, X_{ij} is the success value of ith alternative, in the jth criterion, i= 1, 2, ..., m; j=1, 2, ...n. The values in row A_i indicate success values according to the all criteria of the ith alternative, and the values in column x_j indicate the success values of all the alternatives according to the jth criterion.

Step 1: Since the criteria have different scales, a normalisation process is performed in order to make and evaluation. R = $[r_{ij}]_{mxn}$ normalised decision matrix calculated by the following formula.

$$
r_{cj} = \frac{x_{ij}}{\sum_{p=1}^{m} x_{pj}} , \quad i = 1, 2, \dots m, \quad j = 1, 2, \dots .n
$$

The aim of normalisation is to obtain same scale for all criteria and so to make comparison between them. (Caliskan, 2013).

Step 2: The uncertainty measures for each criterion, entropy value, is found by the following equation:

$$
e_j = -K \sum_{i=1}^{m} r_{ij} \ln r_{cj} , \quad j = 1, 2, \dots .n
$$

Where K = $\frac{1}{\ln(m)}$ is a constant coefficient and $0 \leq e_j \leq 1$ are guaranteed. The value of e_j is the uncertainty measure of the jth criterion or in other words, the entropy value.

Step 3: The degree of diversification d_j for each criterion using the entropy value of the average information contained by the outcomes of criterion j can be obtained as

$$
d_j = 1 - e_j, \quad j = 1, 2, \dots .n
$$

Step 4: Finally, the weight values of the criteria are calculated by proportioning the degree of diversification of each criterion to the sum of the degree of diversification:

$$w_j = \frac{d_j}{\sum_{p=1}^{n} d_p} \ , \ \ j = 1, 2, \ldots . n$$

as addition $\sum_{p=1}^{n} W_j = 1$ is clear.

2.8 Sample Selection

The pharmaceutical industry has been chosen for this study because it is one of the important and fastest growing sectors in the Indian economy. Among 258 pharmaceutical companies in India, the selection of sample companies is based on the following criteria; companies which are listed in BSE; companies which provide financial data for the study period of 13 years and companies which have a market capitalisation above Rs.15,000 crores. On the basis of the above criteria ten companies listed on BSE are used as alternatives or Decision-Making Units (DMU) that includes leading pharmaceutical manufacturers operating in Indian pharmaceutical industry. The list of companies considered in the analysis is given in the Table 1 along with DMU number.

Table 1. List of Companies used in Financial Analysis

Number of Decision Making Units (DMU)	Name of the Pharmaceutical Company
DMU-1	Aurobindo Pharma Limited
DMU2	Cadila Pharmaceutical Limited
DMU3	Cipla Ltd
DMU4	Dr. Reddy's Laboratories Ltd
DMU5	Glaxo Smith Kline Pharma Ltd
DMU6	Glenmark Pharmaceuticals Limited
DMU7	Lupin Ltd
DMU8	Ranbaxy Laboratories Limited
DMU9	Sun Pharmaceutical Industries Ltd
DMU10	Torrent Pharmaceuticals Limited

2.9 Period of Study and Sources of Data

The competitiveness among Indian pharmaceutical companies is made for a period of thirteen years 2006-2007 to 2018-2019. The thirteen years period is chosen in order to have a fairly, long cyclically well balanced, for which reasonably homogeneous, reliable and up to date financial data would be available. The major source of data analysed and interpreted in this study related to all those companies selected is collected from "PROWESS" database, which is the most reliable on the empowered corporate database of Centre for Monitoring Indian Economy (CMIE).

3. Results

In this section, in order to perform objective conclusions in terms of the applicability of SAW and ARAS methods, the influence which the weights of criteria, the used approaches and the applied normalization procedure have on the selection of the most appropriate alternative and obtained ranking orders of alternatives is taken in to consideration. This study presents the ranking results of selected Indian pharmaceutical companies based on objective criteria. These criteria and their sub-criteria adopted in this study are shown in Table 2. The financial ratios used in the study were selected from those which could provide information about earning capacity, utilization of resources, financial soundness and paying ability, debt coverage, management efficiency and investment valuation figures of the company.

Table 2. Ratios or Criterion Used in the Analysis along with the Type and Weights of Criterion

Sl.No.	Criteria/Ratio	Sub-Criteria	Objective Weights*	Type of Criterion
1	**Earning Capacity**	Operating Margin Ratio(OP)	0.007	+
		Net Profit Margin Ratio(NP)	0.018	+
2	**Utilization of Resources**	Return on Capital Employed(ROC)	0.014	+
		Return on Net worth(RON)	0.027	+
3	**Financial Soundness and Paying Ability**	Current Ratio(CR)	0.011	+
		Quick Ratio(QR)	0.015	+
		Debt-Equity ratio(DER)	0.046	-
4	**Debt Coverage**	Interest Cover(IC)	0.263	+
5	**Management Efficiency**	Inventory Turnover(IT)	0.004	+
		Receivables Turnover(RT)	0.063	+
		Fixed Assets Turnover(FT)	0.039	+
		Total Asset Turnover(TAT)	0.005	+
		Cash Conversion Cycle(CCC)	0.006	-
6	**Investment Valuation**	Earnings Per Share(EPS)	0.369	+
		Price Earnings Ratio(PE)	0.034	+
		Book-Value per Share(BV)	0.023	+
		Dividend Yield(DY)	0.055	+
+ indicates Benefit Criteria and – Cost Criteria				
* Objective weights are determined based on Entropy Method				

3.1 SAW Method

The Indian pharmaceutical companies that have decision points, the superiority of which has to be determined through the constituted decision matrix lines, while in the columns, occur in the financial performance ratios which are the evaluation criteria's. Ten decision making units (alternatives) and 17 evaluation criteria's were used in the research. First, the standard decision matrix was set with dimensions (10x17) for the SAW method obtained from Indian pharmaceutical companies. The decision matrix related to the Indian pharmaceutical companies is presented in Table 3.

Table 3. Initial Decision Matrix (SAW Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU1	17.4	9.08	13.9	15.1	1.19	2.53	1.14	9.43	4.35
DMU2	15.5	15.5	19.5	22.7	1.14	1.20	0.56	10.9	5.87
DMU3	22.7	17.1	23.2	20.6	2.17	1.56	0.12	74.9	3.49
DMU4	24.2	17.5	17.8	13.4	2.33	2.49	0.15	172.1	6.13
DMU5	33.3	23.5	45.2	33.7	1.97	1.50	0.31	0.00	6.99
DMU6	23.2	16.3	16.1	18.9	1.88	3.43	0.86	6.57	6.91
DMU7	21.1	14.2	23.5	26.8	1.22	1.73	0.77	27.8	5.48
DMU8	12.1	2.81	12.5	-1.6	1.12	1.04	1.40	18.9	4.31
DMU9	16.3	25.5	21.8	19.5	2.94	2.63	0.32	924.1	5.46
DMU10	21.9	14.7	24.6	24.1	1.51	1.13	0.41	27.6	5.13

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU1	3.00	2.38	0.86	184.7	31.8	2.24	175	0.01
DMU2	6.76	1.91	1.07	145.7	24.3	4.69	106	0.05
DMU3	4.40	2.70	1.08	231.4	20.7	5.16	98	0.04
DMU4	3.70	2.73	0.77	164.8	50.8	8.67	325	0.02
DMU5	26.4	10.9	1.39	95.3	53.3	33.5	173	0.18
DMU6	3.27	3.53	0.76	212.9	10.3	6.19	60	0.02
DMU7	4.27	2.37	1.17	161.7	36.1	3.92	132	0.05
DMU8	4.48	3.00	1.05	167.7	3.41	-46	78	0.06
DMU9	4.91	2.58	0.65	227.3	25.8	4.37	117	0.06
DMU10	7.33	2.11	1.25	144.3	28.5	4.35	116	0.06

Source: Annual Reports of the Respective Companies.

After preparing decision matrix is generally followed by the weighting of the matrix by the weight vector. The weighting of the matrix is important because a weight implies relative priorities given by the researcher to different criteria's. The weighted value of each criteria, sub-criteria and the resulting

weights obtained on the basis of entropy method are shown in Table 2. The procedure for obtaining weights of each criteria presented in Table 10 to 12. The magnitude of the weight value reflects the importance of the criterion. It is observed from Table 2 that Earnings Per Share (EPS) and Interest Cover(IC) have the highest- weighted values. The reason for this is that in some parts of the companies in the analysis such as Aurobindo Pharma Limited, Cipla Limited, Dr.Reddy's Laboratories Limited, Lupin Limited and Ranbaxy Laboratories Limited takes excessively high values. According to the entopy method, inventory turnover and total assets turnover is at the lowest importance level.

The next step in MCDM method is normalization of decision matrix in order to eliminate the scale effect. There are large numbers of normalization techniques that are followed by the different researchers in MCDM literature. In this study, linear scale normalization-sum method is used for normalization and presented in Table 4.

Table 4. Normalized Decision Matrix (SAW Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU1	0.52	0.36	0.31	0.45	0.40	0.74	0.11	0.01	0.62
DMU2	0.47	0.61	0.43	0.67	0.39	0.35	0.21	0.01	0.84
DMU3	0.68	0.67	0.51	0.61	0.74	0.45	1.00	0.08	0.50
DMU4	0.73	0.69	0.39	0.40	0.79	0.73	0.80	0.19	0.88
DMU5	1.00	0.92	1.00	1.00	0.67	0.44	0.39	0.00	1.00
DMU6	0.70	0.64	0.36	0.56	0.64	1.00	0.14	0.01	0.99
DMU7	0.63	0.56	0.52	0.80	0.41	0.50	0.16	0.03	0.78
DMU8	0.36	0.11	0.28	-.05	0.38	0.30	0.09	0.02	0.62
DMU9	0.49	1.00	0.48	0.58	1.00	0.77	0.38	1.00	0.78
DMU10	0.66	0.58	0.54	0.72	0.51	0.33	0.29	0.03	0.73

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU1	0.11	0.22	0.62	0.52	0.60	0.07	0.54	0.06
DMU2	0.26	0.18	0.77	0.65	0.46	0.14	0.33	0.28
DMU3	0.17	0.25	0.78	0.41	0.39	0.15	0.30	0.22
DMU4	0.14	0.25	0.55	0.58	0.95	0.26	1.00	0.11
DMU5	1.00	1.00	1.00	1.00	1.00	1.00	0.53	1.00
DMU6	0.12	0.32	0.55	0.45	0.19	0.18	0.18	0.11
DMU7	0.16	0.22	0.84	0.59	0.68	0.12	0.41	0.28
DMU8	0.17	0.28	0.76	0.57	0.06	-1.4	0.24	0.33
DMU9	0.19	0.24	0.47	0.42	0.48	0.13	0.36	0.33
DMU10	0.28	0.19	0.90	0.66	0.53	0.13	0.36	0.33

Source: Computed.

After determining weights of the criteria and normalized decision matrix, then weightening of the normalized data matrix is done by multiplying normalized data matrix with the weight vector and presented in Table 5. The relative importance of the each alternatives based on SAW method according to the formula (3) and presented in Table 5. The ranking of the alternatives are given as per the value of relative importance given in the Table 5. From the table it can be seen that the three best pharmaceutical companies on the basis of SAW method are Glaxo Smith Kline Pharma Limited, Sun Pharmaceutical Industries Limited and Dr.Reddy's Laboratories Limited. It is also understood from the Table 5 that the least performer belongs to Ranbaxy Laboratories Limited during the study period.

Table 5. Weighted Normalized Decision Matrix (SAW Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
Weights	**0.007**	**0.018**	**0.014**	**0.027**	**0.011**	**0.015**	**0.046**	**0.263**	**0.004**
DMU1	0.004	0.006	0.004	0.012	0.004	0.011	0.005	0.003	0.002
DMU2	0.003	0.011	0.006	0.018	0.004	0.005	0.010	0.003	0.003
DMU3	0.005	0.012	0.007	0.017	0.008	0.007	0.046	0.021	0.002
DMU4	0.005	0.012	0.006	0.011	0.009	0.011	0.037	0.049	0.004
DMU5	0.007	0.017	0.014	0.027	0.007	0.007	0.018	0.000	0.004
DMU6	0.005	0.012	0.005	0.015	0.007	0.015	0.006	0.002	0.004
DMU7	0.004	0.010	0.007	0.021	0.005	0.008	0.007	0.008	0.003
DMU8	0.003	0.002	0.004	-.001	0.004	0.005	0.004	0.005	0.002
DMU9	0.003	0.018	0.007	0.016	0.011	0.012	0.017	0.263	0.003
DMU10	0.005	0.010	0.008	0.019	0.006	0.005	0.013	0.008	0.003

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY	PI	Rank
Weights	**0.063**	**0.039**	**0.005**	**0.006**	**0.369**	**0.034**	**0.023**	**0.055**		
DMU1	0.007	0.009	0.003	0.003	0.220	0.002	0.012	0.003	**0.312**	7
DMU2	0.016	0.007	0.004	0.004	0.168	0.005	0.008	0.015	**0.291**	8
DMU3	0.011	0.010	0.004	0.002	0.143	0.005	0.007	0.012	**0.319**	6
DMU4	0.009	0.010	0.003	0.003	0.352	0.009	0.023	0.006	**0.557**	3
DMU5	0.063	0.039	0.005	0.006	0.369	0.034	0.012	0.055	**0.684**	1
DMU6	0.008	0.013	0.003	0.003	0.071	0.006	0.004	0.006	**0.185**	9
DMU7	0.010	0.008	0.004	0.004	0.250	0.004	0.009	0.015	**0.378**	4
DMU8	0.011	0.011	0.004	0.003	0.024	-.047	0.006	0.018	**0.057**	10
DMU9	0.012	0.009	0.002	0.003	0.179	0.004	0.008	0.018	**0.585**	2

| DMU10 | 0.017 | 0.008 | 0.004 | 0.004 | 0.197 | 0.004 | 0.008 | 0.018 | **0.339** | 5 |

Source: Computed.

3.2 ARAS Method

First of all, the decision matrix related to the Indian pharmaceutical companies is along with the optimal alternative such as maximum value in case of benefit criteria and minimum value in case of cost criteria has been identified and presented in the Table 6.

Table 6. Initial Decision Matrix (ARAS Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU0	33.3	25.5	45.2	33.7	2.94	3.43	0.12	924.1	6.99
DMU1	17.4	9.08	13.9	15.1	1.19	2.53	1.14	9.43	4.35
DMU2	15.5	15.5	19.5	22.7	1.14	1.2	0.56	10.9	5.87
DMU3	22.7	17.1	23.2	20.6	2.17	1.56	0.12	74.9	3.49
DMU4	24.2	17.5	17.8	13.4	2.33	2.49	0.15	172.1	6.13
DMU5	33.3	23.5	45.2	33.7	1.97	1.5	0.31	0	6.99
DMU6	23.2	16.3	16.1	18.9	1.88	3.43	0.86	6.57	6.91
DMU7	21.1	14.2	23.5	26.8	1.22	1.73	0.77	27.8	5.48
DMU8	12.1	2.81	12.5	-1.6	1.12	1.04	1.4	18.9	4.31
DMU9	16.3	25.5	21.8	19.5	2.94	2.63	0.32	924.1	5.46
DMU10	21.9	14.7	24.6	24.1	1.51	1.13	0.41	27.6	5.13

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU0	26.4	10.9	1.39	95.3	53.3	33.5	325	0.18
DMU1	3	2.38	0.86	184.7	31.8	2.24	175	0.01
DMU2	6.76	1.91	1.07	145.7	24.3	4.69	106	0.05
DMU3	4.4	2.7	1.08	231.4	20.7	5.16	98	0.04
DMU4	3.7	2.73	0.77	164.8	50.8	8.67	325	0.02
DMU5	26.4	10.9	1.39	95.3	53.3	33.5	173	0.18
DMU6	3.27	3.53	0.76	212.9	10.3	6.19	60	0.02
DMU7	4.27	2.37	1.17	161.7	36.1	3.92	132	0.05
DMU8	4.48	3	1.05	167.7	3.41	-46	78	0.06
DMU9	4.91	2.58	0.65	227.3	25.8	4.37	117	0.06
DMU10	7.33	2.11	1.25	144.3	28.5	4.35	116	0.06

Source: Annual Reports of the Respective Companies.

The next step in ARAS method is normalization of decision matrix in order to eliminate the scale effect by using linear scale normalization-sum method and presented in Table 7.

Table 7. Normalized Decision Matrix (ARAS Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU0	0.14	0.14	0.17	0.15	0.14	0.15	0.22	0.42	0.11
DMU1	0.07	0.05	0.05	0.07	0.06	0.11	0.02	0.00	0.07
DMU2	0.06	0.09	0.07	0.10	0.06	0.05	0.05	0.00	0.10
DMU3	0.09	0.09	0.09	0.09	0.11	0.07	0.22	0.03	0.06
DMU4	0.10	0.10	0.07	0.06	0.11	0.11	0.18	0.08	0.10
DMU5	0.14	0.13	0.17	0.15	0.10	0.07	0.08	0.00	0.11
DMU6	0.10	0.09	0.06	0.08	0.09	0.15	0.03	0.00	0.11
DMU7	0.09	0.08	0.09	0.12	0.06	0.08	0.03	0.01	0.09
DMU8	0.05	0.02	0.05	-.01	0.05	0.05	0.02	0.01	0.07
DMU9	0.07	0.14	0.08	0.09	0.14	0.12	0.08	0.42	0.09
DMU10	0.09	0.08	0.09	0.11	0.07	0.05	0.06	0.01	0.08

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU0	0.28	0.24	0.12	0.15	0.16	0.55	0.19	0.25
DMU1	0.03	0.05	0.08	0.08	0.09	0.04	0.10	0.01
DMU2	0.07	0.04	0.09	0.10	0.07	0.08	0.06	0.07
DMU3	0.05	0.06	0.09	0.06	0.06	0.09	0.06	0.05
DMU4	0.04	0.06	0.07	0.08	0.15	0.14	0.19	0.03
DMU5	0.28	0.24	0.12	0.15	0.16	0.55	0.10	0.25
DMU6	0.03	0.08	0.07	0.07	0.03	0.10	0.04	0.03
DMU7	0.04	0.05	0.10	0.09	0.11	0.06	0.08	0.07
DMU8	0.05	0.07	0.09	0.08	0.01	-.76	0.05	0.08
DMU9	0.05	0.06	0.06	0.06	0.08	0.07	0.07	0.08
DMU10	0.08	0.05	0.11	0.10	0.08	0.07	0.07	0.08

Sources: Computed.

After determining weights of the criteria and normalized decision matrix, then weightening of the normalized data matrix is done by multiplying normalized data matrix with the weight vector and presented in Table 8.

Table 8. Weighted Normalized Decision Matrix (ARAS Method)

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
Weights	**0.007**	**0.018**	**0.014**	**0.027**	**0.011**	**0.015**	**0.046**	**0.263**	**0.004**
DMU0	0.001	0.003	0.002	0.004	0.002	0.002	0.010	0.111	0.000
DMU1	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.000
DMU2	0.000	0.002	0.001	0.003	0.001	0.001	0.002	0.001	0.000
DMU3	0.001	0.002	0.001	0.002	0.001	0.001	0.010	0.009	0.000
DMU4	0.001	0.002	0.001	0.002	0.001	0.002	0.008	0.021	0.000
DMU5	0.001	0.002	0.002	0.004	0.001	0.001	0.004	0.000	0.000
DMU6	0.001	0.002	0.001	0.002	0.001	0.002	0.001	0.001	0.000
DMU7	0.001	0.001	0.001	0.003	0.001	0.001	0.002	0.003	0.000
DMU8	0.000	0.000	0.001	0.000	0.001	0.001	0.001	0.002	0.000
DMU9	0.000	0.003	0.001	0.002	0.002	0.002	0.004	0.111	0.000
DMU10	0.001	0.001	0.001	0.003	0.001	0.001	0.003	0.003	0.000

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY	S_i
Weights	**0.063**	**0.039**	**0.005**	**0.006**	**0.369**	**0.034**	**0.023**	**0.055**	**1.000**
DMU0	0.018	0.009	0.001	0.001	0.058	0.019	0.004	0.014	**0.258**
DMU1	0.002	0.002	0.000	0.000	0.035	0.001	0.002	0.001	**0.053**
DMU2	0.004	0.002	0.000	0.001	0.027	0.003	0.001	0.004	**0.052**
DMU3	0.003	0.002	0.000	0.000	0.023	0.003	0.001	0.003	**0.063**
DMU4	0.002	0.002	0.000	0.001	0.055	0.005	0.004	0.002	**0.109**
DMU5	0.018	0.009	0.001	0.001	0.058	0.019	0.002	0.014	**0.137**
DMU6	0.002	0.003	0.000	0.000	0.011	0.003	0.001	0.002	**0.034**
DMU7	0.003	0.002	0.001	0.001	0.039	0.002	0.002	0.004	**0.067**
DMU8	0.003	0.003	0.000	0.000	0.004	-0.026	0.001	0.005	**-0.004**
DMU9	0.003	0.002	0.000	0.000	0.028	0.002	0.002	0.005	**0.167**
DMU10	0.005	0.002	0.001	0.001	0.031	0.002	0.002	0.005	**0.062**

Source: Computed.

The overall performance index S_i for each alternative can be calculated as the sum of the weighted normalized performance ratings as prescribed in the equation (4) is calculated and presented in Table 9.

Table. 9 The Overall Performance Indexes and Degree of Utility (ARAS Method)

	S_i	Q_i	Rank
DMU0	**0.258**		
DMU1	**0.053**	0.204	**7**
DMU2	**0.052**	0.203	**8**
DMU3	**0.063**	0.246	**5**
DMU4	**0.109**	0.421	**3**
DMU5	**0.137**	0.532	**2**
DMU6	**0.034**	0.133	**9**
DMU7	**0.067**	0.258	**4**
DMU8	**-0.004**	-0.016	**10**
DMU9	**0.167**	0.648	**1**
DMU10	**0.062**	0.239	**6**

Source: Computed.

While evaluating alternatives, it is not only important that the best ranked alternative should be determined, but also that the relative performances of the considered alternatives should be determined in relation to the best ranked alternative. For this purpose, it is needed to compute the degree of utility (Q_i) of each alternative based on ARAS method according to the formula (5) and presented in Table 9. The considered alternatives are ranked by ascending Q_i, i.e., the alternatives with the higher values of Q_i, have a higher priority (rank) and the alternative with the largest value of Q_i, is the best placed. The ranking of the alternatives are given as per the value of relative importance in the Table 9.   From the table it can be seen that the three best pharmaceutical companies on the basis of ARAS method are Sun Pharmaceutical Industries Ltd, Glaxo Smith Kline Pharma Limited and Dr.Reddy's Laboratories Limited. It is also understood from the Table 9 that the least performer belongs to Ranbaxy Laboratories Limited during the study period.

4. Discussion

4.1 SAW and ARAS Methods—A Comparison

The comparison of results of SAW and ARAS methods are presented in Table 10.

Table 10. Rankings of SAW and ARAS Method—A Comparison

Number of Decision Making Units (DMU)	Name of the Pharmaceutical Company	Rank by SAW Method	Rank by ARAS Method
DMU-1	Aurobindo Pharma Limited	7	7
DMU2	Cadila Pharmaceutical Limited	8	8
DMU3	Cipla Ltd	6	5
DMU4	Dr. Reddy's Laboratories Ltd	3	3
DMU5	Glaxo Smith Kline Pharma Ltd	1	2
DMU6	Glenmark Pharmaceuticals Limited	9	9
DMU7	Lupin Ltd	4	4
DMU8	Ranbaxy Laboratories Limited	10	10
DMU9	Sun Pharmaceutical Industries Ltd	2	1
DMU10	Torrent Pharmaceuticals Limited	5	6

Source: Computed.

It is inferred from the Table 10 that both MCDM methods, SAW and ARAS, revealed same rankings of companies in Indian pharmaceutical industry during the study period except two changes. According to SAW method the first rank is given to Glaxo Smith Kline Pharma Limited whereas in ARAS method, the first rank given to Sun Pharmaceutical Industries Ltd and the Cipla Limited given 6th rank in SAW method, but in ARAS method, it is given 5th rank according to their performance. Except the above changes, all other companies are obtained similar rankings according to SAW and ARAS method during the study period.

5. Conclusion

The study analysed 2006-2019 financial performances of ten selected Indian pharmaceutical companies and employed two simplest MCDM methods such as Simple Additive Weighting (SAW) method and Additive Ratio Assessment (ARAS) as its method of analysis. The results of the study shows that the best performance belongs to Glaxo Smith Kline Pharma Limited in SAW method and Sun Pharmaceutical Industries Ltd in ARAS method and worst performance belongs to Ranbaxy Laboratories Limited in both methods. By comparison, both methods revealed the similar rankings of companies during the study period. The applicability of the SAW and ARAS methods with the use of the entropy weightings to the problem of Indian pharmaceutical company's financial performance evaluation suggests that it is feasible for different sectors. As the scope of this study was only pharmaceutical industry, the large number of industry, financial ratios and period intervals and the wideness of the data set can be considered as a valuable resource for further research.

References

Asir, O., & Emel, E. R. O. L. (2017). Ranking of factoring companies in accordance with ARAS and COPRAS. *International Journal of Academic Research in Accounting, Finance and Management Sciences*, *7*(2), 105-116. https://doi.org/10.6007/IJARAFMS/v7-i2/2876

Bakir, M., & Atalik, O. (2018). Evaluation of service quality in Airlines by Entropy and ARAS method. *Journal of Business Research-Turk*, *10*(1), 617-638. https://doi.org/10.20491/isarder.2018.410

Çalışkan, H. (2013). Selection of boron based tribological hard coatings using multi-criteria decision-making methods. *Materials and Design*, *50*, 742-749. https://doi.org/10.1016/j.matdes.2013.03.059

Capocelli, R. M., & De Luca, A. (1973). Fuzzy sets and Decision Theory. *Information and Control*, *23*(5), 446-473. https://doi.org/10.1016/S0019-9958(73)80009-9

Chatterjee, N. C., & Bose, G. K. (2013). Selection of vendor for wind farm under Fuzzy MCDM environment. *International Journal of Industrial Engineering Computations*, *4*(4), 535-546. https://doi.org/10.5267/j.ijiec.2013.06.002

Chen, T. Y. (2012). Comparative Analysis of SAW and TOPSIS based on Interval—Valued fuzzy sets: Discussion on scare functions and weight constraints. *Expert Systems with Applications*, *39*(2), 1848-1861. https://doi.org/10.1016/j.eswa.2011.08.065

Dedania, H. V., Shah, V. R., & Sanghi, R. C. (2015). Portfolio Management: Stock ranking by multiple attribute decision making methods. *Technology and Investment*, *6*, 141-150. https://doi.org/10.4236/ti.2015.64016

Deng, H., Yeh, C. H., & Willis, R. J. (2000). Inter-company comparison using modified TOPSIS with objective weights. *Computers and Operations Research*, *27*(10), 963-973. https://doi.org/10.1016/S0305-0548(99)00069-6

Ecer, F. (2018). An integrated Fuzzy AHP and ARAS model to evaluate mobile banking services. *Technological and Economic Development of Economy*, *24*(2), 670-695. https://doi.org/10.3846/20294913.2016.1255275

India Brand Equity Foundation. (September 2018). *Industry report on pharmaceutical industry*. Retrieved from https://www.ibef.org

Jaynes, E. T. (1957). Information theory and statistical mechanics. Physical Review, 106(4), 620-630. https://doi.org/10.1103/PhysRev.106.620

Karabasevic, D., Paunkovic, J., & Stanujkic, D. (2016). Ranking of companies according to the indicators of corporate social responsibilities based on SWARA and ARAS method. *Serbian Journal of Management*, *11*(1), 43-53. https://doi.org/10.5937/sjm11-7877

Karabasevic, D., Stanujkic, D., & Urosevic, S. (2015). The MCDM model for personal selection based on SWARA and ARAS method. *Management*, *20*(27), 43-77. https://doi.org/10.7595/management.fon.2015.0029

Keršulienė, V., & Turskis, Z. (2014). An integrated multi-criteria group decision making process: Selection of the chief accountant. *Procedia—Social and Behavioral Sciences*, *110*, 897-904. https://doi.org/10.1016/j.sbspro.2013.12.935

Kutut, V., Zavadskas, E. K., & Lazauskas, M. (2013). Assessment of priority option for preservation of historic city centre buildings using MCDM(ARAS). *Procedia Engineering*, *57*, 657-661. https://doi.org/10.1016/j.proeng.2013.04.083

Mardani, A., Jusoh, A., M. D. Nor, K., Khalifah, Z., & Zakwan, N. (2015). Multiple Criteria decision-making techniques and their applications—A review of literature from 2000 to 2014. Valipour, A. *Economic Research*, *28*(1), 516-571. https://doi.org/10.1080/1331677X.2015.1075139

NijKamp, P. (1977). Stochastic quantitative and qualitative multi criteria analysis for environmental design. *Papers in Regional Science*, *39*(1), 175-199. https://doi.org/10.1111/j.1435-5597.1977.tb01006.x

Raikar Avinash, V. (2019). Financial performance evaluation of selected steel companies in India by using multi criteria decision technique of ARAS, SAW and TOPSIS with DVA based weight determination. *International Journal of Scientific Research and Reviews*, *8*(2), 4261-4277.

Raikar Avinash, V. (2019). *op. cit.e.*

Šaparauskas, J., Zavadskas, E. K., & Turskis, Z. (2011). Selection of façade's alternatives of commercial and public building based on multiple criteria. *International Journal of Strategic Property Management*, *15*(2), 189-203. https://doi.org/10.3846/1648715X.2011.586532

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*(3), 379-423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Stanujkic, D. (2013). *op. cit.e.*

Stanujkic, D. (2015). Extension of the ARAS method for decision-making problems with interval-valued triangular fuzzy numbers. *Informatic*, *2*(3), 234-245. https://doi.org/10.15388/Informatica.2015.51

Stanujkic, D., & Jovanovic, R. (2012). Measuring a quality of faculty website using ARAS method. Contemporary issues in business. *Management in Education*, 545-554.

Stanujkić, D., Đorđević, B., & Đorđević, M. (2013). Comparative analysis of some prominent MCDM methods: A case of ranking Serbian Banks. *Serbian Journal of Management*, *8*(2), 213-241. https://doi.org/10.5937/sjm8-3774

Stanujkic, D., Dordevic, B., & Dordevic, M. (2013). *Op. cit.e.*

Turskis, Z., & Zavadskas, E. K. (2010b). A new fuzzy Additive Ratio Assessment method (ARAS-F) Cases study: The analysis of fuzzy multiple criteria in order to select the logistics centers location. *Transport*, *25*(4), 423-432. https://doi.org/10.3846/transport.2010.52

Turskis, Z., & Zavadskas, E. K. (2011). Multiple Criteria Decision Making (MCDM) methods in Economics—An Overview. *Technological and Economic Development of Economy*, *17*(2), 397-427. https://doi.org/10.3846/20294913.2011.593291

Turskis, Z., Zavadskas, E. K., & Peldschus, F. (2009). Multi-Criteria optimization system for decision making in construction design and management. *Engineering Economics*, *1*, 7-17.

Zavadskas, E. K., & Turskis, Z. (2008). A new logarithmic normalization method in games theory. *Informatica*, *19*(2), 303-314. https://doi.org/10.15388/Informatica.2008.215

Zavadskas, E. K., & Turskis, Z. (2010). *op. cit.e*.

Zavadskas, E. K., Turskis, Z., & Kildienė, S. (2014). State of Art Survey of overviews on MCDM/MADM methods. *Technological and Economic Development of Economy*, *20*(1), 165-179. https://doi.org/10.3846/20294913.2014.892037

Zavadskas, E. K., Vainiunas, P., Turskis, Z., & Tamosaitiene, J. (2012). Multi-criteria decision support system for assessment of project managers in construction. *International Journal of Information Technology and Decision Making*, *11*(2), 501, 520. https://doi.org/10.1142/S0219622012400135

Zavadskas, E. K., Vilutienė, T., Turskis, Z., & Tamosaitienė, J. (2010). Contractor selection for construction works by applying SAW-G and TOPSIS grey Techniques. *Journal of Business Economics and Management*, *11*(1), 34-55. https://doi.org/10.3846/jbem.2010.03

Zavatskas, E. K., & Turskis, Z. (2010). A new additive ratio assessment method in multi criteria decision-making. *Ukio Technologinis ir Ekonominis Vystymas*, *16*(2), 159-172. https://doi.org/10.1007/978-3-642-80808-1

Zeleny, M. (1974). *Linear Multi objective programming*. Berlin: Springer-Verlag. https://doi.org/10.1007/978-3-642-80808-1

Zolfani, S. H., Sedaghat, M., & Zavadskas, E. K. (2012). Performance evaluating of rural ICT centres, Applying Fuzzy AHP,SAW.Gand TOPSIS Graey, A case study in Iran. *Technological and Economic Development of Economy*, *18*(2), 364-387. https://doi.org/10.3846/20294913.2012.685110

Note

Note 1. The process of determining the weighted value for the criteria by the entropy method is as follows:

Table 11. Normalized Decision Matrix for Weight Determination under Entropy Method

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU1	0.08	0.06	0.06	0.08	0.07	0.13	0.19	0.01	0.08
DMU2	0.07	0.10	0.09	0.12	0.07	0.06	0.09	0.01	0.11
DMU3	0.11	0.11	0.11	0.11	0.12	0.08	0.02	0.06	0.06
DMU4	0.12	0.11	0.08	0.07	0.13	0.13	0.02	0.14	0.11
DMU5	0.16	0.15	0.21	0.17	0.11	0.08	0.05	0.00	0.13
DMU6	0.11	0.10	0.07	0.10	0.11	0.18	0.14	0.01	0.13
DMU7	0.10	0.09	0.11	0.14	0.07	0.09	0.13	0.02	0.10
DMU8	0.06	0.02	0.06	-0.01	0.06	0.05	0.23	0.01	0.08
DMU9	0.08	0.16	0.10	0.10	0.17	0.14	0.05	0.73	0.10
DMU10	0.11	0.09	0.11	0.12	0.09	0.06	0.07	0.02	0.09

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU1	0.04	0.07	0.09	0.11	0.11	0.08	0.13	0.02
DMU2	0.10	0.06	0.11	0.08	0.09	0.17	0.08	0.09
DMU3	0.06	0.08	0.11	0.13	0.07	0.19	0.07	0.07
DMU4	0.05	0.08	0.08	0.09	0.18	0.32	0.24	0.04
DMU5	0.39	0.32	0.14	0.05	0.19	1.24	0.13	0.33
DMU6	0.05	0.10	0.08	0.12	0.04	0.23	0.04	0.04
DMU7	0.06	0.07	0.12	0.09	0.13	0.14	0.10	0.09
DMU8	0.07	0.09	0.10	0.10	0.01	-1.70	0.06	0.11
DMU9	0.07	0.08	0.06	0.13	0.09	0.16	0.08	0.11
DMU10	0.11	0.06	0.12	0.08	0.10	0.16	0.08	0.11

Table 12. Value of Entropy

	Value of Entropy		
ln(10)	2.3026		
h=1/ln(10)	0.4343	(-h)=	-0.4343

Source: Computed.

Table 13. Determination of Weights

Companies	OP	NP	ROC	RON	CR	QR	DER	IC	IT
DMU1	-0.21	-0.17	-0.18	-0.20	-0.18	-0.27	-0.31	-0.04	-0.20
DMU2	-0.19	-0.23	-0.22	-0.25	-0.18	-0.17	-0.22	-0.04	-0.24
DMU3	-0.24	-0.24	-0.24	-0.24	-0.26	-0.20	-0.08	-0.17	-0.18
DMU4	-0.25	-0.25	-0.20	-0.19	-0.27	-0.26	-0.09	-0.27	-0.25
DMU5	-0.29	-0.28	-0.33	-0.30	-0.25	-0.20	-0.15	0.00	-0.26
DMU6	-0.24	-0.24	-0.19	-0.23	-0.24	-0.31	-0.28	-0.03	-0.26
DMU7	-0.23	-0.22	-0.24	-0.27	-0.19	-0.22	-0.26	-0.08	-0.23
DMU8	-0.17	-0.07	-0.16	0.00	-0.18	-0.16	-0.34	-0.06	-0.20
DMU9	-0.20	-0.30	-0.23	-0.23	-0.30	-0.27	-0.16	-0.23	-0.23
DMU10	-0.24	-0.22	-0.25	-0.26	-0.21	-0.17	-0.18	-0.08	-0.22
Sum	-2.27	-2.21	-2.23	-2.17	-2.25	-2.23	-2.07	-1.00	-2.28
ej=(-h*Sum)	0.98	0.96	0.97	0.94	0.98	0.97	0.90	0.44	0.99
d=(1-ej)	0.02	0.04	0.03	0.06	0.02	0.03	0.10	0.56	0.01
Weights	0.007	0.018	0.014	0.027	0.011	0.015	0.046	0.263	0.004

Companies	RT	FT	TAT	CCC	EPS	PE	BV	DY
DMU1	-0.14	-0.19	-0.21	-0.24	-0.05	-0.21	-0.26	-0.07
DMU2	-0.23	-0.16	-0.24	-0.21	-0.03	-0.30	-0.20	-0.22
DMU3	-0.18	-0.20	-0.24	-0.27	-0.03	-0.32	-0.19	-0.19
DMU4	-0.16	-0.20	-0.20	-0.22	-0.10	-0.36	-0.34	-0.12
DMU5	-0.37	-0.36	-0.27	-0.16	-0.11	0.26	-0.26	-0.37
DMU6	-0.15	-0.23	-0.20	-0.26	-0.01	-0.34	-0.14	-0.12
DMU7	-0.17	-0.18	-0.25	-0.22	-0.06	-0.28	-0.22	-0.22
DMU8	-0.18	-0.21	-0.24	-0.23	0.00	0.00	-0.16	-0.24
DMU9	-0.19	-0.19	-0.18	-0.27	-0.04	-0.29	-0.21	-0.24
DMU10	-0.24	-0.17	-0.26	-0.21	-0.04	-0.29	-0.21	-0.24
Sum	-1.99	-2.11	-2.28	-2.28	-0.48	-2.13	-2.19	-2.03
ej=(-h*Sum)	0.86	0.92	0.99	0.99	0.21	0.93	0.95	0.88
d=(1-ej)	0.14	0.08	0.01	0.01	0.79	0.07	0.05	0.12
Weights	0.063	0.039	0.005	0.006	0.369	0.034	0.023	0.055

Source: Computed.