Industrial Engineering & Management
ISSN: 2169-0316
Sakib, Ind Eng Manage 2014, 3:5
DOI: 10.4172/2169-0316.1000143
Research Article
Open Access

Identifying Optimum Supply Unit Using an Integrated Fuzzy TOPSIS and MCGP Approach in Apparel Industry Sector

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Abstract

With the inexorability of globalization and open trade system, there has been extension of large business with an increase in the outsourcing of parts and services especially in the apparel sector. Increasing in number, the apparel industries confront dormant competition and need to emphasize on some technical key points to be fortitude. Purchasing and its associated functions are the eminent fields playing important role in this connection as it is most decisive and most of the production cost and time are spent regard to those. As for trading, apparel sector products normally categorize into two - push and pull while pull products are executed in anticipation of the customer order and push products are initiated according to customer order. It engenders dealings with risk and cause more investment which may incur a loss to the industries because of any faltering decision. Appropriate supplier and supply quantity selection triggers the probably of success as other parameters evolve by these and hence they are most important and can reduce risk if it can be handled combined for several products. Using fuzzy-TOPSIS and MCGP, the paper determines the joint (push and pull) amount to take from each supplier based on their performance ranking on selected criteria considering budget, delivery, demand and supply constraints. The result generated solving a LP model formed on the basis of opportunity and threats. The model is solved by LINDO system. The strength of presenting approach is its practical applicability and ability to provide solution under partial or lack of quantitative information and in joint order handling.

Keywords: Multi-criteria problem, push and pull product, fuzzy, TOPSIS, MCGP, LP model

Introduction

The supply chain includes all functions to fulfill the customer demand with the objective to maximize the overall value generated. A Supply chain's success i.e. profitability depend upon the very beginning of the chain which starts from the suppliers and ends to customers, so the road map to have an effective supply chain starts from suppliers. Here the effectiveness depends on a large extent to the selection of suppliers. Typically, manufacturer spends more than 60% of its total sales on purchased items such as raw materials, parts and components [1]. In addition, manufacturers' purchase of goods and services constitute up to 70% of production cost [2]. Therefore, the selection of suppliers is an area of tremendous importance and should be considered as a strategic issue. In recent years, determining the best supplier in the supply chain has become a key strategic consideration for industries. In apparel industry it is very much pivotal because ordering and receiving occurs frequently and industries' success depends a lot on the supplied items. Hence the management needs to be very careful to select suppliers as well as supply quantity. In apparel sector products normally classifies into two- push and pull. Push products are manufactured to push into market assuming customer demand and trends whereas pull products are manufactured after the customer places their specifications. Push products normally are made in large number, they usually manufactured in batch, profit margin is generally kept low and not too many trained person and special machinery attachment required for production. On the other hand customer orders pull products limited in number, product variety is normally large as well as profit margin, trained person and specific machinery attachment often required. As push product is produced a lot in number supply materials needed to order frequently while supply materials for pull product purchased based on customers quantity demand. Dealing with two different products costs large for the industries. If industry ascertain of supplier and supply quantity and combine handling those two products it could save cost and reduce several risks regarding the sector. Here generates a field to combine ordering the supply materials of those products for apparel industries at a time and hence it's challenging to develop a technique to implicate. However, these techniques usually involve several objectives or criteria and it is often necessary to compromise among possibly conflicting factors. Multiple criteria decision making (MCDM) is a useful tool to solve this kind of problem. This paper propounds techniques for order preference by similarity to ideal solution (TOPSIS) and multi choice goal programming (MCGP) to select suppliers and supply quantity required and combine ordering for both the products in an apparel industry. It is a common problem found in many cases of quantitative decision making is - human assessments are uncertain and it is often difficult for decision makers to supply exact numerical values for specific criteria. In this regard most of the selection parameters can't be given precisely and the evaluated data of alternatives' characteristics is expressed in linguistic term by the decision makers. Moreover human judgment on qualitative attributes is always subjective and thus imprecise. For the sake of modeling this type of characteristics in case of human approach, fuzzy logic could be the best means [3]. As the apparel market is volatile as well as industries have to work in uncertainty of demand and risks, fuzzy- TOPSIS is one of the best suits to make better decision here. The proposed method allows decision makers to set multiple aspiration levels for supplier selection problems and insinuate combinational order handling for different apparel products.

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Received October 08, 2014; **Accepted** October 20, 2014; **Published** November 27, 2014

Citation: Sakib N (2014) Identifying Optimum Supply Unit Using an Integrated Fuzzy TOPSIS and MCGP Approach in Apparel Industry Sector. Ind Eng Manage 3: 143. doi: 10.4172/2169-0316.1000143

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Literature Review

Since 1966, many criteria have been employed to evaluate and select supplier. Dickson [4] identified 23 different criteria for supplier selection, based on which Weber, Current, and Benton [5] suggested a number of selection criteria to measure supplier performance, such as price, delivery, quality, productive capability, location, technical capability, management organization, reputation, industry position, financial stability, performance history, and maintainability. Evans [6] proposed that price, quality and delivery are key criteria for supplier evaluation in the industrial market. Shipley [7] suggested that supplier selection involve three criteria, namely, quality, price and delivery lead time. Ellram [8] suggested that in the supplier selection process, firms must to consider whether product quality, offering price, delivery time, and total service quality meet organizational demand. Tam and Tummala [9] proposed an analytic hierarchy process (AHP) based model and adopted quality, cost, problem-solving capabilities, expertise, delivery lead time, response to customer requests, experience, and reputation as selecting attributes. Pi and Low [10] suggested a method for supplier evaluation and selection based on quality, on time delivery, price, and service quality. Recently, the supplier selection process has received considerable attention in the marketing management literature. Chen et al. [11] considered five benefit criteria including profitability of supplier, relationship closeness, technological capability, conformance quality, and conflict resolution. Lin and Chang [12] claimed that communication, reputation, industry position, relationship closeness, customer responsiveness, and conflict solving capabilities are important criteria in vendor selection. In addition, the role of organizational size in the supplier selection process has been addressed by Wang, Cheng, and Cheng [13]. Table 1 summarizes the criteria that have appeared in literature since 1966; most of the articles referenced above suggest that quality, price, and delivery performance are the most important supplier selection criteria.

A closer look at the literature reveals lot of the works that developed methods for solving the SSP. Dahel [14] developed a multi-objective mixed integer linear programming (MOMILP) approach to simultaneously determine the optimal number of suppliers and the optimal order quantities. Chen et al. [11] applied linguistic value to measure the ratings and weights of supplier selection criteria and then used a MCDM model based on fuzzy set theory to analyze a supply chain management case. Krishnan et al. [15] developed a hybrid model that including AHP, DEA and NN approaches for supplier selection problem. Wadhwa and Ravindran [16] modeled the SSP as a multi-objective optimization problem under quantity discounts in a multiple sourcing environment and included three objectives, namely minimizing price, lead-time and the number of rejected items. Amid et al. [17] formulated a multi-objective model that determined the optimal order quantities for each supplier under price breaks. Ebrahim et al. [18] presented an integrated AHP-MOLP approach for the SSP under price discounts. Tsai and Wang [19] used a mixed integer programming approach to address the SSP in a multiple sourcing and multi-items scenario. Önüt et al. [20] developed a supplier evaluation approach based on the ANP and TOPSIS methods. Faez, Ghodsypour, and O'brien [21] presented an integrated fuzzy case-based reasoning and mathematical programming method. Kokangul and Susuz [22] integrated AHP and mathematical programming to consider both nonlinear integer and multiple-objective programming under certain constraints to determine the best suppliers. Among all the methods fuzzy set theory is considered the most effective methods where decision making is in uncertainty and hard also. The fuzzy sets were introduced by Zadeh [23] to mathematically represent data and information. TOPSIS (Technique for order performance by similarity of ideal solution) was incorporated with fuzzy to get a better decision. This approach is based on the idea that a chosen alternative should be the shortest distance from the positive-ideal solution and the farthest distance from the negative ideal solution.

It can be seen, existing works developed lot of models for supplier and quantity selection problem but none of the models show supplier and quantity selection with combined order handling at a time for two totally different products; especially in apparel sector, which is a gap this paper tries to close.

Methodology and Proposed Method

The proposed methodology includes description of fuzzy set and systems, fuzzy TOPSIS and Incorporation with Multi criteria Goal

Attributes	Authors and Years of publications									
	Dickson (1966) [4]	Evans (1980) [6]	Shipley (1985) [7]	Ellram (1990) [8]	Weber et al. (1991) [5]	Tam and Tummala (2001) [9]	Pi and Low (2005) [10]	Chen et al. (2006) [11]	Lin and Chang (2008) [12]	Wang et al. (2009) [13]
1.Price (cost)	√	√	√	√	√		√			
2.Product quality	√	√	√	√	√	√	√	√		
3.On-time delivery	√	√	√	√	√		√			√
4.Warranty and claims	√									
5.After sales service	√					√				
6.Technical support/expertise						√				
7.Performance history	√				√	√				
8.Financial stability	√				√			√		√
9.Labor relations	√									
10.Relationship closeness								√	√	
11.Communication system	√								√	
12.Technical capability	√				√			√		
13.Production capability	√				√					
14.Reputation and position in industry	√				√	√			√	√
15.Business attempt	√									
16.Maintainability	√				√					

Table 1: Supplier selection criteria literature review.

Programming. Elaborated working methodology is presented via a chart below in Figure 1.

Preliminaries of fuzzy set theory: Some related definitions of fuzzy set theory (Buckley, [24]; Zadeh, [23]; Kaufmann and Gupta, [25]; Pedrycz, [26]; Klir and Yuan, [27]) are presented as follows.

Definition1. A fuzzy set ã 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 ã (Kaufmann and Gupta [25]). The nearer the value of $\mu_{\tilde{a}}(x)$ to unity, the higher the grade of membership of x in ã.

Definition2. A triangular fuzzy number is represented as a triplet ã= a_1, a_2, a_2. Figure 2 presents triangular fuzzy numbers ã & $\tilde{b}$.

Due to their conceptual and computation simplicity, triangular fuzzy numbers are very commonly used in practical applications (Pedrycz, [26]; Klir and Yuan, [27]; Yeh and Deng, [28]). The membership function $\mu_{\tilde{a}}(x)$ of triangular fuzzy number ã is given by

$$\mu_{\tilde{a}}(x)=\begin{cases}0, x \le a_1\\ \dfrac{x-a_1}{a_2-a_1}, a_1 \le x \le a_2\\ \dfrac{a_3-x}{a_3-a_2}, a_2 \le x \le a_3\\ 0, x > a_3\end{cases}$$

Where a_1, a_2, a_3 are real numbers and $a_1 < a_2 < a_3$. The value of x at a_2 gives the maximal grade of $\mu_{\tilde{a}}(x)$ i.e.; $\mu_{\tilde{a}}(x)=1$ it is the most probable value of the evaluation data. The value of x at a_1 gives the minimal grade of $\mu_{\tilde{a}}(x)$ i.e.; $\mu_{\tilde{a}}(x)=0$; it is the least probable value of the evaluation data. Constraints a_1 and a_3 are the lower and upper bounds of the available area for the evaluation data. The constants reflect the fuzziness of the evaluation data. The narrower the interval $[a_1 \quad a_3]$, the lower is the fuzziness of the evaluation data.

Property 1. Given two fuzzy triangular numbers $\tilde{a} = a_1, a_2, a_3$ and $\tilde{b} = b_1, b_2, b_3$, the main operations are expressed as follows:

1. Addition of two triangular fuzzy numbers

$$\tilde{a}(+)\tilde{b}=(a_1+b_1, a_2+b_2, a_3+b_3) \quad a_1 \ge 0, b_1 \ge 0$$

2. Multiplication of two triangular fuzzy number

$$\tilde{a}(\times)\tilde{b}=(a_1\times b_1, a_2\times b_2, a_3\times b_3) \quad a_1 \ge 0, b_1 \ge 0$$

3. Subtraction of two triangular fuzzy numbers

$$\tilde{a}(-)\tilde{b}=(a_1-b_1, a_2-b_2, a_3-b_3) \quad a_1 \ge 0, b_1 \ge 0$$

4. Division of two triangular fuzzy numbers

$$\tilde{a}/\tilde{b}=\left(a_1/b_1, a_2/b_2, a_3/b_3\right) \quad a_1 \ge 0, b_1 \ge 0$$

5. Inverse of triangular fuzzy number

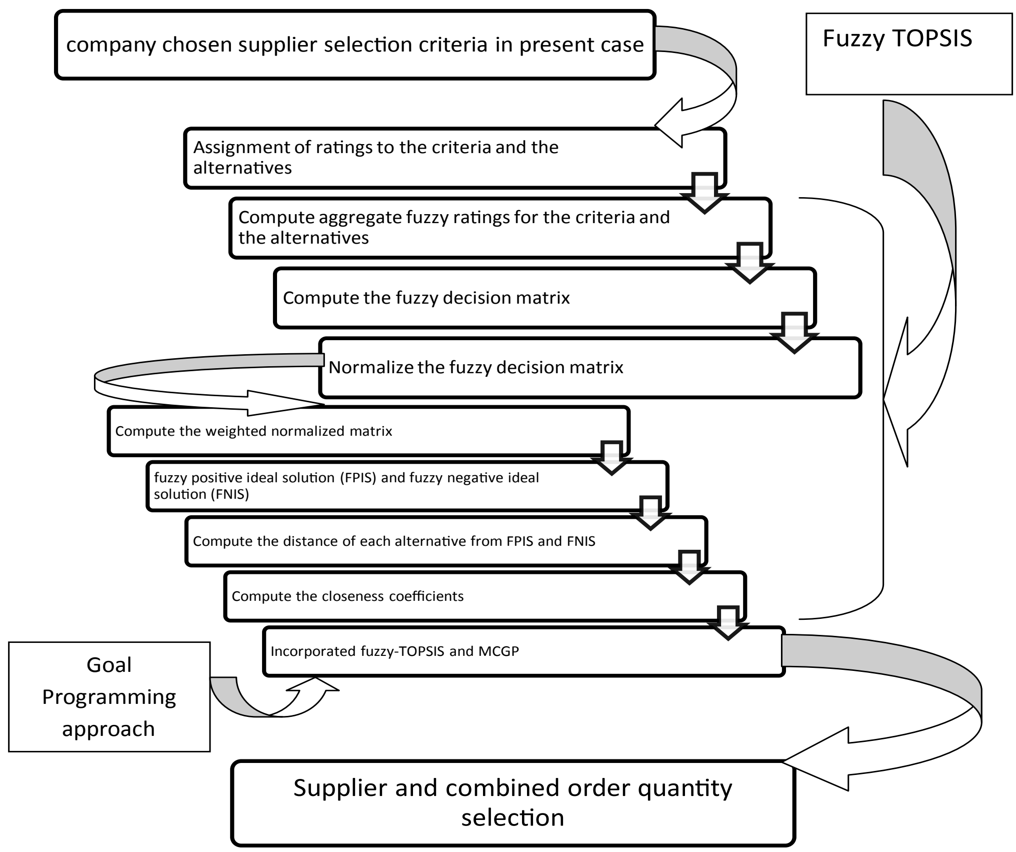

Figure 1: Proposed Methodology.

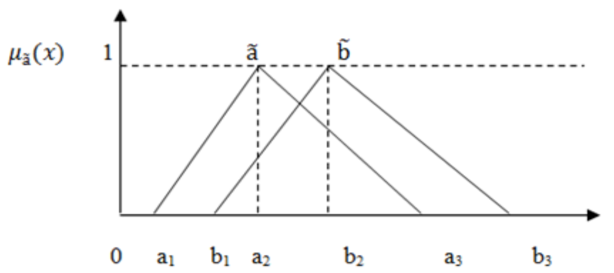

Figure 2: Triangular fuzzy.

$$\tilde{a}^{-1} = \left(\frac{1}{a_1}, \frac{1}{a_2}, \frac{1}{a_3} \right) \; a_1 \ge 0$$

6. Symmetric image

$$-\tilde{a} = -a_1, -a_2, -a_3 \quad a_1 \ge 0$$

Property 2: Given any real number k and a triangular fuzzy number $\tilde{a}$, the operations of the two numbers are given by

1. Multiplication of a triangular fuzzy number by a constant

$$k * \tilde{a} = (ka_1, ka_2, ka_3) \; a_1 \ge 0, k \ge 0$$

2. Division of a triangular fuzzy number by a constant

$$\frac{k}{\tilde{a}} = \frac{k}{a_1}, \frac{k}{a_2}, \frac{k}{a_3} \; a_1 \ge 0, k \ge 0$$

3. Division of a constant by a triangular fuzzy number

$$\frac{\tilde{a}}{k} = \frac{a_1}{k}, \frac{a_2}{k}, \frac{a_3}{k} \; a_1 \ge 0, k \ge 0$$

Property 3: Given two triangular fuzzy numbers ($\tilde{a}, \tilde{b}$) and any real numbers k. The commutative operations of these two numbers are expressed as follows:

$$\tilde{a}(+)\tilde{b} = \tilde{b}(+)\tilde{a} \; a_1 \ge 0, b_1 \ge 0, k \ge 0$$

$$\tilde{a}(\times)\tilde{b} = \tilde{b}(\times)\tilde{a} \; a_1 \ge 0, b_1 \ge 0, k \ge 0$$

$$\tilde{a}(-)\tilde{b} = \tilde{b}(-)\tilde{a} \; a_1 \ge 0, b_1 \ge 0, k \ge 0$$

$$k * \tilde{a} = \tilde{a} * k \; a_1 \ge 0, b_1 \ge 0, k \ge 0$$

Property 4: Let $\tilde{a} = a_1, a_2, a_3$ and $\tilde{b} = b_1, b_2, b_3$ be two triangular fuzzy numbers (Figure 2). The distance between them using the vertex method is given by

$$d(\tilde{a}, \tilde{b}) = \sqrt{\frac{1}{3}\left[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2 \right]}$$

Fuzzy TOPSIS:

The fuzzy TOPSIS approach involves fuzzy assessments of criteria and alternatives in TOPSIS [13]. The TOPSIS approach chooses alternative that is closest to the positive ideal solution and farthest from the ideal solution. A positive ideal solution is composed of the best performance values for each criterion whereas the negative ideal solution consists of the worst performance values as follows:

Step 1: Assignment of ratings to the criteria and the alternatives. Let us assume there are J possible candidates called A={$A_1, A_2, \ldots A_j$} which are to evaluated against n criteria, C={$C_1, C_2, \ldots C_i$}. The criteria weights are denoted by $w_i (i = 1, 2, \ldots m)$. The performance ratings of each decision maker $D_k (k = 1, 2, \ldots K)$ for each alternative $A_J (j = 1, 2, \ldots m)$ with respect to criteria $C_i = (i = 1, 2, \ldots, m)$ are denoted by $= (i = 1, 2, \ldots m; \; j = 1, 2, \ldots n; \; k = 1, 2, \ldots K)$ with membership function $\mu_{\tilde{R}_k}$ (x).

Step 2: Compute aggregate fuzzy ratings for the criteria and the alternatives. If the fuzzy ratings of all decision makers is described as triangular number $\tilde{R}_k = (a_k, b_k, c_k)$, k=1,2,…K, then the aggregated fuzzy rating is given by $\tilde{R}$ = (a, b, c), k=1,2,…K where a= $\min_k \{a_k\}$, b= $\frac{1}{K}\sum_{k=1}^{K} b_k$, c= $\max_k \{c_k\}$. If 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,…,m, j=1,2,…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 $a_{ij} = \min_k \{a_{ijk}\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{K} b_{ijk}, c_{ij} = \max_k \{c_{ijk}\}$. The aggregated fuzzy weights ($\tilde{w}_{ij}$) of each criterion are calculated as $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where $w_{j1} = \min_k \{w_{jk1}\}$, $w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}$, $w_{j3} = \max_k \{c_{jk3}\}$.

Step 3: Compute the fuzzy decision matrix. The fuzzy decision matrix for the alternatives (D˜) and the criteria ($\tilde{W}$) is constructed as follows:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ A_4 \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array}, \; i = 1, 2, \ldots, m; \; j = 1, 2, \ldots, n$$

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

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 R˜ is given by

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}, \text{ i=1, 2 ,…, m ; j=1,2,…,n}$$

Where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*} \right) \text{ and } c_j^* = \max_i c_{ij} \quad \text{(benefit criteria)}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}} \right) \text{and } a_j^- = \min_i a_{ij} \quad \text{(cost criteria)}$$

Step 5: Compute the weighted normalized matrix. The weighted normalized matrix V˜ for criteria is computed by multiplying the weights ($\tilde{w}_j$) of evaluation criteria with the normalized fuzzy decision matrix $\tilde{r}_{ij}$

$$\tilde{V} = [\;_{ij}]_{mxn}, \text{ i=1, 2 …m; j=1,2,…n where } \tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j.$$

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

$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots \tilde{v}_n^*)$ where $\tilde{v}_j^* \underset{i}{max} \{v_{ij3}\}$, where i=1, 2… m; j=1, 2,…n

$A^- = (\tilde{v}_1, \tilde{v}_2, \ldots \tilde{v}_n)$ where $\tilde{v}_j^- = \underset{j}{min} \{v_{ij1}\}$, where i=1, 2,…, m; j=1,2,…n

Step 7: Compute the distance of each alternative from FPIS and FNIS. The distance (d_i^*, d_i^-) of each weighted alternative i=1,2,…m from the FPIS and FNIS is computed as follows:

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*) \quad i=1, 2,\ldots m$$

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-) \quad i=1, 2,\ldots m$$

Where $d_v(\tilde{a}, \tilde{b})$ is the distance measurement between two fuzzy numbers $\tilde{a}$ 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

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, \quad i=1, 2,\ldots m$$

Step 9: Rank the alternatives. In step 9 the different alternatives are 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 fuzzy TOPSIS approach involves fuzzy assessments of criteria and alternatives in TOPSIS [13]. The TOPSIS approach chooses alternative that is closest to the positive ideal solution and farthest from the negative ideal solution. A positive ideal solution is composed of the best performance values for each criterion whereas the negative ideal solution consists of the worst performance values. Integration with MCGP enables to assign order quantities to each supplier by considering the total value created from the procurement. So, the proposed method not only considers decision makers preference and experience for supplier selection, but also the opportunities and threats of buyer and its suppliers such as the buyer's budget, suppliers' capacity and suppliers' delivery time. However, according to Chang, [29] multi-criteria aspiration level on a single attribute can be seen in the following three scenarios:

Goal Programming: GP is an important technique for allowing DMs to consider several objectives in finding a set of acceptable solutions. It has been accomplished with various methods such as Lexicographic (Preemptive), Weight (Archimedean), and MINIMAX achievement functions. It can also be said that GP has been, and still is, the most widely used technique for solving multi-criteria decision-making problems. The purpose of GP is to minimize the deviation between the achievement of goals, $f_i(\mathrm{Y})$, and their acceptable aspiration level g_i

To formulate a GP model:

- Derive the decision variables.
- State the constraints.
- Determine the preemptive priorities if need be
- Determine the relative weights if need be
- State the objective functions
- State the non-negative or given requirements

A mathematical expression for the standard version of GP is given as

$$\text{Minimize} \sum_{i=1}^{n} |f_i(\mathrm{Y}) - g_i| ,$$

Subject to Y ϵ F (F is feasible set);

Where $f_i(\mathrm{Y})$ the linear function of the ith goal, Y is a 1×N vector of decision variables and g_i is the aspiration level of the ith goal. The oldest and still most widely used form of achievement function for GP is represented as

$$Minimize \sum_{i=1}^{n} (d_i^+ + d_i^-)$$

Subject to $f_i(\mathrm{Y}) - d_i^+ + d_i^- = g_i$, for 1, 2, 3, 4, 5… n,

Y ϵ F, (F is feasible set);

Where $d_i \; \epsilon$ (1, 2, 3, 4, 5…..n) are additional continuous functions.

MCGP allows DMs to set multi-choice aspiration levels (MCAL) for each goal to avoid underestimation or overestimation of decision making. According to Chang, [4] MCAL on a single attribute can be seen in the following three scenarios:

- As a type of uncertainly/imprecision where a DM considers only that his/her aspiration level lies in a certain range, in which the aspiration level can be represented by a range of interval values.
- These aspiration levels indicate different levels of optimism, which can happen when maximizing or minimizing attribute values. For example, a DM who claims "I expect nothing less than 95, would be content with 115, and would be very happy with 130".
- Conservative policies are usually adopted by the decision maker to avoid a negative effect. For example, the DM may claim, 'Under company's resource limitations and the incompleteness of available information, I suggest that 120 million should be our initial aspiration levels for the goal this year, then, in the future for higher the aspiration levels. It will be in the long run if we have more available resources".

The algorithm of the multi-person multi-criteria decision-marking with fuzzy TOPSIS and MCGP method for dealing with the supplier selection is given as follows:

1: Choose the appropriate linguistic variables for the importance weight of selection criteria and the linguistic ratings for suppliers.

2: Aggregate the weight $\tilde{w}_j$ of criterion C_j and pool the DMs' ratings to get the aggregated fuzzy rating $\tilde{x}_{ij}$ of supplier Si under criterion C_j

3: Construct the fuzzy-decision matrix and normalize the matrix.

4: Construct weighted normalized fuzzy-decision matrix.

5: Determine FPIS and FNIS.

6: Calculate the distance of each supplier from FPIS and FNIS, respectively.

7: Calculate the closeness coefficient (CCi) of each supplier.

8: According to the closeness coefficients obtained from **Step 7** for each supplier, build the integrated model to find the best suppliers and their optimum order quantities combining both the products.

In order to find the best order quantities, the total value created from the procurement (TVP) should be maximized. The final model which integrates fuzzy TOPSIS and MCGP can be shown as:

Achievement function:

$$Minimize\sum_{i=1}^{n} [\left(d_i^+ + d_i^-\right) + e_i^+ + e_i^-] \quad \text{(Objective function)}$$

Subject to

Goal and system constraints

$$\sum_{i=1}^{n} CC_{I'} X_i - d_1^+ + d_1^- \geq g_{1.min} \quad \text{(TVP goal)}$$

$$\sum_{i=1}^{n} price_i X_i - d_2^+ + d_2^- \geq g_{2.min}\ or \leq g_{2.max}\left(Budget\ constraint\right)$$

$$\sum_{i=1}^{n} time_i X_i - d_3^+ + d_3^- \geq g_{2.min} or \leq g_{2.max}\left(Delivery\ time\ constraints\right)$$

$$\sum_{i=1}^{n} X_i - d_4^+ + d_4^- = D_i\left(Demand\ Constraints\right)$$

$$D_i - e_1^+ + e_1^- = g_{3,min};$$

$$g_{3,min} \leq D_i \leq g_{3,max};$$

$$X_i \leq Cap_i\left(Supplier\ capacity\ constraints\right)$$

$$X_j, d_i^+, d_i^-,\ e_i^+, e_i^- \geq 0, i = 1, 2, \ldots n$$

$$X \in F\left(F\ is\ a\ feasible\ set, X\ is\ unrestricted\ in\ sign\right)$$

g_1, g_2, g_3 are the j[th] aspiration level of i[th] goal. d_i^+, d_i^- are the positive and negative deviations corresponding to the i[th] goal because they represent the deviations below and above right hand side of constraint i. The deviational variables are dependent and hence can't be basic variables simultaneously. This means that in any simplex iteration at most one of the two deviational variables can be assumed as a positive variable. If the original ith inequity is of the type ≤ and its $d_i^- > 0$, then the i[th] goal is satisfied. In essence, the definition of $d_i^+\ and\ d_i^-$ allows meeting or violating the i[th] goal at will. This is the type of flexibility that characterizes goal programming when it seeks a compromising solution. Naturally, a good compromise solution aims at minimizing as much as possible the amount by which each goal is violated. The deviational variables represent the amounts by which the respective goals are violated. Thus the compromise solution tries to satisfy the objective as much as possible:

Minimize= d_1^-

Minimize= d_2^-

Minimize= d_3^-

e_1^+, e_1^- are the positive and negative deviations corresponding to $\left|D_i - g_{3,min}\right|$. CCi is the closeness coefficient of the i[th] supplier, and price$_i$ is the sale price of the i[th] supplier, and time i is the delivery time level of i[th] supplier. D represents the total purchase from X_i, and Cap_i is the capacity of i[th] supplier [30].

Case Study and Data Analysis

In an apparel manufacturing company in Bangladesh, its board of directors wishes to select material suppliers to purchase key components in order to achieve the competitive advantage in the market. A decision committee including three DMs (D1, D2, and D3) has been formed to select a supplier from four qualified suppliers S1; S2; S3; S4. From a complete set of criteria, the company chooses ten supplier selection criteria for the present case among those price is the only cost criterion. They are namely:

1. Price (Cost criteria).
2. Quality of product.
3. Warranty level.
4. On-time delivery.
5. Relationship closeness.
6. Labor relations.
7. Experience time.
8. Operation control.
9. Business attempts.
10. After sale service.

The integrated fuzzy TOPSIS and MCGP method is applied to solve this problem and the computational procedure is summarized as follows Tables 2 and 3 here:

Step 1: Three Decision makers use the linguistic variables to assess the importance weight of each criterion; the results of the weights are presented in Table 4. And the aggregated weight is presented in Table 5 using the equations: $w_{j1} = \underset{k}{min}\ w_{jk1}$, $w_{j2} = \frac{1}{K}\sum_{k=1}^{K} w_{jk2}$, $w_{j3} = \underset{k}{max}\ c_{jk3}$, where, $\tilde{w}_j = w_{j1}, w_{j2}, w_{j3}$

Step 2: Three Decision makers use the linguistic variables shown to rate suppliers with respect to each criterion; the result of the ratings are shown in Table 6.

Linguistic term	Membership function
Very poor (VP)	(1,1,3)
Poor (P)	(1,3,5)
Fair (F)	(3,5,7)
Good (G)	(5,7,9)
Very Good (VG)	(7,7,9)

Table 2: Linguistic terms for alternative ratings.

Linguistic term	Membership function
Very low (VL)	(1,1,3)
Low (L)	(1,3,5)
Medium (M)	(3,5,7)
High (H)	(5,7,9)
Very High (VH)	(7,7,9)

Table 3: Linguistic terms for criteria rating.

Citation: Sakib N (2014) Identifying Optimum Supply Unit Using an Integrated Fuzzy TOPSIS and MCGP Approach in Apparel Industry Sector. Ind Eng Manage 3: 143. doi: 10.4172/2169-0316.1000143

Step 3: The linguistic evaluations shown in Table 5 is converted to triangular fuzzy numbers to construct a fuzzy decision matrix and aggregate fuzzy decision metrics for suppliers is shown in Table 7 using step 3 described in fuzzy-TOPSIS section.

Step 4: Normalized fuzzy decision metrics are calculated and presented in Table 8 using step 4 described in fuzzy-TOPSIS section.

Step 5: Weighted normalized metrics are calculated by using step 5 described in fuzzy-TOPSIS section. FPIS and FNIS are calculated using step 6 described in fuzzy-TOPSIS section (Table 9).

Step 6: Distances between FNIS and supplier ratings are calculated and presented in Table 10 using step 7 described in fuzzy-TOPSIS section.

Step 7: Distances between FPIS and supplier ratings are calculated and presented in Table 11 using step 7 described in fuzzy-TOPSIS section.

Step 8: Closeness coefficient (CCi) for the four suppliers are calculated and shown in Table 12 using step 8 described in fuzzy-TOPSIS section. The values obtained are 0.471; 0.467; 0.423; 0.457 respectively.

No.	Criteria	Decision makers		
		D1	D2	D3
1	Price	VH	VH	VH
2	Quality of Product	VH	H	VH
3	Warranty level	M	H	M
4	On time delivery	H	H	VH
5	Relationship closeness	L	M	H
6	Labor relations	H	H	M
7	Experience time	M	H	M
8	Operation controls	L	M	L
9	Business attempts	M	VL	L
10	After sale service	L	M	H

Table 4: Linguistic assessment of ten criteria.

No	Criteria	Aggregated Weight		
1	Price	7	7	9
2	Quality of Product	5	7	9
3	Warranty level	3	5.67	9
4	On time delivery	5	7	9
5	Relationship closeness	1	5	9
6	Labor relations	3	6.33	9
7	Experience time	3	5.67	9
8	Operation controls	1	3.67	7
9	Business attempts	1	3	7
10	After sale service	1	5	9

Table 5: Aggregated weight.

Step 9: According to the sales chronicle and sales forecast in the last 3 years by and of the early mentioned company top management have established four goals as follows:

1. Total value of procurement (TVP) would be at least 2518.500 units (as we at least want to assure the maximum value of procurement); and the more the better.

2. The total cost of procurement would be not less than 45000 dollars, and not more than 46800 dollar, the less the better.

3. The delivery time (per lot) from supplier would be more less than 4 week but not more than 5 week by no means (push product); the less the better.

4. Current procurement level would less than 5500 unit.

The coefficients of variables are given by the company's R & D department's database analyzing the data of last 3 years. The unit material costs for suppliers (S1, S2, S3, and S4) are defined as \$8.5, \$8.64, \$9, and \$8.45 for push product and \$8, \$9, \$7.5, and \$8.65 for pull respectively. The capacities of the four candidate suppliers S1, S2, S3, and S4 are 2380, 2500, 2850 and 3000 for push product and 60, 65, 55, 60 for the pull product respectively. Furthermore, delivery time (per lot) level of the four candidate suppliers are 5, 4.5, 3, and 4 days for push product and 3, 4, 3.5 and 3.5 for pull respectively. They also noticed that the order they need to submit to suppliers approximately four (4) times more frequent of push product than that of the pull. Lot size the suppliers can provide are 700,500,570,600 for pull product respectively and 12, 13, 11, and 12 for push product. It is to note that they are all linear with delivery time. The following chart summarizes the problem statements (Table 13):

Solving the problem the maximum procurement value obtained 2518.500 units.

Using an integrated fuzzy TOPSIS and MCGP approach the problem is formulated as follows:

$$\text{Min} = d_1^+ + d_1^- + d_2^+ + d_2^- + d_3^+ + d_3^- + d_4^+ + d_4^- + e_1^+ + e_1^- + e_2^+ + e_2^- ;$$

Subject to:

$$0.471(X1+Z1)+0.467(X2+Z2)+0.423(X3+Z3)+0.457(X4+Z4)-d_1^+ + d_2^- \,?\, 2518.500;$$

$$8.5X1+8.64X2+9X3+8.45X4+8Z1+9Z2+7.5Z3+8.65Z4-d_2^+ + d_2^- = Y1;$$

$$Y1 - e_1^+ + e_1^- = 45000;$$

		S1			S2			S3			S4		
No.	Criteria	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
1	Price	G	F	G	F	G	G	VG	G	G	G	VG	G
2	Quality of Product	G	G	G	G	VG	G	G	G	G	G	G	G
3	Warranty level	F	G	F	F	F	F	G	G	F	G	G	VG
4	On time delivery	G	F	F	G	F	G	P	F	F	G	G	VG
5	Relationship closeness	G	G	F	VG	G	G	G	G	G	F	G	F
6	Labor relations	F	F	F	F	F	F	F	F	F	F	F	F
7	Experience time	VG	VG	G	G	G	G	F	F	G	F	F	G
8	Operation controls	F	F	F	G	G	G	F	G	F	F	G	F
9	Business attempts	G	F	F	F	F	F	P	F	F	G	F	G
10	After sale service	F	P	F	P	P	F	VP	P	P	P	VP	VP

Table 6: Linguistic assessment of suppliers.

		Suppliers											
No.	Criteria	S1			S2			S3			S4		
1	Price	3.00	6.33	9.00	3.00	6.33	9.00	5.00	7.00	9.00	5.00	7.00	9.00
2	Quality of Product	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00	5.00	7.00	9.00
3	Warranty level	3.00	5.67	9.00	3.00	5.00	7.00	3.00	6.33	9.00	5.00	7.00	9.00
4	On time delivery	3.00	5.67	9.00	3.00	6.33	9.00	1.00	4.33	7.00	5.00	7.00	9.00
5	Relationship closeness	3.00	6.33	9.00	5.00	7.00	9.00	5.00	7.00	9.00	3.00	5.67	9.00
6	Labor relations	3.00	5.00	7.00	3.00	5.00	7.00	3.00	5.00	7.00	3.00	5.00	7.00
7	Experience time	5.00	7.00	9.00	5.00	7.00	9.00	3.00	5.67	7.00	3.00	5.67	9.00
8	Operation controls	3.00	5.00	7.00	5.00	7.00	9.00	3.00	5.67	9.00	3.00	5.67	9.00
9	Business attempts	3.00	5.67	9.00	3.00	5.00	7.00	1.00	4.33	7.00	3.00	6.33	9.00
10	After sale service	1.00	4.33	7.00	1.00	3.67	7.00	1.00	2.33	5.00	1.00	1.67	5.00

Table 7: Aggregate fuzzy decision metrics for suppliers.

	Suppliers											
Criteria	S1			S2			S3			S4		
1.	1.00	0.47	0.33	1.00	0.47	0.33	0.60	0.43	0.33	0.6	0.43	0.33
2.	0.56	0.78	1.00	0.56	0.78	1.00	0.56	0.78	1.00	0.56	0.78	1.00
3.	0.33	0.63	1.00	0.33	0.56	0.78	0.33	0.70	1.00	0.56	0.78	1.00
4.	0.33	0.63	1.00	0.33	0.70	1.00	0.11	0.48	0.78	0.56	0.78	1.00
5.	0.33	0.70	1.00	0.56	0.78	1.00	0.56	0.78	1.00	0.33	0.63	1.00
6.	0.43	0.71	1.00	0.43	0.71	1.00	0.43	0.71	1.00	0.43	0.71	1.00
7.	0.56	0.78	1.00	0.56	0.78	1.00	0.33	0.63	0.78	0.33	0.63	1.00
8.	0.33	0.56	0.78	0.56	0.78	1.00	0.33	0.63	1.00	0.33	0.63	1.00
9.	0.33	0.63	1.00	0.33	0.56	0.78	0.11	0.48	0.78	0.33	0.70	1.00
10.	0.14	0.62	1.00	0.14	0.52	1.00	0.14	0.33	0.71	0.14	0.24	0.71

Table 8: Normalized fuzzy decision metrics for suppliers.

	Suppliers													
Criteria	S1			S2			S3			S4			FNIS	FPIS
1.	7.00	3.32	3.00	7.00	3.32	3.00	4.20	3.00	3.00	4.20	3.00	3.00	3.00	7.00
2.	2.78	5.44	9.00	2.78	5.44	9.00	2.78	5.44	9.00	2.78	5.44	9.00	2.78	9.00
3.	1.00	3.57	9.00	1.00	3.15	7.00	1.00	3.99	9.00	1.67	4.41	9.00	1.00	9.00
4.	1.67	4.41	9.00	1.67	4.93	9.00	0.56	3.37	7.00	2.78	5.44	9.00	0.56	9.00
5.	0.33	3.52	9.00	0.56	3.89	9.00	0.56	3.89	9.00	0.33	3.15	9.00	0.33	9.00
6.	1.29	4.52	9.00	1.29	4.52	9.00	1.29	4.52	9.00	1.29	4.52	9.00	1.29	9.00
7.	1.67	4.41	9.00	1.67	4.41	9.00	1.00	3.57	7.00	1.00	3.57	9.00	1.00	9.00
8.	0.33	2.04	5.44	0.56	2.85	7.00	0.33	2.31	7.00	0.33	2.31	7.00	0.33	7.00
9.	0.33	1.89	7.00	0.33	1.67	5.44	0.11	1.44	5.44	0.33	2.11	7.00	0.11	7.00
10.	0.14	3.10	9.00	0.14	2.62	9.00	0.14	1.67	6.43	0.14	1.19	6.43	0.14	9.00

Table 9: Weighted normalized metrics.

	D-			
Criteria	S1	S2	S3	S4
1.	2.32	2.32	0.69	0.69
2.	3.91	3.91	3.91	3.91
3.	4.85	3.68	4.93	5.04
4.	5.40	5.53	4.06	5.78
5.	5.33	5.41	5.41	5.26
6.	4.83	4.83	4.83	4.83
7.	5.04	5.04	3.77	4.85
8.	3.11	4.12	4.01	4.01
9.	4.11	3.21	3.17	4.14
10.	5.39	5.31	3.73	3.68

Table 10: Distances between FNIS and supplier rating.

$$Y1 \geq 45000;$$

$$Y1 \leq 46800;$$

$$5(X1/700)+4.5(X2/500)+3(X3/570)+4(X4/600)-d_3^+ + d_3^- = Y2;$$

$$Y2 - e_2^+ + e_2^- = 4;$$

$$Y2 \geq 4;$$

$$Y2 \leq 5;$$

$$X1+X2+X3+X4+Z1+Z2+Z3+Z4-d_4^+ + d_4^- \leq 5500;$$

$$(3(Z1/12)+4(Z2/13)+3.5(Z3/11)+3.5(Z4/12))(1/4)=5(X1/700)+4.5(X2/500)+3(X3/570)+4(X4/600)-d_3^+ + d_3^-$$

$$X1 \leq 2800;\ X2 \leq 2500;\ X3 \leq 2850;\ X4 \leq 3000;\ Z1 \leq 60;\ Z2 \leq 65;\ Z3 \leq 55;\ Z4 \leq 60$$

Where X and Z are quantity of push and pull products for suppliers respectively. Other variables are as defined in MCGP.

Result and Discussion

Optimization is a mathematical process to define devoting the optimal allocation of resources, it also helps to get the best result from the model. In this paper, we consider an examples, and then it is solved by the Lingo 11.0 software to show that this model works well. This software is a comprehensive tool designed to make building

	D+			
Criteria	**S1**	**S2**	**S3**	**S4**
1.	3.14	3.14	3.64	3.64
2.	4.14	4.14	4.14	4.14
3.	5.58	5.84	5.45	5.00
4.	5.00	4.84	5.97	4.14
5.	5.92	5.70	5.70	6.04
6.	5.15	5.15	5.15	5.15
7.	5.00	5.00	5.70	5.58
8.	4.88	4.42	4.71	4.71
9.	4.85	5.01	5.19	4.77
10.	6.15	6.30	6.80	6.98

Table 11: Distances between FPIS and supplier rating.

	S1	S2	S3	S4
D-	44.28	43.34	38.52	42.19
D+	49.80	49.54	52.45	50.14
CC_i	0.471	0.467	0.423	0.457

Table 12: Final evaluation.

Suppliers	Material cost (dollar)		Suppliers capacity		Delivery time		Lot size	
	push	pull	push	pull	push	pull	push	pull
S1	8.5	8	2380	60	5	3	700	12
S2	8.64	9	2500	65	4.5	4	500	13
S3	9	7.5	2850	55	3	3.5	570	11
S4	8.45	8.65	3000	60	4	3.5	600	12

Table 13: Problem statement.

Suppliers							
S1		**S2**		**S3**		**S4**	
push	pull	push	Pull	push	pull	push	pull
2800 unit	60 unit	0 unit	0 unit	0 unit	16 unit	2439 unit	0 unit

Table 14: Product quantity.

and solving linear, nonlinear, and integer optimization models faster, easier, and more efficient. It provides a completely integrated package that includes a powerful language for expressing optimization models. However the problem is coded and implemented by LINGO 11.0 and a global optimum solution is found. The best suppliers and their optimum supply quantities are intended as follows: $S_1(X_1=2800, Z_1=60)$; S_2 $(X_2=0, Z_2=0)$; $S_3(X_3=0, Z_3=16)$; S_4 $(X_4=2439, Z_4=0)$. The result is summerized in the following Table 14.

Analysis, Conclusion, Limitations and Further Research

The model maximizing the TVP decides about the joint quantity unit to order. Based on the result industry can decide upon lot size, transportations facilities, warehouse facilities, routes and several business choices which are other factors related to effective supply chain. Let us assume a total cost by the formula- $CD+\left(\frac{D}{Q}\right)\times S+\left(\frac{Q}{2}\right)\times hC$; Where Q=Number of items per lot to order, D=Annual demand, S=Fixed ordering cost; C=Cost per unit; h=Holding cost. CD=Annual material cost; $\left(\frac{D}{Q}\right)\times S$=Annual order cost; $\left(\frac{Q}{2}\right)\times hC$=Annual handling cost. If the industries order the products jointly assimilating other factors with it, they will be able to save the additional fixed ordering cost (S), thus large amount of money annually. Supplier selection is one of the acute decision making accomplishments for apparel firms to obtain economic advantages. For this, decision makers try to apply effective methods and select suitable criteria for supplier selection. This paper used a method, which integrates fuzzy TOPSIS and MCGP, to evaluate suppliers in apparel sector. In a decision making process, the use of linguistic variables in decision problems is highly beneficial when performance values cannot be expressed by means of numerical values. Normally, supplier selection problems are hazy and tentative, fuzzy set theory helps to convert DMs preferences and experiences into meaningful results by applying linguistic values measuring each criterion corresponding to each supplier. In this paper fuzzy TOPSIS is used because of the haziness in apparel sectors, there fuzzy can pave a way greatly. And the reason of using triangular fuzzy is it easier to perform calculation it and it gives satisfactory solution while TOPSIS separates the cost and benefit criteria. Though the work has significance in supplier selection but the selection for multiple products and various ordering system didn't coverage here; holding cost was assumed as same for the products, this is obviously a limitation of the method. Additionally, price discount with joint ordering can be another scope of further study. Above all the significance of the approach is its practical applicability and ability to provide solution under hazy environment and lack of quantitative information.

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