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Research Paper

Evaluation And Selection Of Supplier In A Healthcare Supply Chain Using TOPSIS

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Abstract— The objective of SS (SS) process is to minimize risk in purchasing, enhance overall profit of the customer, and build the long lasting and close relations between suppliers and buyers. SS process is one of the main key processes of the supply chain management (SCM). So, selection of a supplier has become an important issue for development of a proper supply chain (SC) system.
Here, we have provided a case study for SS using Technique for Order Performance by Similarity to Ideal Solution (TOPSIS). We have explained it using crisp data. In this study, we evaluate five suppliers using crisp TOPSIS. This method can be used when one have to select one particular supplier from no. of suppliers in short period of time. It will be also helpful to the Pharmacists to select the best supplier who can fulfill all their needs. In spite of the no. of studies on SS, the evaluation and selection of suppliers using the specific measures of the healthcare sector are less investigated. In order to fill this gap, this research proposed a guide for SS of antibiotic drug.

Keywords— supplier, TOPSIS, crisp, antibiotic, pharmacist

1. Introduction

In the last thirty years, ideas and thoughts on business management have shown great change and development. SCM is one of the newest emerging and rapidly growing business management processes in all industries around the world. SCM is not an old discipline that has existed for hundreds or thousands of years, but a young and even growing discipline. The business world has just begun to change. Our business environment is changing, including globalization, more competition, higher consumer expectations, technological disruption and geopolitica factors. Some researchers developed SCM models in healthcare sectors as follows: Use references to provide the most salient background rather than an exhaustive review. The last sentence should concisely state your purpose for carrying out the study or a summary of the results [2]. Fernie and Rees [1] analyzed the effectiveness of service delivery from the perspective of three key groups: NHS procurement managers, service providers, managers in hospital trusts, customer service and companies that supply the NHS. McKone-Sweet et al. [2] worked on challenges in implementing SCM applications. Dongsoo an Bauknecht et al. [3] design and developed an integrated SCM system to improve product quality and reduce the cost of using pharmaceutical products in the healthcare industry. Callender [4] said that SCM has been successful in medicine, but there are still many problems to overcome and important practices need to be made more effective, but the client is using SCs. Doba et al. [5] gave an overview of the current challenges facing hospitals in SCM today and describes the steps healthcare organizations are taking to manage their SC. Shou [6] noted the potential use of SCM therapy in developing countries. Kavitha and Nanduri [7] focused on the impact on healthcare operating costs, outcomes in patient care and healthcare SC systems, and the use of RFID technology. Onder and Kabadayi [8] solved the SS problem in a service SC by using one of the popular multi-criteria decision making method, analytical network process (ANP). Choosing the right supplier and assessing supplier execution is an essential job to start with SCM [9]. Classical multi-criteria decision making (MCDM), evaluation and weighting have been validated [10], [11], [12]. TOPSIS a well known classical MCDM that provides the basis for the design of controllable SS models. TOPSIS was first developed by Hwang and Yoon [11] and later developed by [14] and [15]. The main idea is that the chosen option should be closest to the optimal solution (OS) and furthest from the pessimistic solution (PS). The following paper is organized as follows. In section 2, we studied related work of TOPSIS method applied to crisp data. In section 3, TOPSIS method is applied to our numerical example, section 4 gives calculations. Results are mentioned in section 5 followed by sensitivity analysis in section 6 and conclusion in section 7.

1.2 Methodology

Step I:

"Suppose there are m alternatives and n criteria, then decision matrix as proposed by decision makers will be

X = $(x_{ij})_{m*n}$ gives the relationship between criteria and alternatives.

The TOPSIS method (Hwang and Yoon 1981) is described by the following steps:

Step 1. Constitute the decision matrix

$$X = (x_{ij})_{m*n} \quad (1)$$

Using priority scores given to each alternative on each criteria".

Step 2. Compute the importance weight (wj) of the criteria using different techniques for weight assignment to criteria in TOPSIS method

Step 3: Calculating Normalized decision matrix. We normalize each value as follows: where m is the number of rows in the dataset and n is the number of rows. i vary along rows and j varies along the column.

The performance value in each cell is divided by the rooted summation of square value.

$$\bar{X}_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}}$$

$$i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n \quad (2)$$

The value in each cell is known as the normalized performance value

Step 4:

Next we multiply weights of each criteria with the normalized performance value of each cell to get weighted normalized decision matrix.

$$A_{ij} = \bar{X}_{ij} * W_j$$

$$i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n \quad (3)$$

Step II:

We then calculate the best value and the worst value.

It should be a lower value for non-productive operations, ie min is best and max is worst.

But when it comes to good standards, maximum value is requ ired, so the best quality will be the highest price and the best worst price will be the minimum value.

Below are the formulas for calculating the ideal best and ideal worst Euclidean distances.

V_j^+ = indicates the ideal (best) value

V_j^- = indicates the ideal (worst) value

$$S_i^+ = \sqrt{\sum_{i=1}^{m} (V_{ij} - V_j^{+})^2} \quad (4)$$

$$S_j^- = \sqrt{\sum_{j=1}^{m} (V_{ij} - V_j^{-})^2} \quad (5)$$

Step III:

Now the performance score is calculated. The formula for the performance score is

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad i = 1, 2, \ldots, m \quad (6)$$

Based on performance score, we can rank the alternative.

2. Related Work

TOPSIS applied to Crisp Data

TOPSIS method, allows to give ranks to alternatives to solve MCDM problem. Decision makers divides the criteria into benefit criteria and cost criteria according to it. This technique ambitions to choose quality choice having the minimal distance from the positive ideal solution (PIS) and the most distance from the negative ideal solution (NIS) the usage of Euclidean distances given by using formulation [16] In PIS, the benefit standards are maximized and the value standards are minimized, inversely, in NIS the price standards are maximized and the benefit standards are minimized. A set of preferences are evaluated and ranked in the descending order in accordance to their closeness values to the best solution [17]. TOPSIS method was verified by changing the no. of criteria and the no. of users, and determined that the performance was high when the no. of users was less than 320 and the no.of criteria was 16 or less [18]. A graphical model of the TOPSIS method was developed by used to select hospitals for disease diagnosis [19].

The importance weight of multiple criteria and the ranking of alternatives to these criteria were considered crisp variables evaluated by a group of decision makers. TOPSIS method described in the literature was extended by many researchers to facilitate decision-making in a fuzzy environment [20], [21].

SS is the company's interaction with identifying, evaluating, and contracting with suppliers. The supplier decision making process places a heavy burden on the company's financial assets and plays an important role in the results of any organization. The main purpose of the SS process is to reduce purchase risk, increase total value for the buyer, and facilitate the long-term relationship between buyer and seller [22] [23] Discussed the order preference by similarity ideal solution (TOPSIS) method with basic concepts and determine the TOPSIS algorithm. Second, they created a graphical model of the TOPSIS method using the TOPSIS algorithm andused the model to make decisions in daily life. [24] Aimed to demonstrate the quality of the system by comparing it with the best solution (fuzzy TOPSIS) as a technique to assist in making good decisions when posing complex and multidimensional problems. This method is used in many places as it allows the model and other methods to be studied accurately and impartially.

3. Theory/Calculation

Numerical Example:

The pharmacists wanted to keep the antibiotic drug of different companies for sale in the medical shop to make it available to fulfil the need of the patients at any point of time. So, the pharmacists can have same drug with different brands. There are five suppliers (A_1, A_2, A_3, A_4, A_5) for evaluation. Four decision-makers, DM_1, DM_2, DM_3 and DM_4 formed a

committee for selection of most suitable supplier for the same antibiotic drug. There are seven criteria which are considered: (1) relation with supplier (C_1), (2) demand of patients (C_2), (3) quality (C_3), (4) profit associated (C_4), (5) delivery time required (C_5) , (6) service after delivery (C_6) and (7) cost to patient (C_7).
The proposed technique is used for solving this problem.

4. Experimental Method/Procedure/Design

Step I:
Decision makers are the experts which are allotted with the task of weighing each attribute. Here, we have taken four decision makers.
Step 1:

Table 1: Decision matrix for first alternative, Supplier 1 i.e. A_1

Criteria	DM_1	DM_2	DM_3	DM_4	Attribute weights
C_1	9	10	10	9	9.5
C_2	10	10	10	8	9.5
C_3	10	10	10	9	9.75
C_4	9	6	10	7	8
C_5	10	9	10	8	9.25
C_6	9	8	2	9	7
C_7	9	8	10	9	9

Attribute weights are calculated by taking average.

Table 2: Decision matrix for first alternative, Supplier 2 i.e. A_2

Criteria	DM_1	DM_2	DM_3	DM_4	Attribute weights
C_1	10	8	9	7	8.5
C_2	7	8	6	6	6.75
C_3	8	9	5	7	7.25
C_4	8	6	5	7	6.5
C_5	9	9	6	6	7.5
C_6	8	7	2	6	5.75
C_7	10	9	8	7	8.5

Table 3: Decision matrix for first alternative, Supplier 3 i.e. A_3

Criteria	DM_1	DM_2	DM_3	DM_4	Attribute weights
C_1	6	9	5	8	7
C_2	5	8	4	8	6.25
C_3	7	9	4	9	7.25
C_4	7	7	5	7	6.5
C_5	8	9	5	8	7.5
C_6	9	8	2	7	6.5
C_7	9	8	6	8	7.75

Table 4: Decision matrix for first alternative, Supplier 4 i.e. A_4

Criteria	DM_1	DM_2	DM_3	DM_4	Attribute weights
C_1	7	10	4	8	7.25
C_2	5	10	5	7	6.75
C_3	6	9	5	9	7.25
C_4	9	6	5	8	7
C_5	9	9	5	7	7.5
C_6	8	8	2	6	6
C_7	9	8	5	7	7.25

Table 5: Decision matrix for first alternative, Supplier 5 i.e. A_5

Criteria	DM1	DM2	DM3	DM4	Attribute weights
C1	8	10	5	9	8
C2	6	10	3	8	6.75
C3	7	8	4	9	7
C4	9	6	3	7	6.25
C5	9	9	4	7	7.25
C6	9	8	2	8	6.75
C7	9	8	4	8	7.25

Using table1 to table 5, decision matrix can be given as:

Table 6: Decision matrix for all alternatives according to criteria

Criteria	A_1	A_2	A_3	A_4	A_5
C_1	9.5	8.5	7	7.25	8
C_2	9.5	6.75	6.25	6.75	6.75
C_3	9.75	7.25	7.25	7.25	7
C_4	8	6.5	6.5	7	6.25
C_5	9.25	7.5	7.5	7.5	7.25
C_6	7	5.75	6.5	6	6.75
C_7	9	8.5	7.75	7.25	7.25

Step 2: Importance weights of the criteria

Table 7: Importance weights of the criteria

Criteria	DM_1	DM_2	DM_3	DM_4	Attribute weights
C_1	10	10	10	9	9.75
C_2	10	10	10	8	9.5
C_3	10	10	10	9	9.75
C_4	9	7	10	8	8.5
C_5	10	9	10	8	9.25
C_6	9	8	2	9	7
C_7	10	9	10	9	9.5

Step 3: Normalize the decision matrix:
This step converts various attribute sizes to dimensionless fea tures, which allows comparison across criteria's.
For standardizing, each row of decision matrix, is divided by root of sum of square of respective row i.e. $\sqrt{\sum_{i=1}^{m} X_{ij}^{2}}$

Table 8: Normalized Decision Matrix

Criteria	A_1	A_2	A_3	A_4	A_5
C_1	0.5245	0.46929	0.38647	0.40028	0.44168
C_2	0.58248	0.41387	0.38321	0.41387	0.41387
C_3	0.56128	0.41736	0.41736	0.41736	0.40297
C_4	0.52014	0.42261	0.42261	0.45512	0.40636
C_5	0.52803	0.42813	0.42813	0.42813	0.41386
C_6	0.48786	0.40074	0.45301	0.41817	0.47044
C_7	0.50435	0.47633	0.4343	0.40628	0.40628

Step 4:
Next we multiply weights of each criteria with the above standardized decision matrix to get weighted normalized decision matrix (from table7 and table 8).

Table 9: Weighted Normalized Decision Matrix

Criteria	A_1	A_2	A_3	A_4	A_5
C1	5.11387	4.57557	3.76812	3.90269	4.30642
C2	5.53358	3.93176	3.64051	3.93176	3.93176
C3	5.4725	4.06929	4.06929	4.06929	3.92897
C4	4.42116	3.59219	3.59219	3.86851	3.45403
C5	4.8843	3.96025	3.96025	3.96025	3.82824
C6	3.41503	2.8052	3.1711	2.92717	3.29306
C7	4.79131	4.52512	4.12585	3.85966	3.85966

Step II:
Now we calculate the ideal best value and the ideal worst value.
It should be a lower value for non-productive operations, ie min is best and max is worst.
But when it comes to good standards, maximum value is requ ired, so the ideal best will be the maximum and the best worst price will be the minimum value.

Here, except cost to patient C_7 other criteria's are beneficial criteria's

Positive ideal solution V_j^+ = {5.11387, 5.53358, 5.4725, 4.42116, 4.8843, 3.41503, 3.85966}

Negative ideal solution V_j^- = {3.76812, 3.64051, 3.92897, 3.45403, 3.82824, 2.8052, 4.79131}

Table 10: Performance Score and rank of suppliers

Using, $S_i^+ = \sqrt{\sum_{i=1}^{m}(V_{ij}-V_j^+)^2}$ and

$S_j^- = \sqrt{\sum_{j=1}^{m}(V_{ij}-V_j^-)^2}$

Suppliers	A1	A2	A3	A4	A_5
S_i^+	0.931643056	2.679625673	3.005856312	2.720127979	2.768715646
S_i^-	3.193702262	0.929441254	0.795562948	1.093013679	1.2167819
$S_i^+ + S_i^-$	4.125345318	3.609066927	3.80141926	3.813141658	3.985497546
$\frac{S_i^-}{S_i^+ + S_i^-}$	0.774166043	0.257529515	0.209280506	0.286643869	0.305302383
Rank	1	4	5	3	2

Based on performance score, we rank the alternative A_1 as the best alternative among all the five alternatives.

5. Results

Selection of supplier is one of the most important task of pharmaceuticals in healthcare as most criteria's conflict each other, suppliers should be examined properly. SS comes under MCDM problem and it plays crucial role in supply chain management. Here, TOPSIS is used.

We have explained it using crisp data. The priorities of all the suppliers were like supplier 1 (0.774166043) was first, supplier 5 (0.305302383) was second, supplier 4 (0.286643869) was third and supplier 2 (0.257529515) was fourth and supplier 3 (0.209280506) was last using TOPSIS.

6. Sensitivity analysis

A sensitivity analysis was performed to check the robustness and stability of the rankings relative to the weights of the criteria was performed. It helped to validate how the priorities of the alternatives change as we vary the priority of a Criterion. For example if a service becomes much more important does the best choice of drug change?

Case i) Actual

Criteria	C1	C2	C3	C4	C5	C6	C7
Weightage	9.75	9.5	9.75	8.5	9.25	7	9.5
CCi	0.774166043	0.257529515	0.209280506	0.286643869	0.305302383		
Rank	1	4	5	3	2		

Case ii)

Criteria	C1	C2	C3	C4	C5	C_6	C_7
Weightage	9	9	9	9	9	9	9
CCi	1	0.2901852 54	0.1664838	0.1754154 14	0.2326264 28		
Rank	1	2	5	4	3		

Case iii)

Criteria	C1	C2	C3	C4	C_5	C_6	C_7
Weightage	9	8	9	8	9	7	9
CCi	1	0.303561832	0.152605151	0.167219938	0.217159153		
Rank	1	2	5	4	3		

Case iv)

Criteria	C1	C2	C3	C4	C_5	C_6	C_7
Weightage	7	8	9	7	8	9	7
CCi	1	0.261749649	0.176387843	0.167201778	0.238451814		
Rank	1	2	4	5	3		

So by varying weight of criteria's rankings of the suppliers were obtained and we have found that for almost all varied values of weights of all criterion, we got supplier 1 at the position one followed by supplier 2 at position 2. Hence there was no effect on ranking of the best supplier to be selected even if the weights of variables changes.

6. Conclusion

Despite the availability of no. of researches on supplier's selection and assessment, selection of suppliers with precise criteria's of anti-biotic drug are less studied. To address this gap, this research was conducted Depending on varied criteria, selection of supplier is one among the foremost vital tasks for companies. Since most of those criteria conflict one another, the choice suppliers ought to be inspected effectively. So some techniques like TOPSIS, ELECTRE, PROMETHEE, DEMATEL, AHP, ANP, etc., are developed for the same. During this study TOPSIS is employed. Hence TOPSIS model is utilized to solve the SS problem of an anti-biotic drug, which should determine the best supplier among 5 alternatives.

In this paper, we presented methodology to rank the suppliers and also choosing of best supplier on the basis of seven criteria's namely relation, demand, quality, profit, delivery time, service and cost to patient using TOPSIS. In crisp TOPSIS, Supplier 1> Supplier 5> Supplier 4> Supplier 2> Supplier 3 in the decreasing order of preference. The result of TOPSIS framework is able to assist decision makers to examine the rankings of the suppliers as well as strength and weakness of suppliers. However, the effectiveness of the initial assessment depends on the accuracy and value of the judgments they provide.

The plan can be used to make production decisions, production processes, production orders, logistics management and other decisions regarding location selection.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Authors' Contributions
Bhosale has contributed to the analysis, interpretation of the data, formatting, and editing of the manuscript. Umap was engaged in the drafting of the manuscript and gave his final approval for publication after reviewing it for significant intellectual content.

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