MEASURING PERFORMANCE OF HEALTHCARE SUPPLY CHAINS IN INDIA: A COMPARATIVE ANALYSIS OF MULTI-CRITERIA DECISION MAKING METHODS

Sanjib Biswas [1*]

[1] Calcutta Business School, West Bengal, India

Original scientific paper

Abstract: *The supply chain forms the backbone of any organization. However, the effectiveness and efficiency of every activity get manifested in the financial outcome. Hence, measuring supply chain performance using financial metrics carries significance. The purpose of this paper is to carry out a comparative analysis of supply chain performances of leading healthcare organizations in India. In this regard, this paper presents an integrated multi-criteria decision making (MCDM) framework wherein we derive the weights of the criteria based on experts' opinions using PIvot Pairwise RElative Criteria Importance Assessment (PIPRECIA) method. We then apply three distinct frameworks such as Multi-Attributive Border Approximation area Comparison (MABAC), Combined Compromise Solution (CoCoSo) and Measurement of alternatives and ranking according to COmpromise solution (MARCOS) for ranking purpose. In this context, this paper presents a comparative analysis of the results obtained from these approaches. The results show that large cap firms do not necessarily perform well. Further, the results of three MCDM frameworks demonstrates consistency.*

Key words: *Healthcare Supply Chain, Financial Metrics, PIPRECIA, MABAC, CoCoSo, MARCOS.*

1. Introduction

With rapid development in information technology and communication technology (ICT), consumers' nature and requirements have changed to a great extent in order to win the battle at the market place and, more specifically, to survive. Organizations are increasingly putting primary emphasis on strengthening the supply chains. The performance of the supply chain stands as a critical deciding factor for ensuring business sustainability. Hence, Supply Chain Management (SCM) encompasses all related decisions to strike a balance between demand and supply, linked with the financial outcome (Huang et al., 2008). In other words, SCM addresses the issue of

* Corresponding author.
E-mail addresses: sanjibb@acm.org (S. Biswas)

economic sustainability (Al-Hussaini, 2019). Supply chain decision-makers must adequately consider two interdependent objectives such as reduction of cost and improvement of service levels for contributing to the overall profitability of the organization (Parasuraman et al., 1991; Mentzer et al., 1999; Ray et al., 2004; Johnson and Templar, 2011). The basic premise of the supply chain concept is built on horizontal integration and development, shifting away from the functional brilliance (Lester, 1999). Hence, all the activities across the supply chain must be performed in sync and directed towards attaining the overall business objectives of meeting the needs and requirements of the customers and fulfilling the stakeholders' expectations. In effect, supremacy in supply chain performance contributes in achieving overall organizational excellence (Ellram et al., 2002; D'Avanzo et al., 2004; Christopher, 2005) which is beyond the local scope of cost optimization (Lambert and Cooper, 2000; Ellram and Liu, 2002; Farris and Hutchison, 2002). Supply chain practitioners need to connect operational efficiency with financial investment outcomes (LaLonde, 2000). Though the explicit linkage of supply chain performance with financial performance is quite complex to realize (Frohlich and Westbrook, 2001), Christopher (1998) mentioned three dimensions of financial performance: profitability, liquidity, and productivity or asset utilization in which the contributions of supply chain performance can be gauged. Therefore, it is understood that there is a need to bridge the gap between the supply chain operational framework consisting of performance criteria and the financial metrics for assessing business outcomes. Financial metrics help the supply chain decision-makers and executors to understand the impact of the operational decisions and efficiency on the overall profitability of the business unit (Tan, 1999; Ketzenberg et al., 2006; Kremers, 2010; Kancharla and Hegde, 2016). Also, the measurement of supply chain performance in financial terms enables the organizations to get an outlook on future earnings, which would value the shareholders (Krause et al., 2009). In this regard, Wisner (2011) demonstrated the impact of the supply chain's performance on the organization's financial results.

Over the years, several researchers have made significant contributions in developing comprehensive performance assessment frameworks for supply chains. One famous framework, such as the SCOR (Supply Chain Operations Reference) model integrates the primary processes (plan, source, make, deliver and return) of supply chain operation with the overall strategy of the organization (Kocaoğlu et al., 2013; Askariazad and Wanous, 2009; Parkan and Wang, 2007; Lockamy and McCormack, 2004). The SCOR model enables to interconnect the process efficiency with the business effectiveness reflected in, both the financial (e.g., supply chain cost, cost of goods sold or COGS, return on assets, return on working capital) and the operational (e.g., order fulfillment time, supply chain flexibility, supplier relationship, % yield, delivery efficiency, supply chain adaptability, distribution planning, network design) outcomes. In this regard, Elgazzar et al. (2012) identified the firm's financial strategy's priorities and put forth a framework to link the SCOR model-based supply chain performance measures with financial metrics (identified through Du-Pont ratio analysis). In tune with this work, in recent times, many researchers have put their efforts into establishing the relationship of supply chain operational performance and financial outcome of the organization across the industry (Zhu and Sarkis, 2004; Li et al., 2006; Wagner et al., 2012). Innovation is also given due importance for improving supply chain performance (Chithambaranathan et al., 2015). As we see that supply chain performance depends on several parameters, MCDM methods have been used by the researchers. In literature we notice applications of various MCDM frameworks related to supply chain performance measurement (For example, Bhagwat and Sharma, 2007; Wong and Wong, 2007; Varma et al., 2008; Yang, 2009; Najmi and

Makui, 2010; Pramod and Banwet, 2011; Elgazzar et al., 2012; Bhattacharya et al., 2014; Jothimani and Sarmah, 2014; Rouyendegh et al., 2014; Shafiee et al., 2014; Tyagi et al., 2014; Tseng et al., 2014; Dey et al., 2016; Uygun and Dede, 2016; Ghosh and Biswas, 2016; Moharamkhani et al., 2017; Govindan et al., 2017; Janaki et al., 2018; Sufiyan et al., 2019; Grida et al., 2020).

In this paper we focus on the healthcare sector in India. In India, healthcare is one of the most talked-about and promising sectors in terms of customers' attachment and emotion (Schneller and Smeltzer, 2006), complexity, growth, revenue generation and employment potential. The expected business is around INR 8.6 trillion by 2022. The sector has been emphasized by the Govt. of India (GOI) as the plan is to spend 2.5 percent of the country's GDP in public health by 2025 (Source: IFBE Report). Already several initiatives (e.g., Ayushman Bharat) have been conceptualized and implemented by the GOI. A healthcare supply chain is said to be inefficient at utilizing invested capital, which eventually increases operating costs (Kwon et al., 2016). Hence, as compared to supply chain of the other industries (i.e., commercial supply chains) there is enough scope for improving the performance (de Vries and Huijsman, 2011) to bring down the operating through effective utilization of resources, provide quality service to the users at an affordable price while maximizing shareholders' returns. This paper intends to carry out a comparative assessment of supply chain performance of leading organizations belonging to the healthcare sector in India. Financial metrics are used as criteria for assessment. From the methodological point of view, in this paper we consider three recently developed MCDM algorithms such as MABAC, CoCoSo, and MARCOS. We are interested to examine the competitive positions of the sample firms using the lens of these three different algorithms. We aim to compare the results obtained from the applied MCDM methods. We see that most of the past research considered the methods like Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Decision Making Trial and Evaluation Laboratory (DEMATEL), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for measuring supply chain performance. Our work uses a combined framework of both outranking and compromise solution algorithms.

This paper adds value to the growing literature in the following way. First, it addresses the issue of performance measurement of healthcare organizations in India. In the literature, there are evidences of linking supply chain performance with financial performance. However, measuring comparative supply chain performances based on financial metrics, particularly for health care supply chains in India seems to be rare. Second, in this paper we use a combined subjective and objective methodology. We apply PIPRECIA method to prioritize the criteria based on the opinions of experts in the stated field. We then apply three distinct frameworks such as Multi-Attributive Border Approximation area Comparison (MABAC), Combined Compromise Solution (CoCoSo) and Measurement of alternatives and ranking according to COmpromise solution (MARCOS) for for comparing supply chain performance using published financial data. We capture expert opinions for understanding relative priorities of the criteria to infuse practitioners' views which provides a basis for comparing the results obtained from three distinct algorithms. In this paper, we use a combination of similarity based and compromise solution oriented methods. In order to compare supply chain performance, it is not only required to find closeness to average standard, but also trading off or compromising on performances subject to different attributes assume practical relevance. This is required as financial metrics do not reveal a comprehensive view of operational performance. Further, to arrive at the conclusion, we use Simple Additive Weighting (SAW) method which uses the score values as calculated by MABAC, CoCoSo and

MARCOS. To our best knowledge, there has not been any previous work which have attempted to compare the performance of the MCDM algorithms used in this paper.

The rest of the paper is organized as follows. In the section 2, the detailed methodology is presented while section 3 encapsulates the findings and includes a brief discussion of the findings. Section 4 concludes the paper while pointing out some of the implications of this study and future research agenda.

2. Data and Methodology

In this paper the following steps are followed for carrying out the research work.
Step 1: Selection of sample
Step 2: Identification of the criteria
Step 3: Determination of criteria weights using expert opinion based PIPRECIA method
Step 4: Comparative ranking based on supply chain performance using MABAC, CoCoSo, and MARCOS algorithms
Step 5: Comparison of ranking results as obtained by using three distinct methods and arrive at a combined final ranking

2.1. Sample

In this study, leading Indian healthcare organizations listed in BSE, India are considered. In the selection of sample organizations, the size of the company is taken as the classifier. Accordingly, top 20 companies (Source: the database of the Centre for Monitoring Indian Economy Pvt. Ltd., CMIE Prowess IQ) are included under the consideration of this study. Table 1 provides the list of such companies.

Table 1. List of companies under study

Company Name	Code	Company Name	Code
Abbott India Ltd.	A1	Glaxosmithkline Pharmaceuticals Ltd.	A11
Alembic Pharmaceuticals Ltd.	A2	Glenmark Pharmaceuticals Ltd.	A12
Alkem Laboratories Ltd.	A3	Ipca Laboratories Ltd.	A13
Aurobindo Pharma Ltd.	A4	Jubilant Life Sciences Ltd.	A14
Biocon Ltd.	A5	Pfizer Ltd.	A15
Cadila Healthcare Ltd.	A6	Piramal Enterprises Ltd.	A16
Cipla Ltd.	A7	Sanofi India Ltd.	A17
Divi'S Laboratories Ltd.	A8	Strides Pharma Science Ltd.	A18
Dr. Reddy'S Laboratories Ltd.	A9	Sun Pharmaceutical Inds. Ltd.	A19
Fortis Healthcare Ltd.	A10	Torrent Pharmaceuticals Ltd.	A20

2.2. Criteria Selection

In this paper we focus on the following abilities of the supply chains such as customer attractiveness through its products and services, profitable utilization of the working capital, efficient management of the working capital and inventory, and liquidity. Accordingly, we select five criteria for comparing relative supply chain performances of the sample organizations.

165

Sales Growth (SG) *is* a manifest of acceptance of the firm's products and services in the marketplace. SG is an indication of improved product and service quality, timeliness in delivery, flexibility, and responsiveness, which increase revenue. Hence, SG represents the operational efficiency of the activities carried out across the supply chain and holds a positive linkage with supply chain performance (Brewer and Speh, 2000). It is measured in terms of an incremental difference in sales value over two consecutive years. Return on Working Capital (RWC) is an important criterion for assessing the performance of supply chain as it entails the asset management efficiency of the firms (Okumuş et al., 2019). Cash to Current Liabilities (CCL) or cash ratio reflects the liquidity position of an organization. This ratio is one of the indicators that the creditors look at before taking loan related decision. CCL shows the ability of supply chains to generate cash for meeting short-term requirement such as debt repayment. Inventory not only is a cost element for any organization but also it is a part of the total asset (Shah and Shin, 2006). An effective inventory management adds to the overall profitability of the firm and hence, Inventory Turnover Ratio (ITR) needs to be optimized (Ganesan et al., 2009). ITR indicates the ability of the organization to effectively roll out its inventory. Finally, effective management of Cash Conversion Cycle (CCC) increases productivity, revenue generation, and results in a reduction in operating costs (Okumuş et al., 2019). Gunasekaran et al. (2004) reflected on the significance of converting the materials into cash through sales to ensure the return on investment for the shareholders. CCC stands on three components: cash receivables from the customer end, cash payables to the suppliers, and cash held up in the form of inventories (Richards and Laughlin, 1980). CCC is, therefore, an indicator of the efficiency of operations and effectiveness of the operational decisions about working capital management (Özbayraka and Akgün, 2006; Bagchi et al., 2012) which significantly impacts the profitability of the firms (Jose et al., 1996; Padachi, 2006; Lazaridis and Tryfonidis, 2006; Garcia-Teruel and Martinez-Solano, 2007; Falope and Ajilore, 2009; Okumuş et al., 2019). Lesser value of CCC signifies better profitability (Raheman and Nasr, 2007; Uyar, 2009) and lesser opportunity cost. Researchers (Churchill and Mullins, 2001; Farris and Hutchinson, 2002, 2003; Bauer, 2007) have pointed out that shorter the period of DSO, better it is for the firms to utilize the amount in different activities of the supply chain including sales promotion which has a positive impact on the financial performance. Moreover, the higher DSO cycle often leads to credit risk. The organizations usually offer discounts against early payments to encourage customers and maintain a mutual relationship (Moran, 2011). The nature of DIO in this context posits a challenge to the firms. Shah and Shin (2007) opined that drawing relationships between inventory holding and firm performance. The decisions on inventory management stand a bit complex. On one side, a higher inventory level ensures the timely availability of products. It enables the organizations to combat the effect of surge demand while on the other side, holding an additional inventory shot up the carrying costs and other potential hidden losses and bear a negative impact on the firm's liquidity. Keeping excess inventory results in forecasting error and becomes a potential cause of the Bullwhip effect (Tangsucheeva and Prabhu, 2013). Overall lower the DIO better is the performance of the supply chain (Chen et al., 2005; Singhal, 2005; Swamidass, 2007; Koumanakos, 2008; Capkun et al., 2009). On the other hand, more is the value of DPO, better will it be for the firms as the liquidity position is improved (Stewart, 1995). However, here lies a situation of tradeoff. Extending the payment cycle has a significant negative impact on the relationship between the firm and the suppliers (Fawcett et al., 2010). Modern SCM concepts believe in an end-to-end seamless operation, which demands integration among different chain members and mutual development. Higher DPO often generates

a strangulated effect as many suppliers face a liquidity crisis, often results in reduced service level (Raghavan and Mishra, 2011; Timme and Wanberg, 2011). It is evident from the literature that the researchers are of double way opinions. For example, Farris and Hutchison (2002) advocated for longer DPO, while Deloof (2003) and Garcia-Teruel and MartinezSolano (2007) observed evidence of better performance with shorter DPO. In general, within a toleration level as set by the nature of the relationship among the suppliers and users, type of supply, and terms and conditions of the service level agreements, it is a common notion to consider higher DPO for better functioning of the organizations within the CCC. Some of the recent studies also have reported the use of financial metrics for comparing supply chain performances (Avelar-Sosa et al., 2019; Fekpe and Delaporte, 2019; Tripathi et al., 2019). Table 2 summarizes the criteria considered for this study.

Table 2. List of criteria

Criteria	Code	UOM	Definition	Effect Direction
SG	C1	Times	(Sales$_t$-Sales $_{t-1}$)/ Sales $_{t-1}$	(+)
RWC	C2	Times	Earnings before Interest, Depreciation, Tax and Amortization divided by Working Capital	(+)
CCL	C3	Times	Cash and marketable securities/current liabilities	(+)
ITR	C4	Times	Cost of goods sold/average inventory	(+)
CCC	C5	Days	The average time elapsed between cash disbursement and collection	(-)

2.3. Methods

General Notations:

A_i = No. of alternative options (Healthcare companies in this paper); i = 1,2, …. m

C_j = No. of Criteria; j = 1,2, …. n

X = $[X_{ij}]_{m \times n}$; Decision Matrix

X_{ij} = Performance value of ith alternative for jth criterion

X_j^{max} = Maximum value for criterion j

X_j^{min} = Minimum value for criterion j

W_j = Weight or importance level for the criterion j

R = $[r_{ij}]_{m \times n}$; Normalized Decision Matrix

r_{ij} = Normalized performance value of ith alternative for jth criterion

2.3.1. PIPRECIA Method

PIPRECIA is an extension of the widely used group decision making approach such as Stepwise Weight Assessment Ratio Analysis (SWARA) method as developed by Kersuliene *et al.* (2010). Most often in real-life situations, it is very difficult for

reaching a consensus while a considerably larger set of decision makers attempts to find out the expected importance of a set of criteria and order them. The computational steps of PIPRECIA are quite similar to SWARA, but it provides a freedom not to put emphasis on sorting out the criteria based on expected significance in a group decision making environment (Biswas and Pamucar, 2020; Stanujkic *et al*., 2017; Keršulienė and Turskis, 2011). The computational steps as described by Stanujkic *et al.* (2017) are as follows:

Step 1: Selection of a set of relevant criteria for evaluating the alternatives.

Step 2: (Optional) Sort the criteria according to their expected significances as rated by the decision makers in descending order. For a small number of experts, it works well; however, for a large group of respondents, it is very difficult to arrive at a bias-free group consensus. Hence, in that case this step is not required.

Step 3: Determination of the relative importance of the criteria. Starting from the second criterion, the relative importance or significance of any criterion C_j is given by:

$$S_j^r = \begin{cases} > 1 & \text{when } C_j \succ C_{j-1} \\ 1 & \text{when } C_j = C_{j-1} \\ < 1 & \text{when } C_j \prec C_{j-1} \end{cases} \tag{1}$$

Here, 'r' denotes a particular respondent among all.

Step 4: Find out the coefficient K_j^r

$$K_j^r = \begin{cases} 1 & \text{when } j = 1 \\ 2 - S_j^r & \text{when } j > 1 \end{cases} \tag{2}$$

Step 5: Determine the recalculated criteria weights

$$Q_j^r = \begin{cases} 1 & \text{when } j = 1 \\ \dfrac{Q_{j-1}^r}{K_j^r} & \text{when } j > 1 \end{cases} \tag{3}$$

Step 6: Calculate the relative criteria weights

$$W_j^r = \frac{Q_j^r}{\sum_{j=1}^n Q_j^r} \tag{4}$$

In a group decision making environment for each decision maker, the above steps need to be carried out. Finally, for obtaining the group weight calculation, in a simple sense, geometric mean (GM) of individual weights is calculated (Stanujkic *et al.*, 2017) as given by:

$$W_j^* = \left(\prod_{r=1}^R W_j^r \right)^{1/R} \tag{5}$$

Here, 'R' is the total number of respondents.

Final criteria weights are given by:

$$W_j = \frac{W_j^*}{\sum_{j=1}^n W_j^*} \tag{6}$$

2.3.2. MABAC Method

MABAC uses the distance of the alternatives from the boundary approximation area (Upper Approximation Area or UAA for ideal or desirable solutions and Lower Approximation Area or LAA for non-ideal or non-desirable solutions along with Border Approximation Area or BAA) based the performance values under the influence of the criteria (Pamučar and Ćirović, 2015). This method is a widely used approach (Debnath *et al.*, 2017) as

- It produces a stable solution as compared to TOPSIS and VIKOR (Pamučar and Ćirović, 2015)
- It works with qualitative and quantitative data to classify the best, the worst, and borderline solutions (Roy *et al.*, 2018)
- It is based on a comprehensive, rational and sensible algorithm (Xue *et al.*, 2016)
- It compares the alternatives on relative strength and weakness dimensions under the effect of the criteria (Roy *et al.,* 2016).

This method has been applied in solving several social science related decision making problems (Yu *et al.*, 2017; Sharma *et al.,* 2018; Vesković *et al.,* 2018; Roy *et al.,* 2018; Biswas *et al.,* 2019). The methodological steps (in brief) are as under:

Step 1: Formation of the decision matrix X

Step 2: Formation of the normalized decision matrix R

Normalization:

$$r_{ij} = \frac{(x_{ij} - x_j^{min})}{(x_j^{max} - x_j^{min})} ; \text{For beneficial criteria} \tag{7}$$

$$r_{ij} = \frac{(x_{ij} - x_j^{max})}{(x_j^{min} - x_j^{max})} ; \text{For non-beneficial criteria} \tag{8}$$

Step 3: Construction of the weighted normalization matrix $Y = \left[Y_{ij}\right]_{m \times n}$

Where,

$$Y_{ij} = W_j(r_{ij} + 1) \tag{9}$$

Step 4: Determination of the Border Approximation Area (BAA) represented as $T = \left[T_j\right]_{1 \times n}$

Where, $T_j = \left(\prod_{i=1}^m Y_{ij}\right)^{1/m}$ \hfill (10)

Step 5: Derive Q Matrix related to the separation of the alternatives from BAA

$$Q = Y\text{-}T \tag{11}$$

A particular alternative A_i is said to be belonging to the Upper Approximation Area (UAA) i.e. T^+ if $Q_{ij} > 0$ or Lower Approximation Area (LAA) i.e. T^- if $Q_{ij} < 0$ or BAA i.e. T if $Q_{ij} = 0$.

The alternative A_i is considered to be the best among the others if more numbers of criteria pertaining to it possibly belong to T^+.

Step 6: Ranking of the alternatives in descending order based on the final appraisal score given by

$$S_i = \sum_{j=1}^n Q_{ij} \tag{12}$$

2.3.3. CoCoSo Method

The primary objective of any MCDM framework is to determine the best feasible solution among the available options under the influence of the set of relevant criteria. Now, in real-life situations, many times these criteria are characterized by non-commensurable and conflicting nature. Under this circumstance, there is no alternative which can satisfy the requirements of all the criteria to a considerable extent. Hence, decision makers need to accept a tradeoff or compromise solution subject to the criteria considered. Looking into it, researchers have attempted to develop such models which can deal with multiple criteria (conflicting nature) based compromise solution. The popular techniques such as TOPSIS, COPRAS and VIKOR have been used extensively in this regard. However, these techniques suffer from following issues

- TOPSIS and VIKOR consider the negative ideal solution while calculating the Euclidean distance of each alternative
- The traditional COPRAS and TOPSIS methods do not provide meaningful solutions when work with mixed data and suffer fro Bagchi m rank reversal phenomena (Aouadni et al., 2017)

Under this situation, CoCoSo (Yazdani *et al.*, 2018) works with weight aggregation process based on grey relational generation (which enables to cope up with conflicts) and incorporates the following features:

- It uses the power of weights for aggregation. As a result, it provides relatively stronger distance measurement for modelling purposes.
- For validation of ranking result (i.e., index) it uses three different aggregation strategies to generate the cumulative score. Therefore, it gives a complete ranking index taking compromising and conflicting situations into account.
- In a nutshell, this method is an integration of simple additive weighting and exponentially weighted product models.

The methodological steps can be described as follows (Yazdani *et al.*, 2018):

Step 1: Formation of the decision matrix X

Step 2: Derive the normalized decision matrix R

CoCoSo follows a normalization process suggested by Zeleny (1973). Accordingly, the normalized values are obtained as:

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \text{ (For beneficial criteria)} \tag{13}$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \text{ (For non-beneficial criteria)} \tag{14}$$

Step 3: Determine the aggregate of the weighted normalized performance values as given by

$$S_i = \sum_{j=1}^{n} W_j \, r_{ij} \tag{15}$$

Step 4: Calculation of the aggregate of the power weight of comparability values

$$P_i = \sum_{j=1}^{n} (r_{ij})^{W_j} \tag{16}$$

Step 5: Calculations of the relative weights of the alternatives

For this step, in CoCoSo method the relative weights are calculated in three ways such as

$$k_{i1} = \frac{P_i + S_i}{\sum_{i=1}^{m}(P_i + S_i)} \tag{17}$$

$$k_{i2} = \frac{S_i}{\min_i S_i} + \frac{P_i}{\min_i P_i} \tag{18}$$

$$k_{i3} = \frac{\alpha(S_i) + (1 - \alpha)P_i}{\left(\alpha \max_i S_i + (1 - \alpha) \max_i P_i\right)} \tag{19}$$

Here, these three strategies consider weighted arithmetic average; relative scores based on sum and product of performance values and allow the decision makers to flexibly select the α values which can vary from 0 to 1 (the usual value being 0.5).

Step 6: Find out the final ranking score

The final ranking of the alternatives is done depending on the overall k_i value (higher value implies more importance) which is given as:

$$k_i = (k_{i1} k_{i2} k_{i3})^{1/3} + \frac{1}{3} (k_{i1} + k_{i2} + k_{i3}) \tag{20}$$

2.3.4. MARCOS Method

This method is a new addition to the portfolio of compromise solution based MCDA (Stević et al., 2020). It has been used in solving complex research problems (Stević and Brković, 2020; Stanković et al., 2020). The procedural steps are explained below:

170

Step 1: Formation of the extended decision matrix (EDM)

In the EDM the first row is occupied by the anti-ideal solution (AIS) values and the last row indicates the ideal solution (IS) values.

AIS indicates the most pessimistic choice whereas IS is the most optimistic selection. The values are calculated as follows.

$$AIS = \min_i x_{ij} \text{ when } j \in J^+; \ \max_i x_{ij} \text{ when } j \in J^- \tag{21}$$

$$IS = \max_i x_{ij} \text{ when } j \in J^+; \ \min_i x_{ij} \text{ when } j \in J^- \tag{22}$$

Here, J^+ represents a set of beneficial criteria (whose effect direction is +ve) and J^- indicates a set of non-beneficial criteria (having –ve effect direction).

Step 2: Normalization

The normalized values are given by (using linear normalization

$$r_{ij} = \frac{X_{ij} - AIS}{IS - AIS} \ (when \ j \in J^+) \tag{23}$$

$$r_{ij} = 1 - \frac{X_{ij} - AIS}{IS - AIS} \ (when \ j \in J^-) \tag{24}$$

Step 3: Formation of weighted matrix

$$V_{ij} = w_j r_{ij} \tag{25}$$

Step 4: Calculation of utility degrees alternatives with respect to IS and AIS

$$K_i^- = \frac{S_i}{S_{AIS}} \tag{26}$$

$$K_i^+ = \frac{S_i}{S_{IS}} \tag{27}$$

Where,

$$S_i = \sum_{j=1}^n V_{ij} \tag{28}$$

Step 5: Determination of utility functions with respect to IS and AIS

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{29}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{30}$$

Step 6: Calculation of the utility function values for the alternatives

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}} \tag{31}$$

Decision rule: The higher is the utility value, better is the alternative

3. Findings and Discussion

Table 4-7 present the step by step derivation of the criteria weights using PIPRECIA method. For this purpose, we have approached to three experts who have substantial experience in the stated field. Table 3 provides a summary of experts' profiles. In the tables 4-6, their responses are summarized and subsequently, values of the parameters are calculated using eq. (2), (3), and (4).

Table 3. Experts' profiles

Expert	1	2	3
Experience	10 years	18 yrs	25 years
Industry	Healthcare	Healthcare, FMCG	Chemical, Healthcare

Table 4. Response of Expert 1 & Weights of the Criteria

Criteria	Code	Sj1	Kj1	Qj1	Wj1
SG	C1		1.000	1.000	0.2247
RWC	C2	1.15	0.850	1.176	0.2643
CCL	C3	0.8	1.200	0.980	0.2203
ITR	C4	0.4	1.600	0.613	0.1377
NWCC	C5	1.1	0.900	0.681	0.1530

Table 5. Response of Expert 2 & Weights of the Criteria

Criteria	Code	Sj2	Kj2	Qj2	Wj2
SG	C1		1.000	1.000	0.2180
RWC	C2	1.25	0.750	1.333	0.2907
CCL	C3	0.55	1.450	0.920	0.2005
ITR	C4	0.8	1.200	0.766	0.1671
NWCC	C5	0.65	1.350	0.568	0.1238

Table 6. Response of Expert 3 & Weights of the Criteria

Criteria	Code	Sj3	Kj3	Qj3	Wj3
SG	C1		1.000	1.000	0.2787
RWC	C2	0.8	1.200	0.833	0.2323
CCL	C3	0.9	1.100	0.758	0.2111
ITR	C4	0.75	1.250	0.606	0.1689
NWCC	C5	0.45	1.550	0.391	0.1090

Now by applying eq. (5) and (6), we derive the final weights of the criteria (see table 7).

Table 7. Weights of the Criteria

Criteria	Code	Wj*	Wj
SG	C1	0.239	0.2401
RWC	C2	0.261	0.2626
CCL	C3	0.210	0.2115
ITR	C4	0.157	0.1579
NWCC	C5	0.127	0.1279

It is important to ensure harmony in a typical group decision making format. For this purpose, we check the consistency of each individual expert's rating with the aggregated final weight. We calculate Spearman's ρ using IBM SPSS (version 24) software. Spearman's ρ measures the degree of interrelation in terms of the correlation coefficient among the variables compared. Table 8 shows that individual decisions are in sync with the group opinion.

Table 8. Consistency check I

	Group_Weight
Weight_Exp_1	.945*
Weight_Exp_2	.951*
Weight_Exp_3	.910*

* Correlation is significant at the 0.05 level (2-tailed).

Now, we move to rank the sample organizations based on their comparative supply chain performance. Table 9 exhibits performance values of the alternatives (organizations) under different criteria as considered here.

Table 9. Decision matrix

Weight	0.2401	0.2626	0.2115	0.1579	0.1279
Criteria	C1	C2	C3	C4	C5
	(+)	(+)	(+)	(+)	(-)
Company					
A1	0.0973	0.4011	1.96	6.06	90.18
A2	0.2428	2.1991	0.12	4.11	101.15
A3	0.1063	1.2033	0.29	5.76	-5.31
A4	0.1897	0.8828	0.01	2.7	240.85
A5	-0.2638	0.4479	0.54	5.35	144.47
A6	0.1147	2.0538	0.04	4.9	195.12
A7	0.0857	0.5013	0.95	4.31	266.65
A8	0.2713	0.5612	1.69	2.79	242.32
A9	0.1353	0.5313	0.73	4.6	206.03
A10	-0.0084	-0.4166	0.02	15.46	-68.32
Weight	0.2401	0.2626	0.2115	0.1579	0.1279
Criteria	C1	C2	C3	C4	C5
	(+)	(+)	(+)	(+)	(-)
Company					
A11	0.0809	1.5779	0.41	6.43	37.95
A12	0.1372	0.8885	0.12	4.38	66.8
A13	0.1285	0.6983	0.35	3.52	209.58
A14	0.031	-1.8818	0.01	6.43	41.2
A15	0.051	0.4464	2.15	5.38	21.52
A16	0.0703	-0.0758	0.08	14.29	17.57
A17	0.1121	0.8037	0.69	5.74	83
A18	0.0684	1.4684	0.24	3.46	126.97
A19	0.1422	-0.8247	0.04	3.69	233.16
A20	0.3413	4.0801	0.19	3.96	237.09

Next, we carry out the comparative analysis of the organizations under study using the MCDM algorithms as used here. First, we apply MABAC method. Table 10 shows the final rankings based on appraisal scores, obtained using eq. 7-12. Proceeding further, we compare the performances of sample organizations using the compromise solution approach CoCoSo. Using the eq. 13-20 we derive the competitive positions of

the alternatives (see table 11). Finally, table 12 highlights the findings in terms of ranking of the organizations derived as per the procedural steps (eq. 21-31) of the latest compromise solution based MCDM methodology such as MARCOS.

In order to check the consistency among the results obtained from three distinct algorithms, We calculate Kendall's τ and Spearman's ρ using IBM SPSS (version 24) software. Spearman's ρ measures the degree of interrelation in terms of the correlation coefficient among the variables compared while Kendall's τ measures the probability of concordance and discordance among them (Nelsen, 1992).

Table 10. Ranking result (MABAC)

Company	Sum (Si)	Rank_MABAC	Company	Sum (Si)	Rank_MABAC
A1	0.1592	3	A11	0.0758	6
A2	0.0859	5	A12	0.0028	11
A3	0.0658	9	A13	-0.0515	16
A4	-0.0748	17	A14	-0.1371	18
A5	-0.1519	20	A15	0.1794	1
A6	-0.0053	13	A16	0.0713	7
A7	-0.0299	15	A17	0.0561	10
A8	0.1100	4	A18	-0.0215	14
A9	-0.0039	12	A19	-0.1507	19
A10	0.0664	8	A20	0.1610	2

Table 11. Ranking result (CoCoSo)

Company	ki	Rank_CoCoSo	Company	ki	Rank_CoCoSo
A1	2.170174	3	A11	2.060398	6
A2	2.067633	4	A12	1.880885	11
A3	2.036865	8	A13	1.699495	15
A4	1.42355	18	A14	1.357961	19
A5	1.270518	20	A15	2.202375	1
A6	1.860046	12	A16	2.062095	5
A7	1.475917	16	A17	1.993071	9
A8	1.922084	10	A18	1.792973	14
A9	1.817654	13	A19	1.44915	17
A10	2.038985	7	A20	2.185628	2

Table 12. Ranking result (MARCOS)

Company	Ki-	Ki+	f(Ki-)	f(Ki+)	f(Ki)	Rank
A1	4.211465	0.617644	0.12790	0.8721	0.606271	3
A2	3.704441	0.543284	0.12790	0.8721	0.533281	6
A3	2.911298	0.426964	0.12790	0.8721	0.419103	15
A4	3.282138	0.481351	0.12790	0.8721	0.472488	10
A5	2.103364	0.308474	0.12790	0.8721	0.302795	19
A6	3.552041	0.520934	0.12790	0.8721	0.511342	8
A7	3.787117	0.55541	0.12790	0.8721	0.545183	5
A8	4.735647	0.694519	0.12790	0.8721	0.681731	2
A9	3.62839	0.532131	0.12790	0.8721	0.522333	7
A10	2.539582	0.372449	0.12790	0.8721	0.365591	18
A11	3.248171	0.476369	0.12790	0.8721	0.467598	12
A12	2.849102	0.417843	0.12790	0.8721	0.410149	16

Company	Ki-	Ki+	f(Ki-)	f(Ki+)	f(Ki)	Rank
A13	3.277273	0.480637	0.12790	0.8721	0.471788	11
A14	1.602783	0.23506	0.12790	0.8721	0.230732	20
A15	3.959377	0.580673	0.12790	0.8721	0.569981	4
A16	3.090712	0.453276	0.12790	0.8721	0.444931	13
A17	3.36252	0.493139	0.12790	0.8721	0.484059	9
A18	3.018697	0.442715	0.12790	0.8721	0.434564	14
A19	2.642797	0.387586	0.12790	0.8721	0.38045	17
A20	5.103074	0.748405	0.12790	0.8721	0.734625	1

For identifying top and worst performers, the geometric mean of the year wise ranks is calculated for each organization. In literature, there are instances where researchers (Basak and Saaty, 1993; Barzilai and Lootsma, 1997; Stanujkic et al., 2015) have mentioned the use of the geometric mean in finding out the synthesized view to reach group consensus in case different opinions or methodologies are adopted. In these cases, the geometric mean is a useful measure for averaging (Fleming and Wallace, 1986). But, in this paper, for more objective evaluation, we use Simple Additive Weighting (SAW) method to compare the results obtained from three algorithms used here. We take the score values of the alternatives obtained from each algorithm and apply SAW method (Simanaviciene and Ustinovichius, 2010) using linear max-min normalization. We assign equal priorities to all three algorithms. Table 13 provides the summary of rankings and table 14 shows the result of the consistency test. For further investigation we perform related sample Wilcoxon Signed Rank Test (WSRT). Table 15 indicates the test result. The null hypothesis for WSRT states that the median of differences between rankings of any two algorithms is equal to zero.

Table 13. Ranking summary

Company	Ranking Results			Final Rank (SAW)
	MABAC	CoCoSo	MARCOS	
A1	3	3	3	3
A2	5	4	6	5
A3	9	8	15	9
A4	17	18	10	17
A5	20	20	19	19
A6	13	12	8	11
A7	15	16	5	16
A8	4	10	2	4
A9	12	13	7	12
A10	8	7	18	10
A11	6	6	12	6
A12	11	11	16	13
A13	16	15	11	15
A14	18	19	20	20
A15	1	1	4	2
A16	7	5	13	7
A17	10	9	9	8
A18	14	14	14	14
A19	19	17	17	18
A20	2	2	1	1

Table 14. Consistency test II

		Rank MABAC	Rank CoCoSo	Rank MARCOS	Final Rank
Kendall's tau	Rank_MABAC	1			
	Rank_CoCoSo	.884**	1		
	Rank_MARCOS	.463**	.368*	1	
	Final_Rank	.895**	.842**	.526**	1
Spearman's rho	Rank_MABAC	1			
	Rank_CoCoSo	.959**	1		
	Rank_MARCOS	.638**	.528*	1	
	Final_Rank	.980**	.952**	.690**	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 15. Result of WSRT

Pair	Significance Value*	Decision
MABAC and CoCoSo	0.439	The null hypothesis is supported
MABAC and MARCOS	0.965	The null hypothesis is supported
MARCOS and CoCoSo	1.000	The null hypothesis is supported

* at the 0.05 level (Asymptotic significance, 2-sided)

In order to check the stability of the results obtained by using these three algorithms we carry out the sensitivity analysis. Sensitivity analysis is useful for achieving a rational and reliable results while reducing subjectivity and bias (Mukhametzyanov and Pamucar, 2018; Pamučar et al., 2016). For carrying out the sensitivity analysis, we perform four experients wherein we replace the weights of the criteria other than that holds the highest weight. It means in each experiement, the weight of a particular criterion (not having the highest weight) gets replaced with the highest value while keeping the priorities of other criteria same. Accordingly, we rank the companies under each circumstance applying all three methods as mentioned here. Table 16 describes the experiments done for carrying out the sensitivity analysis. Table 17-22 demonstrates the results of sensitivity analysis for all the MCDM frameworks.

Table 16. Experimental cases for sensitivity analysis

Criteria	Weights				
	Actual	Case 1	Case 2	Case 3	Case 4
C1	0.2401	0.2626	0.2401	0.2401	0.2401
C2	0.2626	0.2401	0.2115	0.1579	0.1279
C3	0.2115	0.2115	0.2626	0.2115	0.2115
C4	0.1579	0.1579	0.1579	0.2626	0.1579
C5	0.1279	0.1279	0.1279	0.1279	0.2626

Table 17. Result of sensitivity analysis (MABAC)

Company	Ranks under different cases				
	Actual	Case 1	Case 2	Case 3	Case 4
A1	3	2	2	2	2
A2	5	5	8	10	9
A3	9	9	10	8	5
A4	17	17	17	18	18
A5	20	20	20	20	19
A6	13	13	14	13	15
A7	15	15	13	14	16
A8	4	4	3	5	8
A9	12	12	11	11	12
A10	8	8	7	3	3
Company	Ranks under different cases				
	Actual	Case 1	Case 2	Case 3	Case 4
A11	6	7	6	7	6
A12	11	11	12	12	11
A13	16	16	16	16	17
A14	18	18	18	17	14
A15	1	1	1	1	1
A16	7	6	5	4	4
A17	10	10	9	9	7
A18	14	14	15	15	13
A19	19	19	19	19	20
A20	2	3	4	6	10

Table 18. Consistency check III (Among the rankings obtained through sensitivity analysis for MABAC)

		Actual	Case1	Case2	Case3	Case4
Kendall's tau	Actual	1				
	Case1	.979**	1			
	Case2	.895**	.916**	1		
	Case3	.821**	.842**	.884**	1	
	Case4	.705**	.726**	.726**	.842**	1
Spearman's rho	Actual	1				
	Case1	.997**	1			
	Case2	.977**	.982**	1		
	Case3	.935**	.946**	.971**	1	
	Case4	.863**	.878**	.892**	.950**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 19. Result of sensitivity analysis (CoCoSo)

Company	Ranks under different cases				
	Actual	Case 1	Case 2	Case 3	Case 4
A1	3	3	2	4	3
A2	4	4	7	9	8
A3	8	8	8	6	5
A4	18	18	18	23	19
A5	20	20	20	24	20
A6	12	12	13	13	14
A7	16	16	16	21	18
A8	10	10	10	10	11
A9	13	13	12	12	13
A10	7	7	5	1	2
Company	Ranks under different cases				
	Actual	Case 1	Case 2	Case 3	Case 4
A11	6	6	6	5	6
A12	11	11	11	11	9
A13	15	15	15	19	15
A14	19	19	19	22	16
A15	1	1	1	3	1
A16	5	5	4	2	4
A17	9	9	9	8	7
A18	14	14	14	14	12
A19	17	17	17	20	17
A20	2	2	3	7	10

Table 20. Consistency check IV (Among the rankings obtained through sensitivity analysis for CoCoSo)

		Actual	Case1	Case2	Case3	Case4
Kendall's tau	Actual	1				
	Case1	1.000**	1			
	Case2	.937**	.937**	1		
	Case3	.800**	.800**	.863**	1	
	Case4	.737**	.737**	.800**	.874**	1
Spearman's rho	Actual	1				
	Case1	1.000**	1			
	Case2	.986**	.986**	1		
	Case3	.916**	.916**	.956**	1	
	Case4	.890**	.890**	.926**	.970**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 21. Result of sensitivity analysis (MARCOS)

Company	Ranks under different cases				
	Actual	Case 1	Case 2	Case 3	Case 4
A1	3	3	3	3	4
A2	6	6	7	8	10
A3	15	15	15	15	17
A4	10	10	11	14	7
A5	19	19	19	19	18
A6	8	8	9	11	9
A7	5	5	5	6	3
A8	2	2	1	1	1
A9	7	7	6	7	5
A10	18	18	18	10	19
Company	Actual	Case 1	Case 2	Case 3	Case 4
A11	12	12	12	12	15
A12	16	16	16	17	16
A13	11	11	10	13	8
A14	20	20	20	20	20
A15	4	4	4	4	6
A16	13	13	13	5	13
A17	9	9	8	9	12
A18	14	14	14	16	14
A19	17	17	17	18	11
A20	1	1	2	2	2

Table 22. Consistency check V (Among the rankings obtained through sensitivity analysis for MARCOS)

		Actual	Case1	Case2	Case3	Case4
Kendall's tau	Actual	1				
	Case1	1.000**	1			
	Case2	.958**	.958**	1		
	Case3	.758**	.758**	.800**	1	
	Case4	.768**	.768**	.768**	.589**	1
Spearman's rho	Actual	1				
	Case1	1.000**	1			
	Case2	.994**	.994**	1		
	Case3	.872**	.872**	.880**	1	
	Case4	.917**	.917**	.920**	.758**	1

** Correlation is significant at the 0.01 level (2-tailed).

This study reveals a number of observations. First, we observe that there is a variation in the comparative positions of the sample organizations as derived by using three MCDM frameworks. Top five positions are occupied by a same group of companies with some variations within the group. However, we see the bottom five group shows considerable changes in the positions as we apply three methods. Second, if we analyze specifically, MABAC based ranking shows highest correlation with the aggregate final result. Among the methods, the results obtained from MABAC, CoCoSo, and MARCOS are statistically consistent with each other as it gets revealed

from table 14. Here, MABAC and CoCoSo show more consistency between the results obtained by using these algorithms. Third, considering overall, we find that the large cap firms have not done well as far as supply chain performance is concerned. Fourth, we observe that all methods responds more or less in a similar fashion to the sensitivity analysis. However, looking at the values of correlation coefficients, one can infer that CoCoSo performs slightly better under different situations. Figure 1-3 graphically present the result of sensitivity analysis for all three methods.
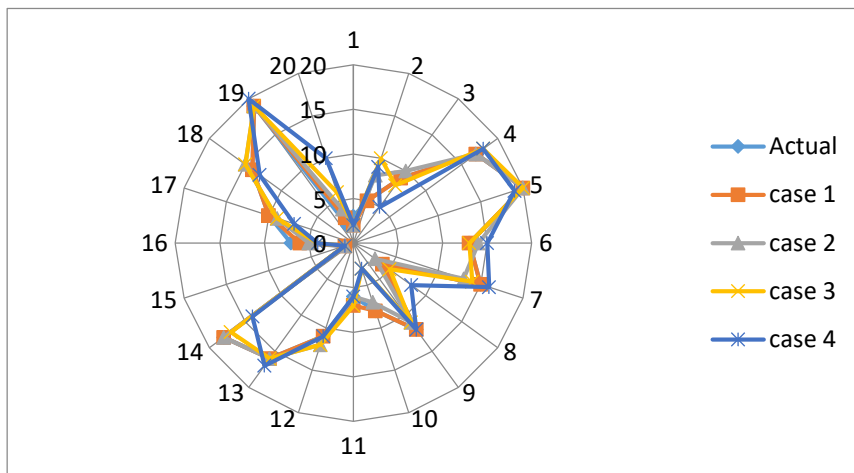
Figure 1. Sensitivity Analysis (MABAC)
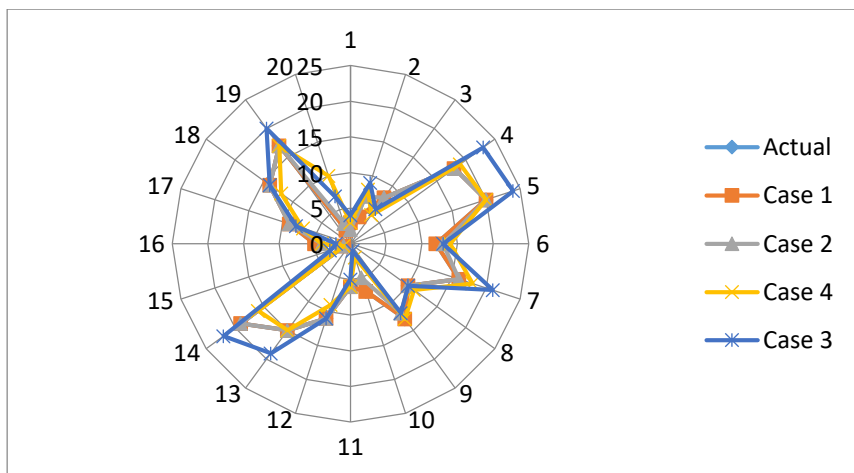
Figure 2. Sensitivity Analysis (CoCoSo)
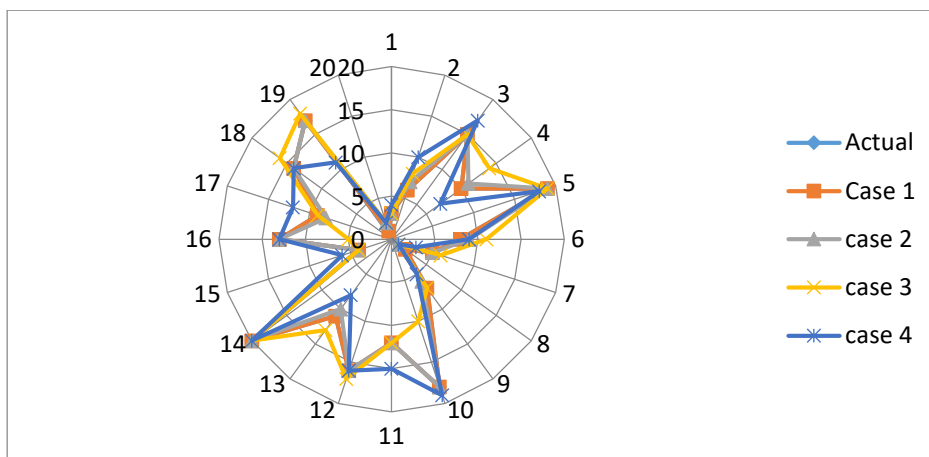
Figure 3. Sensitivity Analysis (MARCOS)

4. Conclusion

In this study, we attempt to compare a number of leading healthcare companies based on their supply chain performances measured in financial terms. For this purpose, we present a comparative analysis of three distinct algorithms such as MABAC, CoCoSo and MARCOS. We find that the large cap firms do not perform well. The results obtained from three MCDM frameworks show consistency while CoCoSo appears to be comparatively better. The present study has a number of managerial and social implications. First, with the effects of the factors like increasing population and pollution level, transformation in the climate, and changes in the lifestyle, healthcare operations have become critical and delicate in nature particularly in the diverse country like India. In addition, as the level of competition has got amplified to a large extent, the pressure of reducing prices for providing requisite service invokes a focused approach by the service providers. SCM is one of the key areas which can provide a competitive edge to the organizations. Hence, measuring supply chain performances following a multiple criteria based holistic framework linked with financial outcomes enables the organizations to take appropriate strategic and operational decisions. This study provides such a framework. Second, understanding relative performances of the focused organization and its competitors help the decision makers to take the appropriate futuristic course of actions. Third, most often policy makers need to know the nature of the industry and performances of the key players for formulating policies for the sector. The findings show significant variations across the organizations which might help the policy makers and industry analysts to intervene and formulate contemporary policies. Fourth, many a times the price for the offered services is decided from a cost plus margin point of view. Heath care is a typical sector where this approach often creates a disconnect between the service provider and the service users (i.e., the patients). This eventually impacts on the long-term business growth and brand value of the organization. Measuring supply chain performance and delving into its impact on the profitability of the organization helps the decision makers to come up with innovative and robust service offerings at an affordable price. Finally, the comparative analysis of MCDM algorithms. However, in the present study, the opinions of a few experts have been sought for measuring financial performances of the healthcare supply chains. In the future study, a larger

group of experts and consumers can be approached to identify critical success factors for the healthcare supply chains and based on that a comparative assessment may be carried out. Nevertheless, we believe that this limitation does not necessarily dilute the usefulness and relevance of this work.

References

Al-Hussaini, A. (2019). A study on sales growth and market value through supply chain. Uncertain Supply Chain Management, 7(3), 457-470.

Avelar-Sosa, L., García-Alcaraz, J. L., & Maldonado-Macías, A. A. (2019). Supply chain performance attributes and benefits in the manufacturing industry. In *Evaluation of Supply Chain Performance* (pp. 129-147). Springer, Cham.

Aouadni, S., Rebai, A., & Turskis, Z. (2017). The meaningful mixed data TOPSIS (TOPSIS-MMD) method and its application in supplier selection. Studies in Informatics and Control, 26(3), 353-363.

Askariazad, M., & Wanous, M. (2009). A proposed value model for prioritising supply chain performance measures. International Journal of Business Performance and Supply Chain Modelling, 1(2-3), 115-128.

Bagchi, B., Chakrabarti, J., & Basu Roy, P. (2012). Influence of working capital management on profitability: A study on Indian FMCG companies. International Journal of Business and Management, 7(22), 1-10.

Basak, I., & Saaty, T. (1993). Group decision making using the analytic hierarchy process. Mathematical and Computer Modelling, 17(4-5), 101-109.

Barzilai, J., & Lootsma, F. A. (1997). Power relations and group aggregation in the multiplicative AHP and SMART. Journal of Multi-Criteria Decision Analysis, 6(3), 155-165.

Bauer, D. (2007). Working capital management: Driving additional value within AP. Financial Executive, 23(8), 60- 63.

Bhagwat, R., & Sharma, M. K. (2007). Performance measurement of supply chain management using the analytical hierarchy process. Production Planning and Control, 18(8), 666-680.

Bhattacharya, A., Mohapatra, P., Kumar, V., Dey, P. K., Brady, M., Tiwari, M. K., & Nudurupati, S. S. (2014). Green supply chain performance measurement using fuzzy ANP-based balanced scorecard: a collaborative decision-making approach. Production Planning and Control, 25(8), 698-714.

Biswas, S., & Pamucar, D. (2020). Facility Location Selection for B-Schools in Indian Context: A Multi-Criteria Group Decision Based Analysis. Axioms, 9(3), 77. https://doi.org/10.3390/axioms9030077

Biswas, S., Bandyopadhyay, G., Guha, B., & Bhattacharjee, M. (2019). An ensemble approach for portfolio selection in a multi-criteria decision making framework. Decision Making: Applications in Management and Engineering, 2(2), 138-158.

Brewer, P. C., & Speh, T.W. (2000). Using the balanced scorecard to measure supply chain performance Peter C Brewer; Thomas WSpeh. Journal of Business logistics, 21(1), 75-93

Capkun, V., Hameri, A. P., & Weiss, L.A. (2009). On the relationship between inventory and financial performance in manufacturing companies. International Journal of Operations and Production Management, 29(8), 789-806.

Chen, H., Frank, M. Z., & Wu, O. Q. (2005). What actually happened to inventories of American companies between 1981 and 2000? Management Science, 51(7), 1015-1031.

Chithambaranathan, P., Subramanian, N., & Palaniappan, P. K. (2015). An innovative framework for performance analysis of members of supply chains. Benchmarking: An International Journal, 22(2), 309-334.

Christopher, M. (2005). Logistics and Supply Chain Management: Creating Value-Adding Networks, FT/Prentice-Hall, Harlow

Christopher, M. (1998). Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service, FT/Prentice-Hall, Harlow.

Churchill, N. C., & Mullins, J. W. (2001). How fast can your company afford to grow? Harvard Business Review, 79(5), 135-142.

D'Avanzo, R. L., Starr, C. E., & Von Lewinski, H. (2004). Supply chain and the bottom line: A critical link. Outlook, 1(1), 38-45.

Debnath, A., Roy, J., Kar, S., Zavadskas, E.K., & Antucheviciene, J. (2017) A hybrid MCDM approach for strategic project portfolio selection of agro by-products. Sustainability, 9(8), 1302.

Deloof, M. (2003). Does working capital management affect profitability of Belgian firms? Journal of Business Finance and Accounting, 30(3/4), 573-587.

de Vries, J., & Huijsman, R. (2011). Supply chain management in health services: an overview. Supply Chain Management: An International Journal, 16(3), 159-165.

Dey, B., Bairagi, B., Sarkar, B., & Sanyal, S. K. (2016). Multi objective performance analysis: A novel multi-criteria decision making approach for a supply chain. Computers & Industrial Engineering, 94, 105-124.

Elgazzar, S. H., Tipi, N. S., Hubbard, N. J., and Leach, D. Z. (2012). Linking supply chain processes' performance to a company's financial strategic objectives. European Journal of Operational Research, 223(1), 276-289.

Ellram, L.M., & Liu, B. (2002). The financial impact of supply management. Supply Chain Management Review, 6(6), 30-37.

Ellram, L.M., Zsidisin, G.A., Siferd, S.P., & Stanly, M.J. (2002).The impact of purchasing and supply management activities on corporate success. Journal of Supply Chain Management, 38(1), 4-17.

Falope, O.I., & Ajilore, O.T. (2009). Working capital management and corporate profitability: evidence from panel data analysis of selected quoted companies in Nigeria. Research Journal of Business Management, 3, 73-84.

Farris, M.T., & Hutchison, P.D. (2002). Cash-to-cash: the new supply chain management metric. International Journal of Physical Distribution and Logistics Management, 32(4), 288-98.

Farris, M. T. II & Hutchison, P. D. (2003). Measuring cash-to-cash performance. The International Journal of Logistics Management, 14(2), 83-91.

Fawcett, S. E., Waller, M. A., & Fawcett, A. M. (2010). Elaborating a dynamic systems theory to understand collaborative inventory successes and failures. The International Journal of Logistics Management, 21(3), 510-537.

Fekpe, E., & Delaporte, Y. (2019). Sustainability integration and supply chain performance of manufacturing small and medium size enterprises. *African Journal of Economic and Management Studies*, 10 (2), 130-147. https://doi.org/10.1108/AJEMS-05-2018-0152

Fleming, P. J., & Wallace, J. J. (1986). How not to lie with statistics: the correct way to summarize benchmark results. Communications of the ACM, 29(3), 218-221.

Frohlich, M.T., & Westbrook, R. (2001). Arcs of integration: an international study of supply chain strategies. Journal of Operations Management, 19(2), 185-200.

Ganesan, S., George, M., Jap, S., Palmatier, R. W., & Weitz, B. (2009). Supply chain management and retailer performance: emerging trends, issues, and implications for research and practice. Journal of retailing, 85(1), 84-94.

García-Teruel, J. P., & Martinez-Solano, P. (2007). Effects of working capital management on SME profitability. International Journal of managerial finance, 3(2), 164-177.

Ghosh, I., & Biswas, S. (2016). A comparative analysis of multi-criteria decision models for ERP package selection for improving supply chain performance. Asia-Pacific Journal of Management Research and Innovation, 12(3-4), 250-270.

Govindan, K., Mangla, S. K., & Luthra, S. (2017). Prioritising indicators in improving supply chain performance using fuzzy AHP: insights from the case example of four Indian manufacturing companies. Production Planning & Control, 28(6-8), 552-573.

Grida, M., Mohamed, R., & Zaid, A. H. (2020). A Novel Plithogenic MCDM Framework for Evaluating the Performance of IoT Based Supply Chain. Neutrosophic Sets and Systems, 33(1), Article 21, 323-341.

Gunasekaran, A., Patel, C. & McGaughey, R. E. (2004). A framework for supply chain performance measurement. International Journal of Production Economics, 87(3), 333-347.

Huang, X., Kristal, M. M., & Schroeder, R. G. (2008). Linking learning and effective process implementation to mass customization capability. Journal of Operations Management, 26(6), 714- 729.

Janaki, D., Izadbakhsh, H., & Hatefi, S. (2018). The evaluation of supply chain performance in the Oil Products Distribution Company, using information technology indicators and fuzzy TOPSIS technique. Management Science Letters, 8(8), 835-848.

Johnson, M., & Templar, S. (2011). The relationships between supply chain and firm performance: the development and testing of a unified proxy. International Journal of Physical Distribution and Logistics Management, 41(2), 88-103.

Jose, M. L., Lancaster, C., & Stevens, J. L. (1996). Corporate returns and cash conversion cycles. Journal of Economics and finance, 20(1), 33-46.

Jothimani, D., & Sarmah, S. P. (2014). Supply chain performance measurement for third party logistics. Benchmarking: An International Journal, 21(6), 944-963.

Kancharla, S. P., & Hegde, V. G. (2016). Inferences about Supply Chain Practices using Financial Ratios. Journal of Supply Chain and Operations Management, 14(1), 144-161.

Keršulienė, V., & Turskis, Z. (2011). Integrated fuzzy multiple criteria decision making model for architect selection. Technological and Economic Development of Economy, 17(4), 645-666.

Keršuliene, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). Journal of business economics and management, 11(2), 243-258.

Ketzenberg, M. E., Van Der Laan, E., and Teunter, R. H. (2006). Value of information in closed loop supply chains. Production and Operations Management, 15(3), 393-406.

Kocaoğlu, B., Gülsün, B., and Tanyaş, M. (2013). A SCOR based approach for measuring a benchmarkable supply chain performance. Journal of Intelligent Manufacturing, 24(1), 113-132.

Koumanakos, D. P. (2008). The effect of inventory management on firm performance. International Journal of Performance Management, 57(5), 355-369.

Krause, D. R., Vachon, S., and Klassen, R. D. (2009). Special topic forum on sustainable supply chain management: introduction and reflections on the role of purchasing management. Journal of Supply Chain Management, 45(4), 18-25.

Kremers, L. (2010). The link between supply chain and finance. Supply Chain Asia, 22-25.

Kwon, I. W. G., Kim, S. H., and Martin, D. G. (2016). Healthcare supply chain management; strategic areas for quality and financial improvement. Technological Forecasting and Social Change, 113, 422-428.

Lalonde, B.J. (2000). Making finance take notice. Supply Chain Management Review, 4(5), 11-12.

Lambert, D.M., and Cooper, M.C. (2000). Issues in supply chain management. Industrial Marketing Management, 29(1), 65-83.

Lazaridis, I., and Tryfonidis, D. (2006). Relationship between working capital management and profitability of listed companies in the Athens stock exchange. Journal of Financial Management and Analysis, 19 (1), 26 – 35.

Lester, M. (1999). An interview with Bill L. Ramsey: One on one. Journal of Supply Chain Management, 35(4), 2-6.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T. S., and Rao, S. S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. Omega, 34(2), 107-124.

Lockamy III, A., and McCormack, K. (2004). Linking SCOR planning practices to supply chain performance: An exploratory study. International journal of operations and production management, 24(12), 1192-1218.

Moharamkhani, A., Bozorgi-Amiri, A., and Mina, H. (2017). Supply chain performance measurement using SCOR model based on interval-valued fuzzy TOPSIS. International Journal of Logistics Systems and Management, 27(1), 115-132.

Moran, P. (2011). Competitive edge: How early payment discounts can help your business. Accountancy Ireland, 43(1), 41-43.

Mentzer, J. T., Flint, D. J., and Kent, J. L. (1999). Developing a logistics service quality scale. Journal of Business logistics, 20(1.1999).

Mukhametzyanov, I., & Pamucar, D. (2018). A sensitivity analysis in MCDM problems: A statistical approach. Decision making: applications in management and engineering, 1(2), 51-80.

Najmi, A., & Makui, A. (2010). Providing hierarchical approach for measuring supply chain performance using AHP and DEMATEL methodologies. International Journal of Industrial Engineering Computations, 1(2), 199-212.

Nelsen, R. B. (1992). On measures of association as measures of positive dependence. Statistics and Probability Letters, 14(4), 269-274.

Okumuş, H., Ghorbani, S., and Karatepe, S. (2019). A study on relationship between financial performance and supply chain in the accepted companies in Borsa Istanbul. Uncertain Supply Chain Management, 7(3), 417-426.

Özbayraka, M., and Akgün, M. (2006). The effects of manufacturing control strategies on the cash conversion cycle in manufacturing systems. International Journal of Production Economics, 103(2), 535-550.

Padachi, K. (2006). Trends in working capital management and its impact on firms' performance: an analysis of Mauritian small manufacturing firms. International Review of Business Research Papers, 2 (2), 45 - 58.

Pamučar, D. S., Božanić, D., & Ranđelović, A. (2016). Multi-criteria decision making: An example of sensitivity analysis. Serbian journal of management, 12(1), 1-27. DOI:10.5937/sjm12-9464

Pamučar, D., and Ćirović, G. (2015). The selection of transport and handling resources in logistics centers using Multi-Attributive Border Approximation area Comparison (MABAC). Expert Systems with Applications, 42(6), 3016-3028.

Parasuraman, A., Berry, L. L., and Zeithaml, V. A. (1991). Refinement and reassessment of the SERVQUAL scale. Journal of retailing, 67(4), 420-451.

Parkan, C., and Wang, J. (2007). Gauging the performance of a supply chain. International Journal of Productivity and Quality Management, 2(2), 141-176.

Pramod, V. R., and Banwet, D. K. (2011). Performance measurement of SHER service supply chain: a balanced score card–ANP approach. International Journal of Business Excellence, 4(3), 321-345.

Raghavan, N. S. and Mishra, V. K. (2011). Short-term financing in a cash-constrained supply chain. International Journal of Production Economics, 134(2), 407-412.

Raheman, A., and Nasr, M. (2007). Working capital management and profitability–case of Pakistani firms. International review of business research papers, 3(1), 279-300.

Ray, G., Barney, J. B., and Muhanna, W. A. (2004). Capabilities, business processes, and competitive advantage: choosing the dependent variable in empirical tests of the resource-based view. Strategic management journal, 25(1), 23-37.

Richards, V. D., and Laughlin, E. J. (1980). A cash conversion cycle approach to liquidity analysis. Financial Management, 9(1), 32-38.

Rouyendegh, B. D., Baç, U., and Erkan, T. E. (2014). Sector selection for ERP implementation to achieve most impact on supply chain performance by using AHP-TOPSIS hybrid method. Tehnicki Vjesnik-Technical Gazette, 21(5), 933-937.

Roy, J., Ranjan, A., Debnath, A., and Kar, S. (2016). An extended MABAC for multi-attribute decision making using trapezoidal interval type-2 fuzzy numbers. arXiv preprint arXiv:1607.01254.

Roy, J., Chatterjee, K., Bandyopadhyay, A., and Kar, S. (2018). Evaluation and selection of medical tourism sites: A rough analytic hierarchy process based multi-attributive border approximation area comparison approach. Expert Systems, 35(1), e12232.

Schneller, E. S., and Smeltzer, L. R. (2006). Strategic management of the health care supply chain. Jossey-Bass.

Shafiee, M., Lotfi, F. H., and Saleh, H. (2014). Supply chain performance evaluation with data envelopment analysis and balanced scorecard approach. Applied Mathematical Modelling, 38(21-22), 5092-5112.

Shah, R., and Shin, H. (2007). Relationships among information technology, inventory, and profitability: An investigation of level invariance using sector level data. Journal of Operations Management, 25(4), 768- 784.

Sharma, H. K., Roy, J., Kar, S., and Prentkovskis, O. (2018). Multi Criteria Evaluation Framework for Prioritizing Indian Railway Stations Using Modified Rough AHP-Mabac Method. Transport and Telecommunication Journal, 19(2), 113-127.

Simanaviciene, R., & Ustinovichius, L. (2010). Sensitivity analysis for multiple criteria decision making methods: TOPSIS and SAW. *Procedia-Social and Behavioral Sciences*, 2(6), 7743-7744.

Singhal, V. (2005). Excess inventory and long-term stock price performance. Working Paper. Georgia Institute of Technology.

Stanković, M., Stević, Ž., Das, D. K., Subotić, M., & Pamučar, D. (2020). A new fuzzy MARCOS method for road traffic risk analysis. Mathematics, 8(3), 457. https://doi.org/10.3390/math8030457

Stanujkic, D., Zavadskas, E. K., Karabasevic, D., Smarandache, F., and Turskis, Z. (2017). The Use of the Pivot Pairwise Relative Criteria Importance Assessment Method for Determining the Weights of Criteria. Romanian Journal of Economic Forecasting, 20(4), 116-133.

Stanujkic, D., Djordjevic, B., and Karabasevic, D. (2015). Selection of Candidates in the Process of Recruitment and Selection of Personnel Based on the SWARA and ARAS Methods. Quaestus Multidisciplinary Research Journal,(7) June, 55, 53-64.

Stević, Ž., Pamučar, D., Puška, A., & Chatterjee, P. (2020). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). Computers & Industrial Engineering, 140, 106231. https://doi.org/10.1016/j.cie.2019.106231

Stević, Ž., & Brković, N. (2020). A Novel Integrated FUCOM-MARCOS Model for Evaluation of Human Resources in a Transport Company. Logistics, 4(1), 4. https://doi.org/10.3390/logistics4010004

Stewart, G. (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. Logistics Information Management, 8(2), 38-44.

Sufiyan, M., Haleem, A., Khan, S., & Khan, M. I. (2019). Evaluating food supply chain performance using hybrid fuzzy MCDM technique. Sustainable Production and Consumption, 20, 40-57.

Swamidass, P. M. (2007). The effect of TPS on US manufacturing during 1991-1998: Inventory increased or decreased as a function of plant performance. International Journal of Production Research, 45(16), 3763- 3778.

Tan, K. C., Kannan, V. R., Handfield, R. B., and Ghosh, S. (1999). Supply chain management: an empirical study of its impact on performance. International journal of operations and production Management, 19(10), 1034-1052.

Tangsucheeva, R., and Prabhu, V. (2013). Modeling and analysis of cash-flow bullwhip in supply chain. International Journal of Production Economics, 145(1), 431-447.

Timme, S. G., and Wanberg, E. (2011). How supply chain finance can drive cash flow. Supply Chain Management Review, (January/February), 18-24.

Tripathi, S., Rangarajan, K., & Talukder, B. (2019). Segmental differences in pharmaceutical industry and its impact on supply chain performance. *International Journal of Pharmaceutical and Healthcare Marketing*, 13(4), 516-540. https://doi.org/10.1108/IJPHM-12-2018-0063

Tyagi, M., Kumar, P., and Kumar, D. (2014). A hybrid approach using AHP-TOPSIS for analyzing e-SCM performance. Procedia Engineering, 97, 2195-2203.

Tseng, M. L., Lin, Y. H., Tan, K., Chen, R. H., and Chen, Y. H. (2014). Using TODIM to evaluate green supply chain practices under uncertainty. Applied Mathematical Modelling, 38(11-12), 2983-2995.

188

Uyar, A. (2009). The relationship of cash conversion cycle with firm size and profitability: an empirical investigation in Turkey. International Research Journal of Finance and Economics, 24(2), 186-193.

Uygun, Ö., & Dede, A. (2016). Performance evaluation of green supply chain management using integrated fuzzy multi-criteria decision making techniques. Computers & Industrial Engineering, 102, 502-511.

Varma, S., Wadhwa, S., and Deshmukh, S. G. (2008). Evaluating petroleum supply chain performance: application of analytical hierarchy process to balanced scorecard. Asia Pacific Journal of Marketing and Logistics, 20(3), 343-356.

Vesković, S., Stević, Ž., Stojić, G., Vasiljević, M., and Milinković, S. (2018). Evaluation of the railway management model by using a new integrated model DELPHI-SWARA-MABAC. Decision Making: Applications in Management and Engineering, 1(2), 34-50.

Wagner, S. M., Grosse-Ruyken, P. T., and Erhun, F. (2012). The link between supply chain fit and financial performance of the firm. Journal of Operations Management, 30(4), 340-353.

Wisner, P. (2011). Linking supply chain performance to a firm's financial performance. Supply Chain Management Review.

Wong, W. P., & Wong, K. Y. (2007). Supply chain performance measurement system using DEA modeling. Industrial Management & Data Systems, 107(3), 361-381.

Xue, Y.X., You, J.X., Lai, X.D., and Liu, H.C. (2016). An interval-valued intuitionistic fuzzy MABAC approach for material selection with incomplete weight information. Applied Soft Computing, 38, 703–713.

Yang, J. (2009). Integrative performance evaluation for supply chain system based on logarithm triangular fuzzy number-AHP method. Kybernetes, 38(10), 1760-1770.

Yazdani, M., Zarate, P., Zavadskas, E.K., and Turskis, Z. (2018). A Combined Compromise Solution (CoCoSo) method for multi-criteria decision-making problems. Management Decision. https://doi.org/10.1108/MD-05-2017-0458 (Accessed on Jan 10, 2019)

Yu, S. M., Wang, J., and Wang, J. Q. (2017). An interval type-2 fuzzy likelihood-based MABAC approach and its application in selecting hotels on a tourism website. International Journal of Fuzzy Systems, 19(1), 47-61.

Zeleny, M. (1973). Compromise programming, in Cocchrane, J.L. and Zeleny, M. (Eds), Multiple Criteria Decision Making, University of South Carolina Press, Columbia, SC, 262-301.

Zhu, Q., and Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. Journal of operations management, 22(3), 265-289.