Original Paper

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

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Received: July 5, 2020          Accepted: July 18, 2020          Online Published: July 29, 2020
doi:10.22158/jetr.v1n2p23                        URL: http://dx.doi.org/10.22158/jetr.v1n2p23

Abstract

While assessing the performances of companies, the decision makers to take not only a single criterion for making the right decisions into 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 options, Multiple-Criteria Decision Making (MCDM) methods are used. This study is to provide insight into 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.

\[ D = [x_{ij}]_{m \times n} \] \hspace{2cm} (1)

\[ W = [w_j]_n \] \hspace{2cm} (2)

Where \( D \) is decision matrix, \( x_{ij} \) is performance of \( i \)-th alternative with respect to \( j \)-th criterion, \( W \) is the weight vector, \( w_j \) is weight of \( j \)-th criterion, \( i = 1, 2, \ldots, m \); \( m \) is the number of compared alternatives, \( j = 1, 2, \ldots, n \); \( n \) is the number of criteria.
Information stored in a decision matrix expressed using different units of measure. Therefore, data should be transformed into 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 into 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 & Turkskis, 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 & Turkskis, 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
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:

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

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

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:

\[ A^*_{SAW} = \{ A_i = \max_i Q_i \} \]

The method involves three steps:

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

\[
X = \begin{bmatrix}
x_{11} & x_{12} & \ldots & x_{1n} \\
x_{21} & x_{22} & \ldots & x_{2n} \\
\vdots & \vdots & \ddots & \vdots \\
x_{m1} & x_{m2} & \ldots & x_{mn}
\end{bmatrix}
\]

Where \( x_{ij} \) represents performance of \( i \)th alternative on the \( j \)th criteria; \( i=1,2, \ldots,m \) and \( j=1,2, \ldots,n \)

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

(a) Linear Scale Transformation—Max Method:
(b) Linear Scale Transformation—Sum Method:

\[ r_{ij} = \begin{cases} \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} : j \in \Omega_{\text{max}} \\ \frac{1}{x_{ij}} \left( \sum_{i=1}^{n} \frac{1}{x_{ij}} \right) : j \in \Omega_{\text{min}} \end{cases} \]

(c) Vector Normalisation:

\[ r_{ij} = \begin{cases} \frac{x_{ij}}{\left( \sum_{i=1}^{n} x_{ij}^2 \right)^{\frac{1}{2}}} : j \in \Omega_{\text{max}} \\ 1 - \frac{x_{ij}}{\left( \sum_{i=1}^{n} x_{ij}^2 \right)^{\frac{1}{2}}} : j \in \Omega_{\text{min}} \end{cases} \]

(d) Linear Scale Transformation—Max Min Method:

\[ r_{ij} = \begin{cases} \frac{x_{ij} - x_{ij}^-}{x_{ij}^-} : j \in \Omega_{\text{max}} \\ \frac{x_{ij}^- - x_{ij}}{x_{ij}^-} : j \in \Omega_{\text{min}} \end{cases} \]

Where \( x_{ij}^- \) is the largest performance ratings and \( x_{ij}^- \) is the smallest performance rating of \( j^{th} \) criterion, \( \Omega_{\text{max}} \) and \( \Omega_{\text{min}} \) are sets of benefit and cost criteria, respectively.

Step 3: Calculate relative importance of the \( i^{th} \) 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

\[ Q_i = \frac{S_i}{S_o} ; i = 1, 2, \ldots, n \]

..... (5)

Where \( S_i \) is overall performance index of \( i^{th} \) 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
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.

$$A_{ARS}^* = \left\{ A_i = \max_{i} Q_i \right\} \quad i = 1, 2, \ldots, m$$

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

$$x_{oj} = \begin{cases} \max_{i} x_{ij} : & j \in \Omega_{\text{max}} \\ \min_{i} x_{ij} : & j \in \Omega_{\text{min}} \end{cases}$$

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.

$$D = \begin{bmatrix} C_1 & C_2 & \cdots & C_n \\ A_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ A_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ A_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}$$

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

**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 makers do not have preferences, the optimal performance ratings are calculated as

$$x_{oj} = \begin{cases} \max_{i} x_{ij} : & j \in \Omega_{\text{max}} \\ \min_{i} x_{ij} : & j \in \Omega_{\text{min}} \end{cases}$$

Where $x_{oj}$ is optimal performance rating in relation to the $j^{th}$ criterion, $\Omega_{\text{max}}$ denote a set of benefit type criteria, i.e., optimisation direction is maximization: and $\Omega_{\text{min}}$ 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.

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad \text{if } j = \text{benefit criteria}$$
Where \( r_{ij} \) is the normalised performance rating of the \( i^{th} \) alternative on \( j^{th} \) criteria.

**Step 4: Calculated the weighted normalised decision matrix.**

The weighted normalised performance ratings \( \{V_{ij}\} \) 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 \( i^{th} \) 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.

\[
S_i = \sum_{j=1}^{n} V_{ij}; \quad i = 1, 2, \ldots, m
\]  

(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.

\[
Q_i = \frac{s_i}{s_o}; \quad i = 1, 2, \ldots, m
\]

Where \( Q_i \) is degree of utility of \( i^{th} \) 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:

\[
S(P_1, P_2, \ldots, P_n) = -K \sum_{j=1}^{n} P_j \ln P_j
\]

(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 \( P_i \approx \frac{1}{n} \) 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:

\[
D = \begin{bmatrix}
X_1 & X_2 & \ldots & X_j & \ldots & X_n \\
A_1 & x_{11} & x_{12} & \ldots & x_{1j} & \ldots & x_{1n} \\
A_2 & x_{21} & x_{22} & \ldots & x_{2j} & \ldots & x_{2n} \\
\vdots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
A_m & x_{m1} & x_{m2} & \ldots & x_{mj} & \ldots & x_{mn}
\end{bmatrix}
\]

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

\[
r_{ij} = \frac{x_{ij}}{\sum_{p=1}^{m} x_{pj}}, \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n
\]

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:

\[
e_j = -K \sum_{i=1}^{m} r_{ij} \ln(r_{ij}), \quad j = 1, 2, \ldots, n
\]

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 \(j^{th}\) 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

\[
d_j = 1 - e_j, \quad j = 1, 2, \ldots, n
\]

**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:
as addition \( \sum_{p=1}^{n} W_p = 1 \) 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.

| 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 into 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           | 0.014             | +               |
|       |                         | Employed(ROC)               |                   |                 |
|       |                         | 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.

| 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  | 6.99  | 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 criterion 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 entropy 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.

| 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 | -0.05| 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 | 0.80 | 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.

| Companies | OP   | NP   | ROC  | RON  | CR   | QR   | DER  | IC   | IT  |
|-----------|------|------|------|------|------|------|------|------|-----|
| 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| 0.006| 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 |
|-----------|------|------|------|------|------|------|------|------|------|------|
| DMU1      | 0.063| 0.039| 0.005| 0.006| 0.369| 0.034| 0.023| 0.055|      |      |
| DMU2      | 0.007| 0.009| 0.003| 0.003| 0.220| 0.002| 0.012| 0.003| 0.312| 7    |
| DMU3      | 0.016| 0.007| 0.004| 0.004| 0.168| 0.005| 0.008| 0.015| 0.291| 8    |
| DMU4      | 0.011| 0.010| 0.004| 0.002| 0.143| 0.005| 0.007| 0.012| 0.319| 6    |
| DMU5      | 0.009| 0.010| 0.003| 0.003| 0.352| 0.009| 0.023| 0.006| 0.557| 3    |
| DMU6      | 0.063| 0.039| 0.005| 0.006| 0.369| 0.034| 0.012| 0.055|      |      |
| DMU7      | 0.008| 0.013| 0.003| 0.003| 0.071| 0.006| 0.004| 0.006| 0.185| 9    |
| DMU8      | 0.010| 0.008| 0.004| 0.004| 0.250| 0.004| 0.009| 0.015| 0.378| 4    |
| DMU9      | 0.011| 0.011| 0.004| 0.003| 0.024| -0.047| 0.006| 0.018| 0.057| 10   |
| DMU10     | 0.012| 0.009| 0.002| 0.003| 0.179| 0.004| 0.008| 0.018| 0.585| 2    |
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| 0.11| 0.07| 0.22| 0.03| 0.06| 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| 0.05| 0.05| -0.01| 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| -0.76| 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 |      |      |      |      |      |      |      |      |
| 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 |

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)

| DMU   | $S_i$ | $Q_i$ | 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.
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Note

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

| Companies | OP | NP | ROC | RON | CR | QR | DER | IC | IT |
|-----------|----|----|-----|-----|----|----|-----|----|----|
| DMU1      | 0.08 | 0.06 | 0.06 | 0.08 | 0.07 | 0.13 | 0.01 | 0.08 |
| DMU2      | 0.07 | 0.10 | 0.09 | 0.12 | 0.07 | 0.06 | 0.09 | 0.11 |
| DMU3      | 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.