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AN EFFICIENT SUPPLIER SELECTION FOR INDIAN PHARMACEUTICAL INDUSTRY BY APPLYING FUZZY TOPSIS METHOD

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***Abstract*- Supplier selection is one of the critical processes in supply chain management which is associated with the flow of goods and services from the supplier of raw material to the last consumer. It is a multi-criteria problem which includes both qualitative and quantitative factors (criteria). Under many conditions the values of the criteria are often inaccurately defined for the decision makers. To reduce this problem, fuzzy multi-criteria decision making approach can be used. In this paper, a multi-criteria decision-making approach has been used for selecting supplier under uncertainty. The aim of this study is to develop a method to evaluate suppliers in supply chain based on technique for order preference by similarity to ideal solution method (TOPSIS) to select the most efficient supplier. This paper presents a successful application of FUZZY TOPSIS to an actual supplier selection problem in Indian pharmaceutical industry.**

Keywords- **supplier selection, supply chain management, multi-criteria decision-making, FUZZY TOPSIS method**

I. INTRODUCTION

Suppliers are key aspect of modern supply chain and play important role in the success or failure of any business. Supplier has substantial impact on the efficiency and effectiveness of the entire supply chain. Therefore, selecting the efficient suppliers can result in reduced cost, decreased supplying risk and improved quality. In the present market of global competition, it has become necessary for the manufactures to reduce their fixed costs and supply the goods at the right place in the right time to sustain the competition and survive in the market. India supplies 20% of global generic medicines market export in terms of volume, making the country the largest provider of generic medicines globally and expected to expand even further in coming years. It is likely that the manufacturer allocates more than 70% of its total production on purchased services and materials (Athena Forghani, 2018). It would not be easy for the decision makers to select best suppliers who can fulfill all the needs of the firm based on different criteria.

The pharmacies are ready to utilize a tremendous amount of pharmacy's financial resources in supplier selection process. In return, the pharmacy managers expect the reliable supplier in all the way to fulfill the service, on-time delivery at low-cost compared to other suppliers (P. Kelle, J. Woosley, and H. Schneider 2012). Other point to be considered is that, as a multiple criteria decision-making (MCDM) problem, the supplier selection would lie under the effect of many qualitative and quantitative conflicting factors. In general, multi criteria group decision-making (MCDM) problems are frequently used in this type of cases.
This study intends to adopt a qualitative method by using fuzzy TOPSIS algorithm with triangular fuzzy number. The extent method has been used to calculate the weight of criteria and Fuzzy TOPSIS method has been used to evaluate rate of alternatives. Fuzzy TOPSIS is a method that can help in objective and systematic evaluation of alternatives on multiple criteria. The fuzzy TOPSIS method hinges on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). The Fuzzy TOPSIS approach has been applied to various MCDM problems like location selection (Farimah mokhatab rafiei, 2012), optimal location airport fire stations (Mehmet Sevkli, 2014).

II. LITERATURE REVIEW

According to (Tahiri et al. 2008)"supplier selection problem has become one of the most important issues for establishing an effective supply chain system". Indeed, supplier selection and evaluation represents one of the significant roles of purchasing and supply management function (Kumara et al. 2003) contend that strategic partnership with the right supplier must be integrated within the supply chain to contain costs, improve quality and flexibility to meet end-customers' value and reduce lead time at different stages of the supply chain (Chris I., Bell-Hanyes, 2010).

The analysis of criteria for selection and measuring the performance of suppliers has been the focus of many academicians and purchasing practitioners since 1960s. (Weber,Current, Benton, 1991) Based on (Dickson's 1966) empirical study, 23 criteria were identified which purchasing managers generally consider when selecting a supplier. Of the identified criteria, quality, on-time delivery, and supplier's performance history were found vital in supplier selection regardless of the type of purchasing environment.

A two-stage model was developed by (Liao and Kao, 2011) by applying Fuzzy TOPSIS and multi-choice GP for selection the appropriate suppliers and allocating the orders.Also Fuzzy TOPSIS and multi-choice GP were used (Rouyendegh and Saputro, 2014) in a fertilizer and chemical producing company.

The Fuzzy TOPSIS approach has been applied to various MCDM problems ranging from facility location selection (T.C. Chu, 2002), robot selection (T.C. Chu, and Y.C. Lin, 2003), selection of system analysis engineer for a software company and choosing optimal initial training aircraft in Air Force Academy in Taiwan (T.C. Wang, and T.H. Chang, 2007), to service quality in hotel industry (J.M. Benitez, J.C. Martin, and C. Roman, 2007), plant layout design problem (T.Yang and C.C. Hung, 2007), transshipment site selection (S.Onut,andS.Sonar, 2008), and machine tool selection problem (M.Yurdakul, and Y.T. Ic, 2008).

The AHP approach was used to carry out an analysis of strategic supplier selection and evaluation in a generic pharmaceutical firm supply chain (Enyinda, et al., 2010). The researchers developed a model to aid them in the evaluation and selection of the important criteria and hence the best supplier for a pharmaceutical manufacturing firm. The selected criteria for the evaluation were regulatory compliance, quality, cost, service, supplier profile and risk. The researchers recommended that supplier selection process and evaluation represents one of the key activities that organizations must integrate into their core strategic decisions. Based on their research findings, the regulatory compliance selection criterion was most favored, followed by quality, risk, cost, supplier profile, and service. The model also enabled the researchers to select the best supplier for the case company (David Asamoah, J. A. 2012).

III. RESEARCH METHODOLOGY

The study approach comprises of two steps. In the first step, various criteria for suppliers rating selection are identified. In second step the experts in pharmaceutical industry were asked to give linguistic ratings to the criteria and the alternatives. The major supplier selection criteria in pharmaceutical companies are grouped under sixteen factors and a questionnaire was prepared to collect information about the importance of the criteria. Then the Fuzzy TOPSIS method has been applied which here consist of supplier's criteria as given below.

Supplier's criteria

In pharmaceutical companies, the main criterions are grouped under sixteen factors, which are shown in table-1 (Athena Forghani, 2018). Furthermore, an online questionnaire was prepared to collect rating information of selected criteria assessment and alternative assessment under study. Rating information of alternative assessment consists of a scale from 1 to 5, where 1 shows very low, 2 shows low, 3 shows medium, 4 shows high and 5 shows very high. Whereas, rating information of criteria assessment consists of a scale from 1 to 5, where 1 shows very poor, 2 shows poor, 3 shows fair, 4 shows good and 5 shows very good. Then the Fuzzy TOPSIS method was applied to get the alternative rating and to find the proper weightage to various criteria.

Table-1 Factors for supplier selection

Sr. no.	Factors	Significance
1	Response time (C_1)	Commitment of supplier towards fastest response time.
2	On time delivery (C_2)	Increases awareness about on time delivery importance.

3	Product quality (C_3)	Commitment by supplier towards product quality.
4	Product price (C_4)	Supplier pricing strategies could shape our overall profitability for the future.
5	Complete shipping document (C_5)	Properly completed documentation will help your shipment reach its destination on time.
6	Reputation (C_6)	A supplier good reputation is definitely preferred for better business.
7	Past record documentation (C_7)	Keeping clear past record documentation for just good relations.
8	Geographic location (C_8)	Global it is important to consider the geographical location of the supply.
9	Social factor (C_9)	Social factor represents another important set of influences on consumer behavior.
10	Environment factor (C_{10})	Environment respective image in the view of society, on any supplier.
11	Service warranty(C_{11})	To better understand the importance of product warranties in supplier today.
12	Flexibility (response to change) (C_{12})	Supplier flexibility refers to the ability of the supplier organization to respond to the changing demand.
13	Overall personal capability (C_{13})	Better overall personal capability of any supplier.
14	Supplier profile (C_{14})	Supplier profile important in business for market.
15	Financial status (C_{15})	Commitment of supplier to take financial rise.
16	Communication system (C_{16})	Effective communication between buyers and suppliers helps support long terms goals.

Table-2 Detailed profile of the criteria ratings of decision makers.

DM	Experts	Designation	Department/Area of expertise	Experience (years)
DM_1	1	Head of quality control	Quality	14
DM_2	2	Medical representative	Sales	9
DM_3	3	Procurement manager	Purchase	19
DM_4	4	Purchase executive	Purchase	8

The FUZZY TOPSIS theory details

The *Technique for order of preference by similarity to ideal solution* (TOPSIS) is a multi criteria decision analysis method which was originally developed by Hwang and Yoon in 1981 with further developments by Yoon in 1987 and Hwang, Lai and Liu in 1993 (Tonekaboni, 2012). The technique called Fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) can be used to evaluate multiple alternatives against the selected criteria. In the TOPSIS approach an alternative that is nearest to the Fuzzy Positive Ideal Solution (FPIS) and farthest from the Fuzzy Negative Ideal Solution (FNIS) is chosen as optimal. An FPIS is composed of the best performance values for each alternative whereas the FNIS consists of the worst performance values (Tonekaboni, 2012). The definitions of this method are as follow:

Definition 1: A fuzzy set $\tilde{a}$ in a universe of discourse X is characterized by a membership function $\mu_{\tilde{a}}(x)$ that maps each element x in X to a real number in the interval [0,1]. The function value $\mu_{\tilde{a}}(x)$ is termed the grade of membership of x in $\tilde{a}$. The nearer the value of $\mu_{\tilde{a}}(x)$ to unity, the higher the grade of membership of x in $\tilde{a}$ (Kore, 2017).

Definition 2: A triangular fuzzy number is represented as a triplet $\tilde{a}$ = (a_1, a_2, a_3). The membership function $\mu\tilde{a}(x)$ of triangular fuzzy number $\tilde{a}$ (Kore, 2017).

A fuzzy set $\tilde{a}$, membership function $\mu\tilde{a}$ that maps each element x in X to a real number in the interval [0, 1]. A triangular fuzzy number is represented $\tilde{a} = (a_1, a_2, a_3)$.

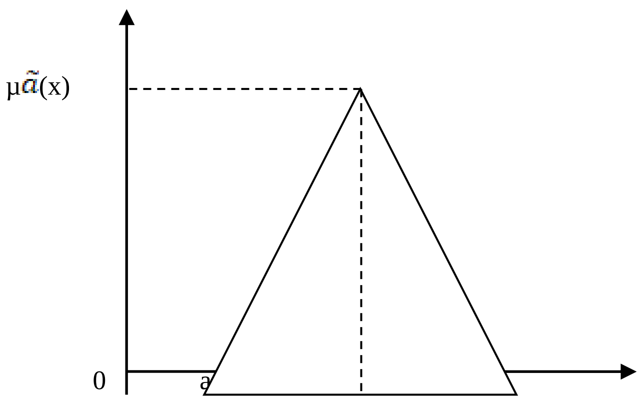

Figure-1: Triangular Fuzzy number system, (Kore, 2017)

a_2 gives the maximal grade of μ_a that $\mu_a=1$

a_1 gives the minimal grade of μ_a that $\mu_a=0$

a_1 and a_3 are the lower and upper bounds of the available area for the evaluation data.

$$\mu\tilde{a}(x) = \begin{cases} (x-a_1) / (a_2 - a_1) & \text{if } a_1 \leq x \leq a_2 \\ (a_3 - x) / (a_3 - a_2) & \text{if } a_2 \leq x \leq a_3 \\ 0 & \text{otherwise} \end{cases}$$

$$\mu\tilde{a}(x) = \begin{cases} 0 & \text{if } x < a_1 \\ (x - a_1) / (a_2 - a_1) & \text{if } a_2 \geq x \geq a_1 \\ (x - a_2) / (a_3 - a_2) & \text{if } a_2 \geq x \geq a_3 \\ 0 & \text{if } x > a_3 \end{cases}$$

The distance between fuzzy triangular numbers

Let $\tilde{a} = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ be two triangular Fuzzy numbers. The distance between them is given using the vertex method by:

$$d(\tilde{a},\tilde{b}) = \sqrt{1/3[(a_1-b_1)^2+(a_2-b_2)^2+(a_3-b_3)^2]} \quad \textbf{....(1)}$$

The various steps of fuzzy TOPSIS are presented as follows:

Step 1: assignment of rating to the criteria and the alternatives.

Let us assume there are J possible candidates called $S = \{S_1, S_2 \ldots.., S_j\}$ which are to evaluated against n criteria $C=\{C_1,C_2,\ldots\ldots C_n\}$. The criteria weights are denoted by $W_i(i=1\ldots..,m)$. The performance ratings of each decision maker $D_K(k=1,\ldots..K)$ for each alternative $A_j(j=1,\ldots.,n)$ with respect to criteria $C_i(i=1,\ldots\ldots..,m)$ are denoted by $\tilde{R}_k = \tilde{x}_{ijk}(I = 1,\ldots\ldots,m,\ j = 1,\ldots\ldots,n,\ k = 1,\ldots..,k)$ with membership function μ_{Rk}.

Step 2: Compute aggregate fuzzy ratings for the criteria and the alternatives.

If the fuzzy ratings of all decision makers is described as triangular fuzzy number $\tilde{R}_k=(a_k, b_k, c_k)$, $k=1,\ldots,K$, then the aggregated fuzzy rating is given by $\tilde{R}=(a,b,c)$, $k = 1,\ldots..,K$, where

$$a = \min_k\{a_k\},\ b = \frac{1}{K},\ c = \max_k\{c_k\} \textbf{.........(2)}$$

If the fuzzy rating and importance weight of the k^{th} decision maker are $\tilde{x}_{ijk} = (a_{ijk}, b_{ijk}, c_{ijk})$ and $\tilde{w}_{ijk} = (w_{jk1}, w_{jk2}, w_{jk3})$, $i= 1, 2,\ldots.,m$; $j=1,2,\ldots.,n$ respectively, then the aggregated fuzzy ratings ($\tilde{X}_{ij}$) of alternatives with respect to each criteria are given by $\tilde{x}_{ij} = (a_{ij}, b_{ij}, c_{ij})$ where

$$a_{i\,j} = \min_k\{a_{ijk}\},\ b_{ij} = \frac{1}{k}\sum_{k=1}^{k}\{b_{ijk}\},\ c_{ij} = \max_k\{c_{ijk}\} \textbf{...........(3)}$$

The aggregated fuzzy weights ($\tilde{w}_{ij}$) of each criterion are calculated as $\tilde{w}_j = (w_{j1},w_{j2},w_{j3})$ where:

$$W_{j1} = \min_k\{w_{jk1}\},\quad w_{j2} = \frac{1}{k}\sum_{k=1}^{k}\{w_{jk2}\},\quad w_{j3} = \max_k\{w_{jk3}\} \textbf{.....(4)}$$

Step 3: Compute the fuzzy decision matrix.

The fuzzy decision matrix for the alternatives ($\tilde{D}$) and the criteria ($\tilde{W}$) is constructed as follows:

$$\tilde{D} = \begin{array}{c c} & C_1 \quad C_2 \ldots\ldots C_{16} \\ \begin{array}{c} S_1 \\ S_2 \\ .. \\ S_n \end{array} & \begin{bmatrix} x_{11} & x_{12}\ldots\ldots x_{1n} \\ x_{21} & x_{22}\ldots\ldots x_{2n} \\ .. & .. \quad \ldots \quad .. \\ x_{m1} & x_{m2}\ldots \quad x_{mn} \end{bmatrix} \end{array} I = 1,..,m;\ j = 1,\ldots.,n$$

$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, \ldots, \tilde{w}_n)$

Step 4: Normalize the fuzzy decision matrix.

The raw data are normalized using linear scale transformation to bring the various criteria scales into a comparable scale. The normalized fuzzy decision matrix $\tilde{R}$ is given by:

$\tilde{R} = [\tilde{r}_{ij}]_{m\times n}$, i = 1,…m, j = 1,….,n

Where,

$\tilde{r}_{ij} = (a_{ij}/c_j^*\ ,\ b_{ij}/\ c_j^*\ ,\ c_{ij}/\ c_j^*)$ and $c_j^* = \max_i c_{ij}$ **(benefit criteria)……………(5)**

$\tilde{r} = (\bar{a}_j/c_{ij}\ ,\ \bar{a}_j/\ b_{ij},\ \bar{a}_j/\ a_{ij})$ and $\bar{a}_j = \min_i a_{ij}$ **(cost criteria)……………(6)**

Step 5: Compute the weighted normalized matrix

The weighted normalized matrix $\tilde{P}$ for criteria is computed by multiplying the weights $(\tilde{w}_j)$ of evaluation criteria with the normalized fuzzy decision matrix $\tilde{r}_{ij}$

$\tilde{p} = [p_{ij}]_{m\times n}$, i = 1,….., m, j = 1,…..n

Where $\tilde{p}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j$**…………….(7)**

Step 6: Compute the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS).

The FPIS and FNIS of the alternatives are computed as follows:

$A^+ = (\tilde{p}_1^+, \tilde{p}_2^+, \ldots, \tilde{p}_n^+)$, where $\tilde{p}_j^+ = \max_i(p_{ij3})$, i = 1,…..,m, j = 1,…..,n**……….(8)**

$A^- = (\tilde{p}_1^-, \tilde{p}_2^-, \ldots, \tilde{p}_n^-)$, where $\tilde{p}_j^- = \min_i(p_{ij1})$, i = 1,…..,m, j = 1,…..,n**……………(9)**

Step 7: Compute the distance of alternative from FPIS and FNIS.

The distance (d_i^+, d_i^-) of each weighted alternative I = 1,….m from the FPIS and the FNIS is computed as follows:

$d_i^+ = \sum_{j=1}^{n} d_p(\tilde{p}_{ij}, \tilde{p}_j^+)$, i = 1,….,m**………..(10)**

$d_i^- = \sum_{j=1}^{n} d_p(\tilde{p}_{ij}, \tilde{p}_j^-)$, i = 1,….,m**…………..(11)**

Where, $d_p(\tilde{a}, \tilde{b})$ is the distance measurement between two fuzzy number $\tilde{a}$ and $\tilde{b}$

Step 8: Compute the closeness coefficient (CC_i) of each alternative.

The closeness coefficient CC_i represents the distances to the fuzzy positive ideal solution (A^+) and the fuzzy negative ideal solution (A^-) simultaneously. The closeness coefficient of each alternative is calculated as:

$CC_i = d_i^- / (d_i^+ + d_i^-)$, I = 1,2…….m**……….(12)**

The Case Study

Fuzzy set theory was firstly introduced by Zadeh 1965 (Vinod Yadav, M. K., 2016). Conversion scales are applied to transform the linguistic terms into fuzzy numbers. Usually apply a scale of 1 to 9 for rating the criteria and the alternatives. The intervals are chosen so as to have a uniform representation from 1 to 9 for the fuzzy triangular numbers used for the five linguistic ratings.

Table-3 Fuzzy ratings for linguistic variables

Fuzzy number	Criteria assessment	Alternative assessment
(1,1,3)	Very Poor (VP)	Very low (VL)
(1,3,5)	Poor (P)	Low (L)
(3,5,7)	Fair (F)	Medium (M)
(5,7,9)	Good (G)	High (H)
(7,9,9)	Very Good (VG)	Very high(VH)

Steps to illustrate Fuzzy TOPSIS method

Let's say, the decision group has K members and the i^{th} alternative on j^{th} criterion. The fuzzy rating and importance weight of the k^{th} decision maker, about the i^{th} alternative on j^{th} criterion.

Step 1: We have five alternatives such as S_1, S_2, S_3, S_4 and S_5 for comparison with sixteen criteria such as C_1, C_2, C_3 ……… and C_{16} also we have four decision makers namely DM_1, DM_2, DM_3 and DM_4.

Step 2: Criteria rating by decision makers.

Table-4 Criteria rating

Criteria	**DM_1**	**DM_2**	**DM_3**	**DM_4**
C_1	G	VG	VG	G
C_2	VG	VG	G	VG
C_3	VG	VG	G	VG
C_4	G	P	F	F
C_5	G	VG	VG	VG
C_6	F	VG	F	F
C_7	F	VP	F	P
C_8	P	P	P	VP
C_9	G	G	F	F
C_{10}	VG	VG	F	G
C_{11}	G	G	G	G
C_{12}	F	F	G	F
C_{13}	G	P	F	F
C_{14}	G	G	F	G
C_{15}	F	G	F	F
C_{16}	G	VG	G	VG

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Step 3: Now, decision makers are rating the alternatives as shown in table-5.

Table-5 Alternative rating

	S_1				S_2				S_3				S_4				S_5			
Criteria ↓	**DM 1**	**DM 2**	**DM 3**	**DM 4**	**DM 1**	**DM 2**	**DM 3**	**DM 4**	**DM 1**	**DM 2**	**DM 3**	**DM 4**	**DM 1**	**DM 2**	**DM 3**	**DM 4**	**DM 1**	**DM 2**	**DM 3**	**DM 4**
C_1	M	VH	VH	L	H	M	H	L	H	H	H	VH	H	VH	M	H	L	L	L	M
C_2	H	VH	H	L	H	VH	H	L	H	H	VH	H	H	H	M	H	H	M	M	M
C_3	M	VH	M	H	H	VH	VH	H	M	M	VH	H	H	H	H	H	H	L	H	VH
C_4	VL	VL	H	H	M	L	VH	H	M	H	VH	H	M	M	H	VH	M	VH	L	VH
C_5	L	VH	M	H	VH	H	M	H	H	H	H	M	L	VH	VH	M	H	H	H	H
C_6	H	M	H	H	H	M	VH	H	H	H	VH	H	M	H	M	H	M	VH	M	H
C_7	M	L	M	H	H	VL	H	H	M	L	VH	VH	M	M	H	H	VL	H	M	VH
C_8	M	VL	M	H	H	H	L	H	M	VH	M	M	H	VH	H	H	H	M	VH	H
C_9	H	VH	L	M	H	H	H	H	M	H	VH	H	M	VH	VH	H	VH	VH	H	VH
C_{10}	M	M	VH	M	M	M	H	L	H	M	VH	L	M	VH	H	M	M	H	M	M
C_{11}	M	VH	M	M	H	VH	H	H	H	VH	H	M	M	H	VH	M	H	VH	H	H
C_{12}	H	VL	M	H	VH	VL	H	H	H	L	H	H	M	M	VH	H	M	M	H	H
C_{13}	H	M	H	H	M	H	VH	M	VL	L	VH	H	M	M	L	H	M	M	M	M
C_{14}	L	VH	M	VH	M	VH	H	VH	L	H	VH	H	M	M	M	VH	H	H	M	H
C_{15}	M	H	M	VH	M	H	H	VH	H	M	H	VH	M	L	H	VH	M	VL	L	VH
C_{16}	M	M	H	L	H	M	VH	L	M	H	VH	VH	M	H	M	H	M	L	M	M

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Step 4: Apply fuzzy numbers (refer table -3)

Table-6 Fuzzy numbers for criteria rating

Criteria	DM_1	DM_2	DM_3	DM_4
C_1	(5,7,9)	(7,9,9)	(7,9,9)	(5,7,9)
C_2	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)
C_3	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)
C_4	(5,7,9)	(1,3,5)	(3,5,7)	(3,5,7)
C_5	(5,7,9)	(7,9,9)	(7,9,9)	(7,9,9)
C_6	(3,5,7)	(7,9,9)	(3,5,7)	(3,5,7)
C_7	(3,5,7)	(1,1,3)	(3,5,7)	(1,3,5)
C_8	(1,3,5)	(1,3,5)	(1,3,5)	(1,1,3)
C_9	(5,7,9)	(5,7,9)	(3,5,7)	(3,5,7)
C_{10}	(7,9,9)	(7,9,9)	(3,5,7)	(5,7,9)
C_{11}	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)
C_{12}	(3,5,7)	(3,5,7)	(5,7,9)	(3,5,7)
C_{13}	(5,7,9)	(1,3,5)	(3,5,7)	(3,5,7)
C_{14}	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)
C_{15}	(3,5,7)	(5,7,9)	(3,5,7)	(3,5,7)
C_{16}	(5,7,9)	(7,9,9)	(5,7,9)	(7,9,9)

Table-7 Fuzzy numbers for alternative rating

	S1				**S2**				**S3**				**S4**				**S5**			
CRITERIA	**DM_1**	**DM_2**	**DM_3**	**DM_4**	**DM_1**	**DM_2**	**DM_3**	**DM_4**	**DM_1**	**DM_2**	**DM_3**	**DM_4**	**DM_1**	**DM_2**	**DM_3**	**DM_4**	**DM_1**	**DM_2**	**DM_3**	**DM_4**
C_1	(3,5,7)	(7,9,9)	(7,9,9)	(1,3,5)	(5,7,9)	(3,5,7)	(5,7,9)	(1,3,5)	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(7,9,9)	(3,5,7)	(5,7,9)	(1,3,5)	(1,3,5)	(1,3,5)	(3,5,7)
C_2	(5,7,9)	(7,9,9)	(5,7,9)	(1,3,5)	(5,7,9)	(7,9,9)	(5,7,9)	(1,3,5)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5,7)
C_3	(3,5,7,)	(7,9,9)	(3,5,7)	(5,7,9)	(5,7,9)	(7,9,9)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(1,3,5)	(5,7,9	(7,9,9)
C_4	(1,1,3)	(1,1,3)	(5,7,9)	(5,7,9)	(3,5,7)	(1,3,5)	(7,9,9)	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,9)	(3,5,7)	(7,9,9)	(1,3,5)	(7,9,9)
C_5	(1,3,5)	(7,9,9)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(1,3,5)	(7,9,9)	(7,9,9)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)
C_6	(5,7,9,)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(5,7,9)	(3,5,7)	(5,7,9)	(3,5,7)	(7,9,9)	(3,5,7)	(5,7,9)
C_7	(3,5,7)	(1,3,5)	(3,5,7)	(5,7,9)	(5,7,9)	(1,1,3)	(5,7,9)	(5,7,9)	(3,5,7)	(1,3,5)	(7,9,9)	(7,9,9)	(3,5,7)	(3,5,7)	(5,7,9)	(5,7,9)	(1,1,3)	(5,7,9)	(3,5,7)	(7,9,9)
C_8	(3,5,7)	(1,1,3)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(1,3,5)	(5,7,9)	(3,5,7)	(7,9,9)	(3,5,7)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(7,9,9)	(5,7,9)
C_9	(5,7,9)	(7,9,9)	(1,3,5)	(3,5,7)	(5,7,9)	(5,7,9)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)	(7,9,9)	(5,7,9)	(7,9,9)
C_{10}	(3,5,7)	(3,5,7)	(7,9,9)	(3,5,7)	(3,5,7)	(3,5,7)	(5,7,9)	(1,3,5)	(5,7,9)	(3,5,7)	(7,9,9)	(1,3,5)	(3,5,7)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(3,5,7)	(3,5,7)
C_{11}	(3,5,7)	(7,9,9)	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(7,9,9)	(3,5,7)	(5,7,9)	(7,9,9)	(5,7,9)	(5,7,9)
C_{12}	(5,7,9)	(1,1,3)	(3,5,7)	(5,7,9)	(7,9,9)	(1,1,3)	(5,7,9)	(5,7,9)	(5,7,9)	(1,3,5)	(5,7,9)	(5,7,9)	(3,5,7)	(3,5,7)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)	(5,7,9)
C_{13}	(5,7,9)	(3,5,7)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,9)	(3,5,7)	(1,1,3)	(1,3,5)	(7,9,9)	(5,7,9)	(3,5,7)	(3,5,7)	(1,3,5)	(5,7,9)	(3,5,7)	(3,5,7)	(3,5,7)	(3,5,7)
C_{14}	(1,3,5)	(7,9,9)	(3,5,7)	(7,9,9)	(3,5,7)	(7,9,9)	(5,7,9)	(7,9,9)	(1,3,5)	(5,7,9)	(7,9,9)	(5,7,9)	(35,7)	(3,5,7)	(3,5,7)	(7,9,9)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)
C_{15}	(3,5,7)	(5,7,9)	(3,5,7)	(7,9,9)	(3,5,7)	(5,7,9)	(5,7,9)	(7,9,9)	(5,7,9)	(3,5,7)	(5,7,9)	(7,9,9)	(3,5,7)	(1,3,5)	(5,7,9)	(7,9,9)	(3,5,7)	(1,1,3)	(1,3,5)	(7,9,9)
C_{16}	(3,5,7,)	(3,5,7)	(7,9,9)	(1,3,5)	(5,7,9)	(3,5,7)	(7,9,9)	(1,3,5)	(3,5,7)	(5,7,9)	(7,9,9)	(7,9,9)	(3,5,7)	(5,7,9)	(3,5,7)	(5,7,9)	(3,5,7)	(1,3,5)	(3,5,7)	(3,5,7)

Step 5: Aggregated alternative and criteria weightage fuzzy decision matrix.

Table-8 Aggregated fuzzy decision matrix for alternative

Criteria	S_1	S_2	S_3	S_4	S_5
C_1	(1,6.5,9)	(1,5.5,9)	(5,7.5,9)	(3,7,9)	(1,3.5,7)
C_2	(1,6.5,9)	(1,6.5,9)	(5,7.5,9)	(3,6.5,9)	(3,5.5,9)
C_3	(3,6.5,9)	(5,8,9)	(3,6.5,9)	(5,7,9)	(1,6.5,9)
C_4	(1,4,9)	(1,6,9)	(3,7,9)	(3,6.5,9)	(5,7,9)
C_5	(1,6,9)	(3,7,9)	(3,7.5,9)	(1,6.5,9)	(3,6.5,9)
C_6	(3,6.5,9)	(3,7,9)	(1,6.5,9)	(3,6,9)	(3,6.5,9)
C_7	(1,5,9)	(1,5.5,9)	(1,6.5,9)	(3,6,9)	(1,5.5,9)
C_8	(1,4.5,9)	(1,6,9)	(3,6.5,9)	(5,7.5,9)	(3,7,9)
C_9	(1,6,9)	(5,7,9)	(3,7.5,9)	(3,7.5,9)	(5,7,9)
C_{10}	(3,6,9)	(1,5,9)	(1,6,9)	(3,6.5,9)	(3,5.5,9)
C_{11}	(3,6,9)	(5,7.5,9)	(3,7,9)	(3,6.5,9)	(5,7.5,9)
C_{12}	(1,5,9)	(1,6,9)	(3,6.5,9)	(3,6.5,9)	(3,6,9)
C_{13}	(3,6.5,9)	(3,6.5,9)	(1,5,9)	(1,5,9)	(3,5,7)
C_{14}	(1,6.5,9)	(3,7.5,9)	(1,6.5,9)	(3,6,9)	(3,6.5,9)
C_{15}	(3,6.5,9)	(3,7,9)	(3,7,9)	(1,6,9)	(1,4.5,9)
C_{16}	(1,5.5,9)	(1,5.5,9)	(3,7.5,9)	(3,6,9)	(1,4.5,7)

Taking first criteria (C_1) and first supplier value (S_1) from table-7 (use equation 2)

1. $a_{ij} = \min_k\{a_{kij}\} = 1.000$ [i.e. minimum value of first place (3,5,7 ; 7,9,9 ; 7,9,9 & 1,3,5)]

2. $b_{ij} = 1 / k\sum_{k=1}^{k}\{b_{kij}\} = 6.5$ [i.e. average value of middle place (3,5,7 ; 7,9,9 ; 7,9,9 & 1,3,5)]

3. $c_{ij} = \max_k\{c_{kij}\} = 9.000$ [i.e. maximum value of last place (3,5,7 ; 7,9,9 ; 7,9,9 & 1,3,5)]

Same procedure has been used to evaluate table-9 by using table- 6 and equation 2.

Table-9 Aggregated fuzzy decision matrix for criteria weightage

Criteria	Aggregate Weightage
C_1	(5,8,9)
C_2	(5,8.5,9)
C_3	(5,8.5,9)
C_4	(1,5,9)
C_5	(5,8,5,9)
C_6	(3,6,9)
C_7	(1,3,5,7)
C_8	(1,2.5,5)
C_9	(3,4,9)
C_{10}	(3,7.5,9)
C_{11}	(5,7,9)
C_{12}	(3,5.5,9)
C_{13}	(1,5,9)
C_{14}	(3,6.5,9)
C_{15}	(3,5.5,9)
C_{16}	(5,8,9)

Step 6: Fuzzy multi criteria group decision making and process of normalizing.

As we are working on various criteria for decision-making, some might be benefit criteria and some might be cost criteria. Aim is to maximize benefit and minimize the cost. A fuzzy multi criteria group decision-making problem has been concisely expressed in matrix format using step 3 and step 4 of research methodology and also using equation 5 & 6.

In this study we considered criteria no. 4, 7, 8 and 14 under cost criteria and rest criteria 1, 2, 3, 5, 6, 9, 10, 11, 12, 13, 15 and 16 under benefit criteria.

Table-10 Normalized aggregated fuzzy decision matrix for alternatives

Criteria	S_1	S_2	S_3	S_4	S_5
C_1	(0.111,0.722,1)	(0.111,0.611,1)	(0.556,0.833,1)	(0.333,0.778,1)	(0.111,0.944,0.778)
C_2	(0.111,0.722,1)	(0.111,0.722,1)	(0.556,0.833,1)	(0.333,0.722,1)	(0.333,0.611,1)
C_3	(0.333,0.722,1)	(0.556,0.889,1)	(0.333,0.722,1)	(0.556,0.778,1)	(0.111,0.722,1)
C_4	(0.111,0.25,1)	(0.111,0.167,1)	(0.111,0.143,0.333)	(0.111,0.154,0.333)	(0.111,0.154,1)
C_5	(0.111,0.667,1)	(0.333,0.778,1)	(0.333,0.833,1)	(0.111,0.722,1)	(0.556,0.778,1)
C_6	(0.333,0.722,1)	(0.333,0.778,1)	(0.111,0.722,1)	(0.333,0.667,1)	(0.333,0.722,1)
C_7	(0.111,0.2,1)	(0.111,0.182,1)	(0.111,0.154,1)	(0.111,0.167,0.333)	(0.111,0.182,1)
C_8	(0.111,0.222,1)	(0.111,0.167,1)	(0.111,0.154,0.333)	(0.111,0.133,0.2)	(0.111,0.143,0.333)
C_9	(0.111,0.667,1)	(0.556,0.778,1)	(0.333,0.778,1)	(0.333,0.833,1)	(0.556,0.778,1)
C_{10}	(0.333,0.667,1)	(0.111,0.556,1)	(0.111,0.667,1)	(0.333,0.722,1)	(0.333,0.611,1)
C_{11}	(0.333,0.667,1)	(0.556,0.833,1)	(0.333,0.778,1)	(0.333,0.722,1)	(0.556,0.833,1)
C_{12}	(0.111,0.556,1)	(0.111,0.667,1)	(0.111,0.667,1)	(0.333,0.722,1)	(0.333,0.667,1)
C_{13}	(0.333,0.722,1)	(0.333,0.722,1)	(0.111,0.556,1)	(0.111,0.556,1)	(0.333,0.556,0.778)
C_{14}	(0.111,0.154,1)	(0.111,0.133,0.33)	(0.111,0.154,1)	(0.111,0.167,0.333)	(0.111,0.154,0.333)
C_{15}	(0.333,0.722,1)	(0.333,0.778,1)	(0.333,0.778,1)	(0.111,0.667,1)	(0.111,0.5,1)
C_{16}	(0.111,0.611,1)	(0.111,0.611,1)	(0.333,0.833,1)	(0.333,0.667,1)	(0.111,0.5,0.778)

The ranges of normalized triangular fuzzy numbers belong to (0,1).

Table-11 Weighted normalized fuzzy decision matrix.

Criteria	S_1	S_2	S_3	S_4	S_5
C_1	(0.556,5.776,9)	(0.556,4.889,9)	(2.78,6.664,9)	(1.665,6.224,9)	(0.555,7.552,7.002)
C_2	(0.555,6.137,9)	(0.555,6.137,9)	(2.78,7.081,9)	(1.665,6.137,9)	(1.665,5.194,9)
C_3	(1.665,6.137,9)	(2.787,0.557,9)	(1.665,6.137,9)	(2.78,6.613,9)	(0.555,6.137,9)
C_4	(0.111,1.25,9	(0.111,0.835,9)	(0.111,0.715,2.997)	(0.111,0.770,2.997)	(0.111,0.77,9)
C_5	(0.555,5.670,9)	(1.665,6.613,9)	(1.665,7.081,9)	(0.555,,6.137,9)	(2.78,6.613,9)
C_6	0.999,4.332,9	(0.999,4.668,9)	(0.333,4.332,9)	(0.999,4.002,9)	(0.999,4.332,9)
C_7	0.111,0.7,7	(0.111,0.637,7)	(0.111,0.539,7)	(0.111,0.585,2.333)	(0.111,0.637,7)
C_8	0.111,0.555,5	(0.111,0.418,5)	(0.111,0.385,1.665)	(0.111,0.333,1)	(0.111,0.358,1.665)
C_9	0.333,2.668,9	(1.668,3.112,9)	(0.999,3.112,9)	(0.999,3.332,9)	(1.668,3.112,9)
C_{10}	0.999,5.003,9	(0.333,4.17,9)	(0.333,5.003,9)	(0.999,5.415,9)	(0.999,4.583,9)
C_{11}	1.665,4.669,9	(2.78,5.831,9)	(1.665,5.446,9)	(1.665,5.054,9)	(2.78,5.831,9)
C_{12}	0.333,3.058,9	(0.333,3.669,9)	(0.333,3.669,9)	(0.999,3.971,9)	(0.999,3.669,9)
C_{13}	0.333,3.61,9	(0.333,3.61,9)	(0.111,2.78,9)	(0.555,2.78,9)	(0.333,2.78,7.002)
C_{14}	(0.333,4.693,9)	(0.333,0.865,2.997)	(0.999,5.057,9)	(0.333,4.336,9)	(0.333,1.001,2.997)
C_{15}	(0.999,3.971,9)	(0.999,4.279,9)	(0.999,4.279,9)	(0.333,3.669,9)	(0.333,2.75,9)
C_{16}	(0.555,4.888,9)	(0.555,4.888,9)	(1.665,6.664,9)	(1.665,5.336,9)	(0.555,4,7.002)

Table-11 has been evaluated by using data of table-9, table-10 and applying it in equation 7.

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Step 7: FPIS and FNIS

Using equation number 8 & 9, we have selected the maximum value from each row as p^+ and minimum value from each row as p^- as shown in table-11. Table-12 shows both these values.

Table–12 Final list of values of p^+ and p^- for each alternative

A^+	A^-
$P^+_1(9,9,9)$	$P^-_1(0.555,0.555,0.555)$
$P^+_2(9,9,9)$	$P^-_2(0.555,0.555,0.555)$
$P^+_3(9,9,9)$	$P^-_3(0.555,0.555,0.555)$
$P^+_4(9,9,9)$	$P^-_4(0.111,0.111,0.111)$
$P^+_5(9,9,9)$	$P^-_5(0.555,0.555,0.555)$
$P^+_6(9,9,9)$	$P^-_6(0.333,0.333,0.333)$
$P^+_7(7,7,7)$	$P^-_7(0.111,0.111,0.111)$
$P^+_8(5,5,5)$	$P^-_8(0.111,0.111,0.111)$
$P^+_9(9,9,9)$	$P^-_9(0.333,0.333,0.333)$
$P^+_{10}(9,9,9)$	$P^-_{10}(0.333,0.333,0.333)$
$P^+_{11}(9,9,9)$	$P^-_{11}(1.665,1.665,1.665)$
$P^+_{12}(9,9,9)$	$P^-_{12}(0.333,0.333,0.333)$
$P^+_{13}(9,9,9)$	$P^-_{13}(0.111,0.111,0.111)$
$P^+_{14}(9,9,9)$	$P^-_{14}(0.333,0.333,0.333)$
$P^+_{15}(9,9,9)$	$P^-_{15}(0.333,0.333,0.333)$
$P^+_{16}(9,9,9)$	$P^-_{16}(0.555,0.555,0.555)$

Step 8: FPIS and FNIS for each criteria

Here, we have to use equation-1 and table-12. Then, we have to find distance of each criterion from FPIS and FNIS for five alternatives.

Table-13 Distance of criteria of each alternative from FPIS and FNIS

Criteria	**FPIS(S_1)**	**FNIS(S_1)**	**FPIS(S_2)**	**FNIS(S_2)**	**FPIS(S_3)**	**FNIS(S_3)**	**FPIS(S_4)**	**FNIS(S_4)**	**FPIS(S_5)**	**FNIS(S_5)**
C_1	5.218	5.732	5.422	5.480	3.836	6.153	4.528	5.907	5.079	5.493
C_2	5.148	5.845	5.148	5.845	3.758	6.294	4.546	5.879	4.771	5.600
C_3	4.546	5.879	3.686	6.463	4.546	4.883	3.846	6.136	5.148	5.845
C_4	6.808	5.174	6.969	5.145	7.825	1.702	7.805	1.709	6.994	5.146
C_5	5.241	5.700	4.453	6.035	4.377	6.195	5.148	5.845	3.846	6.136
C_6	5.348	5.524	5.253	5.608	5.684	5.511	5.447	5.447	5.348	5.524
C_7	5.389	3.992	5.414	3.989	5.453	3.985	6.067	1.311	5.414	3.989
C_8	3.815	2.834	3.869	2.828	3.992	3.985	4.534	.530	4.343	0.908
C_9	6.198	5.184	5.429	5.311	5.735	5.269	5.661	5.309	5.429	5.311
C_{10}	5.164	5.697	5.728	5.472	5.510	5.684	5.062	5.813	5.276	5.586
C_{11}	4.917	4.576	4.030	4.913	4.706	4.764	4.809	4.665	4.030	4.913
C_{12}	6.067	5.245	5.875	5.362	5.875	5.362	5.456	5.440	5.551	5.375
C_{13}	5.893	5.516	5.893	5.517	6.264	5.358	6.055	5.365	6.266	4.268
C_{14}	5.588	5.601	7.688	1.568	5.150	5.712	5.682	5.512	7.641	1.585
C_{15}	5.456	5.440	5.364	5.512	5.364	5.512	5.875	5.362	6.169	5.195
C_{16}	5.423	5.480	5.423	5.480	4.444	6.052	4.734	5.640	7.309	4.220

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For evaluating first cell value of table-13, we consider first cell C_1 of table-11 and then calculating distance of criteria for that alternative.

Criteria	S_1
C_1	(0.556,5.776,9)

From table-12, $p^+_1(9, 9, 9)$
From equation-1
Now, for (C_1-S_1) from table-11 and P^+_1 from table-12
d=

$$\sqrt{1/3\ [(0.556\ -\ 9)2+\ (5.776-9)2\ +\ (9-9)2]}$$

= 5.218 (likewise use same process to find remaining values of table-13)

Step 9: The distance of each weighted alternative (by using equation 10 and 11)

d^+_1 = 86.219, d^+_2 = 85.644, d^+_3 = 82.518, d^+_4 = 85.255, d^+_5 = 88.614
d^-_1 = 83.419, d^-_2 = 80.528, d^-_3 = 82.421, d^-_4 = 75.87, d^-_5 = 75.094

Step 10: Closeness coefficient of each alternative (by using equation 12)

CC_1 = 0.492, CC_2 = 0.485, CC_3 = 0.50, CC_4 = 0.471, CC_5 = 0.459

IV. RESULTS AND DISCUSSION

In this study fuzzy TOPSIS technique has been adopted. Study has been conducted with five alternatives S_1, S_2, S_3, S_4 and S_5 with sixteen criteria C_1, C_2, C_3, ……… and C_{16} and four decision makers namely DM_1, DM_2, DM_3 and DM_4.

Different suppliers have been ranked according to the closeness coefficient CC_i in decreasing order. The best alternative is closest to the FPIS and farthest from the FNIS. The ranking order of S_1, S_2, S_3, S_4 and S_5 has been tabulated in table-14.

TABLE-14 Rank assigned to suppliers

Alternatives	**CC_i**	**Rank**
$Supplier_1$	0.492	2
$Supplier_2$	0.485	3
$Supplier_3$	0.50	1
$Supplier_4$	0.471	4
$Supplier_5$	0.459	5

It was found that the supplier S_3 to be the best supplier among the suppliers. It doesn't justify that S_1, S_2, $S_4$and S_5 are the efficient. The results may vary, based on the criterion priority levels by decision makers as analysis was carried out based on the criteria suggested by the various decision makers. The final results have been shown in table-14. By comparing CC_i values of the five alternatives, we find that S_3>S_1 >S_2> S_4> S_5. S_3 is the Best choice considering the given criteria and S_5 is the worst choice considering given criteria. The idea for decisions about remaining suppliers S_1, S_2, and S_4 can be obtained from the rank assigned to them in table-14.

V. CONCLUSION:

This paper discusses a study with an objective to analyze, how to select the most efficient supplier in Indian pharmaceutical industry by fuzzy TOPSIS method in supplier MCDM problems when decision makers set the target value of each criterion. In this study, total 16 criteria were considered and a multi-criteria decision-making approach has been used for the supplier rating under fuzzy environment. This study approach comprises of two steps. In step first, the criteria for suppliers rating selection are identified. In second step the experts in pharmaceutical industry were asked to give linguistic ratings to the criteria and the alternatives. This study proposed a method and a procedure to extend the

TOPSIS method to solve the problem. The results obtained from this case study may be used for decision-making of supplier selection rating in Indian pharmaceutical industry. The suppliers rating problem discussed in this paper can also be solved by Fuzzy AHP and the obtained results can be compared with the results obtained using Fuzzy TOPSIS method.

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