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Developing a Method for Order Allocation to Suppliers in Green Supply Chain

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KEYWORDS

Supplier selection,
Order allocation,
Green supply chain,
MOLP

ABSTRACT

Due to increased competition in the services and manufacturing, many companies are trying to lower price and offer good quality products to the market. In this paper, the multi-criteria decision-making techniques to evaluate and select the best supplier from among the existing suppliers are applied. First, hierarchical structure for selecting suppliers of raw materials is used, and the analytic hierarchy process to obtain the relative importance of quantitative and qualitative criteria related to the green supply chain is applied. Then, a fuzzy TOPSIS technique ranked the suppliers for each raw material according to the relevant criteria. Finally, regarding the weight of suppliers and demand of raw material and resource constraints by a multi-objective mathematical model, optimum order is determined. The objectives are to minimize the total cost, maximize the amount of purchases from desirable suppliers, and minimize raw materials required which are not provided. The proposed method is performed in a real case study of Food Company, and the relevant results are expressed.

1. Introduction

In a competitive environment, supplier selection is one of the most important issues that manufacturing companies face it. The cost of supplying raw materials in some industries includes the major portion of a product's final cost, and selection of a suitable supplier can significantly reduce it (Ghodsypour and O’Brien, 1998). Supply chain is a set of methods which is used to integrate suppliers, manufacturers, warehouses, and stores. Therefore, necessary products will be produced in a certain time and place with specified quantities and will be delivered to the customers in order to minimize the total cost of the chain and satisfy the buyer's needs in high-quality service. According to governmental legislation and increased awareness of people about protecting the environment, companies cannot ignore environmental issues for maintaining their competitive advantage and staying in the globalization trend. Increasing environmental concerns means considering the fact that the environmental pollution issue along with industrial development in supply chain management activities is important, leading to the emerging concept of green supply chain

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management (Hsu and Hu 2009). Srivastava defined green supply chain as follows: "considering environmental issues in supply chain management including product designing, selection and materials sourcing, production process, delivery of the final product to the customer and product management after consumption and expiration of its shelf-life". Supplier selection is one of the most important activities that its results represent a big picture of good quality, organization performance, and supply chain (Chen et al. 2006). Therefore, the organizations should apply environmental management to all of the life cycles of their products to ensure the improving environmental performance of the supply chain. Green supply chain management is an integrator of supply chain management with environmental requirements in all steps of product designing, selection and materials supply, production, processes of distribution and transfer, delivery to the customer. In addition, after consumption, it is considered as recovery management of reuse for maximizing efficiency of energy consumption and its source for improving performance of the entire supply chain. In fact, green supply chain includes the processes of raw materials supply, production, logistics management, distribution, and service (Junior et al. 2014). You can refer to a reviewed paper (Govandin et al. 2015) to review the previous researchers about supplier selection in a green supply chain.

An appropriate supplier selection leads to reducing operating costs, increasing productivity and product quality, improving competition in the market, and satisfying customer's demands faster (Abdollahi et al, 2015). Supplier selection and evaluation are an issue of multi-criteria decision-making (MCDM) including quantitative and qualitative factors such as total cost, delivery time, the satisfaction level of the customer which is broken into two related issues: 1- Which supplier should be selected? 2- How much/many selected sources should be purchased? According to Weber and Current's statement (1993), these two cases of decision-making are called supplier selection.

Since the 1950s, supplier selection issue was introduced into scientific literature as a research issue coinciding with the emergence of linear programming and before propounding concepts relevant to supply chain in the business space (Aissaoui et al. 2007). Dickson (1966) conducted a study to identify and prioritize criteria used in supplier's evaluation. The obtained result specified 23 criteria that were often used in the evaluation by the firms and the most important criteria such as quality, delivery time, producer validity, facilities, manufacturing capacity, and price. Most of the studies conducted in this domain have considered the supplier selection issue as a multi-criteria issue and have focused on various quantitative and qualitative criteria, so that the necessity of using multi-criteria decision-making criteria is discovered. Due to multi-criteria's nature of supplier selection issue, analytic hierarchy process (AHP) technique was suggested which has determined weight coefficients of criteria and suppliers score based on pairwise comparisons. This technique has been applied by many researchers up to now, like Barbarsoglu et al. 1997.

2. Green Supplier Selection

Green supply chain management focuses on encouraging suppliers to improve their environmental performance and providing this green supplier for supply chain management, which is considered as an important factor in decision making for purchase (Kannan et al. 2013). Many researchers have done studies about evaluating indicators of green suppliers to get familiar with environmental criteria. Noci (1997) applied AHP to design a green supplier rating system. Sarkis (1998) categorized business method of the environment into five major components: planning for the environment (green planning), life cycle analysis, comprehensive environmental quality management, green supply chain, and certificate related to the environment such as ISO 14000. Handfield et al. (2002) worked on Delphi method in order to collect viewpoints of environmental experts in different companies based on AHP. Sarkis (2003) used ANP (analytic network process) to develop a six dimensions strategic decision framework in green supply chain management. Hsu and Hu (2009) proposed new criteria for supplier selection with hazardous substances management including green purchasing, green materials coding and recording, capability of green design, a list of hazardous substances, management of hazardous substances, legal-compliance competency, and environmental management system. Lee (2009) applied quality, technology, pollution control, environmental management, green products, and competencies for green supplier selection in the high-tech industry. Bai and Sarkis (2010) used grey system and rough set method to integrate sustainability into supplier selection and summarized environmental criteria as pollution control, pollution prevention, environmental management system, resource consumption, and pollution production. Awasthi et a1. (2010) proposed a fuzzy multi-criteria approach to evaluate environmental performance for green supplier selection which applied available clean materials, environmental effects, green image, environmental costs, green products, environmental management and green management process. Yeh and Chuang (2011) developed two multi-objective genetic algorithms for green partner selection which included four objectives, e.g., cost, time, product quality, and green score evaluation. They offered green image of renewal products, green design, green supply chain management, pollution treatment cost, and evaluation criteria of environmental performance. Govindan et al. (2013) proposed a fuzzy multi-criteria approach for measuring sustainability of a supplier and considering pollution production, consumable resource and available resource, compatibility with environment, and environmental management system as environmental criteria. Trapp and Sarkis (2016) developed an optimization model which considers the supplier selection, supplier development, and its sustainability. They believed that decision-making for the supplier selection is difficult in the supply chain of the organization. Because the integration of sustainability issue in the chain causes more complexity in decision making, it should be done well to improve the total performance of the supply chain. Also, sustainability criteria may be variable. In the developing countries, the customers do not want to pay more for the compatible products with the environment (Gandhi et al. 2016). According to the relevant literature, there is a wide range of work with focus on the green supplier selection (Akman 2015 and Kannan et al. 2015). Aknan (2015) ignored social dimension in decision-making of the supplier selection.

In the past, the life cycle of product included some processes from design to consumption. Now, due to environmental management approach, it includes processes of preparing raw materials, design, production, recycle, reuse and formation of a closed ring from materials circulation for reducing resource consumption and environmental harmful effects. Green supply chain includes processes of raw materials supply, production, logistics management, distribution, services, and recycle (Strivasta, 2007). Importance and advantages of green supply chain management do not limit the decrease of hazardous and poisonous substance consumption or decrease of harmful pollutants. Principles of green supply chain management can be utilized for all parts of an organization and their effects can spread on all tangible and intangible domains. Companies should accept green approach and compatibility with green supply chain management because of ten reasons as follows:

- Resource sustainability
- Cost reduction
- Efficiency
- Attainment of competitive advantage
- Compatibility with rules
- Risk reduction
- Gaining brand reputation
- Refund
- Assurance staff
- Morals

In some papers, evaluated green production variables are as follows:

- Utilization of compatible raw materials with environment
- Elimination of harmful raw materials for environment
- Accuracy in compatible criteria with environment
- Accuracy in compatible design with environment
- Optimization of processes for waste reduction
- Utilization of clean technologies for saving water and energy consumption and reducing pollutants
- Raw materials recycling in production stage
- Utilization of principles of comprehensive quality management

3. The Proposed Integrated Approach

According to the Spiegler et a1. (2012), there have been many literature reviews about flexibility in supply chain since recent years, but there are a few models which show the performance of supply chain flexibility or evaluate the impact of different strategies for giving flexibility in the supply chain (Torabi et al. 2015). In this article, an integrated approach is proposed for green supplier evaluation. Figure 1 shows the framework of the proposed method.

At first, AHP is used for measuring weights of supplier selection criteria. Then, fuzzy TOPSIS technique is used to rank suppliers of raw materials. After, a multi-objective linear programming (MOLP) model, order allocation of each raw material to the suppliers is done regarding demand and resource constraints. According to the relevant literature, there are just a few papers which have been developed and have mixed some methods among green and economic supplier selection criteria regarding resource allocation methods for multi-objective supplier selection problem in green supplier chain.

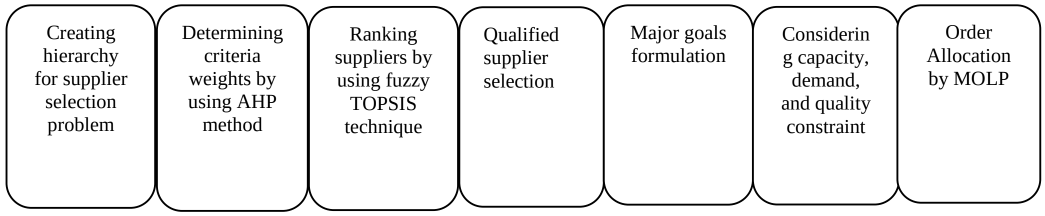

Fig. 1. The framework of the proposed method

3-1. Analytic Hierarchy Process

Multi-criteria decision-making techniques can evaluate different options with regard to various criteria which do not have the same units. It is an important advantage over the traditional methods that all the criteria should turn into the same unit from them. An important advantage of the other MCDM techniques is that they can analyze and evaluate qualitative and qualitative criteria simultaneously. One of the most efficient decision techniques is AHP that were proposed by Tomas Al-Saati (1980) for the first time. Dweiri et al. (2016) proposed ranking of forecasting model for production planning in the supply chain. This model is based on the AHP from multi-criteria decision making. It is useful in many industries and easy life application. One of the strongest features of the AHP is that it can generate numerical priority through the subjective knowledge. This method is very applicable in evaluating supplier’s weights in terms of various factors based on the pairwise comparison matrix. The problem is divided into two hierarchies (main criteria and sub-criteria). The main criteria are price, quality, on-time delivery, service were identified based on literature review. These criteria have been ranked based on the expert’s opinions. Implementation of AHP in decision-making includes four phases: 1-making hierarchy; 2- doing pair-wise comparison; 3- calculation of weights; 4- system compatibility. This method is one of the most famous methods of decision making. For more details, refer to the relevant sources about this domain.

3-2. Fuzzy Set Theory

In the real world, ambiguous and inexact information involves evaluation and prioritization of the options. Therefore, fuzzy set theory is used in the evaluation of different options for reflecting unreliability and ambiguities related to the feeling and understanding of decision-maker (DM). Fuzzy set theory was developed by Zadeh (1965) and used to formulate some problems with inadequate and inexact information related to different criteria in the real-world decision-making. Koumar et al. (2006) used an ideal fuzzy programming method to solve a multi-objective vendor selection problem by minimizing total cost, total rejected cost, delivery delay time, buyer's demand constraint, sellers capacity, seller ration flexibility, value of items purchasing, and budget allocation to the individual sellers. In addition, Amid et al. (2006) utilized a fuzzy model for supplier selection problem to resolve ambiguous input parameters in determination of the weight of quantitative and qualitative by finding different sources and constraint capacities. Ozgen et al. (2008) proposed integration of fuzzy set theory and multi-objective linear programming to model uncertainty in supplier evaluation and order allocation. Crispim and Souza (2009) developed a process to help the decision-makers to identify company’s criteria and to reach goals and needs of each project. They continued their procedure to find a multi-objective function which is considered as a good approximation from TOPSIS for ranking virtual alternatives of the company. Using previous similar cases, Faez et al. (2009) proposed a reasoning approach based on the sample for solving seller selection problem. They resolved ambiguity of some selection criteria by fuzzy set theory and formulated a programming model of complex integer number regarding seller selection and order allocation simultaneously. For more details about fuzzy set theory in supplier selection problem, refer to the following studies: (Moghaddam 2015, Junior 2014, Amid et al., 2011, Ozkok and Tiryaki, 2011; Wu 2010, Yucel and Guneri 2011).

3-3. The Fuzzy TOPSIS Method for Ranking Suppliers

TOPSIS is one of the classical methods for solving MCDM problem, originally proposed by

Hwang and Yoon (1981). Shih et al. (2007) described this method in more details. TOPSIS is a simple computation process, systematic procedure, and a sound logic representing the rationale of human choice. This set includes an unlimited range of criteria and alternative performance. There is an explicit trade-off between options in this set. Furthermore, pairwise comparisons required by methods such as AHP are avoided (Shih et al. 2007; Wang and Chang, 2007; Govindan et al. 2013). The TOPSIS method finds the distance between PIS and NIS at the same time by defining relative closeness to the ideal solution. Finally, the ideal solution closest to the PIS and farthest to the NIS is obtained. Steps of TOPSIS solution are as follows (Hwang and Yoon, 1981; Chen et al. 2006):

Step 1: The normalized fuzzy decision matrix $(\tilde{R})$ can be obtained as:

$$\tilde{R}=\left[\tilde{r}_{ij}\right]_{m\times n}$$

$$\tilde{r}_{ij}=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{c_j^*},\frac{c_{ij}}{c_j^*}\right),\ j\in B \tag{1}$$

$$c_j^* = Max_i\, c_{ij},\ j\in B$$

$$\tilde{r}_{ij}=\left(\frac{a_{ij}}{c_j^*},\frac{b_{ij}}{c_j^*},\frac{c_{ij}}{c_j^*}\right),\ j\in C \tag{2}$$

$$a_j^- = Min_i\, a_{ij},\ j\in C$$

where B and C are the sets of benefit and cost criteria, respectively.

Step 2: Regarding the weights of different criteria, weighted fuzzy decision matrix is obtained by multiplying the coefficient of each criterion importance with fuzzy normalized matrix:

$$V=\left[\tilde{v}_{ij}\right]_{m\times n} \quad i=1,2,\dots,m;\ j=1,2,\dots,n$$
$$\tilde{v}_{ij}=\tilde{r}_{ij}\cdot\tilde{w}_j \tag{3}$$

where $\tilde{w}_j$ is coefficient of criterion importance, c_j.

Step 3: The positive ideal solution (PIS, A^*) and negative ideal solution (NIS, A^-) are defined as:

$$A^*=\left\{\tilde{v}_1^*,\tilde{v}_2^*,\dots,\tilde{v}_n^*\right\}$$
$$A^-=\left\{\tilde{v}_1^-,\tilde{v}_2^-,\dots,\tilde{v}_n^-\right\} \tag{4}$$

Step 4: The distance of each alternative from PIS and NIS is calculated as:

$$d_i^*=\sum_{j=1}^{n} d\left(\tilde{v}_{ij},\tilde{v}_j^*\right),\ i=1,2,\dots,m \tag{5}$$

$$d_i^-=\sum_{j=1}^{n} d\left(\tilde{v}_{ij},\tilde{v}_j^-\right),\ i=1,2,\dots,m \tag{6}$$

Step 5: The closeness coefficient (CC_i) is calculated as:

$$CC_i=\frac{d_i^-}{d_i^*+d_i^-},\ i=1,2,\dots,m \tag{7}$$

Step 6: The ranking of alternatives: They are ranked according to the descending order of calculated closeness coefficients CC_i.

3-4. Mathematical Model for Supplier Selection Problem

In this section, a MOLP model is proposed for order allocation to the suppliers. The objective function of MOLP includes a set of objectives which should be optimized simultaneously. The aim of MOLP is to find the best solution among the most efficient points (Wang and Yang, 2009). Wodhwa and Ravindran (2007) developed the supplier selection problem as a multi-objective programming problem, in which there are three objective functions. Here, we determine optimum order by a multi-objective mathematical model regarding the weight of suppliers, demand for raw materials, and resource constraints. The objectives are minimizing the total cost, maximizing amount of purchase from desirable suppliers, and minimizing required raw materials that are not provided. The following notations are used in order to formulate this model:

Raw materials $r=1,2,3,\dots,R$

Suppliers s = 1,2,3, …… , S

Parameters:

p_{rs}: Price of purchasing the rth raw materials from the sth supplier

o_{rs}: Cost of ordering the rth raw materials to the sth supplier

t_s: Cost of transporting the rth raw materials

d_s: Distance from the sth supplier from company.

h_r: Cost of holding the rth raw materials

W_{rs}: The weight of the sth supplier for rth raw materials supply

q_{rs}: The average defect of the rth raw materials from the sth supplier

Q_r: Maximum acceptable defect from the rth raw materials.
D_r: Demand of the rth raw materials
c_{rs}: Maximum capacity of the sth supplier for the rth raw materials supply
c'_{rs}: Minimum acceptable order of the rth raw materials for the sth supplier

Decision variables:

X_{rs}: Amount of purchasing the rth raw materials from the sth supplier
Y_{rs}: is one, if the rth raw materials are supplied from supplier *s*. Otherwise, it is zero.
L_r: The amount of rth raw materials that are not supplied.

Objective functions:

The first objective function minimizes the total costs of purchasing, ordering, transportation, and holding. The second objective function maximizes the purchasing from qualified suppliers. The third objective function minimizes the amount of demand, those raw materials that are not supplied.

$$MinTCP = \sum_r \sum_s p_{rs} X_{rs} + \sum_r \sum_s o_{rs} X_{rs} + \sum_r \sum_s t_r$$

$$MaxTVP = \sum_r \sum_s W_{rs} X_{rs}$$

$$MinL = \sum_r L_r$$

Constraints:

$$\sum_s q_{rs} X_{rs} \le Q_r D_r \quad \forall r \quad (8)$$

$$\sum_s X_{rs} = D_r - l_r \quad \forall r \quad (9)$$

$$X_{rs} \le c_{rs} \quad \forall r, s \quad (10)$$

$$X_{rs} \ge c'_{rs} Y_{rs} \quad \forall r, s \quad (11)$$

$$X_{rs} \ge 0 \quad \forall s \quad (12)$$

$$Y_{rs} \in \{0,1\} \quad \forall r, s \quad (13)$$

Constraint (8) ensures that overage number of defect of raw materials cannot be higher than the maximum acceptable defect of demand. Constraint (9) is a balance constraint for each raw material. In this constraint, the number of orders of the rth raw materials from each supplier should be equal to demanded quantity of the rth raw materials minus quantity of the rth raw materials that would not be provided. Constraint (10) controls the maximum capacity of each supplier to provide any type of raw material. Constraint (11) states that the order quantity of raw materials from a supplier cannot be less than the minimum acceptable. (The order quantity of the rth raw materials from the sth supplier should be more than the minimum capacity of the sth supplier to be economical). Constraints (12) and (13) show kinds of decision variables.

3-5. Goal Programming for Decision-Making

Many of the real-life concepts are designed into a single objective linear programming model. Researchers are more and more aware of the presence of multi-criteria in real-world problems of decisions and management (Tamiz et al. 1998). The goal programming (GP), first formulated by Charnes and Cooper (1961), is a tool for solving multi-objective decision-making problems, achieving a set of compromise solutions. The main idea of GP is to introduce auxiliary variables, called deviations, which work not as 'decision makers' but as 'facilitators' to formulate the model. These deviations present the distance between aspiration levels of goals and the realized solutions. Two kinds of deviations are excited, under-achievement of the goal, shown by negative deviation (d^-) and over-achievement of the goal, shown by positive deviation (d^+). GP consists of two sets of constraints: system constraints and goal constraints. System constraints are formulated following the linear programming concepts, while goal constraints are auxiliary constraints, which determine the best possible solution with respect to a set of desired goals. In this study, weighted linear programming model with multi-objective function can be formulated as follows:

$$MinZ = \sum_{i=1}^{m} (w_i^+ .d_i^+ + w_i^- .d_i^-)$$

Subject to

$$\sum_{i=1}^{m} a_{ij} .x_j - d_i^+ + d_i^- = g_i ; j = 1,2,...,n$$

$$x_j \ge 0; j = 1,2,...,r$$

$$x_j \in z; j = r+1, r+2,...,n$$

$$d_i^+ , d_i^- \ge 0; i = 1,2,...,m$$

where Z is an optional set of hard constraints in linear programming. In this model, function Z is the weighted sum of deviation variables, and W_i^- and W_i^+ are negative and positive weights, respectively, related to the ith goal. In addition, d_i^+ and d_i^- represent the positive and negative deviations from the ith objective value, respectively, and g_i is the ith goal value.

4. A Case Study

This paper aims to provide a clear image from the structure of purchasing manager's activities and supply of raw materials by the proposed method and through supplier selection and evaluation of food raw materials in Green Service Food Company in Shahrekord city in Iran. Sunil Luthra et al (2016) focused on the initiative of green practice for the complicated decision making; the supplier selection has been done for obtaining economic, environmental, and social benefits. In addition, the proposed framework of this study improves the complex selection of an alternative to extend the products and the green process regarding the other criterion of the company, which is the profit, so that it can remain in the competitive climate. We identify and evaluate the criteria for green supplier selection in this study. Then, we recognize the relative importance of weights in the green supplier selection and evaluate the green supply chain. The proposed model has been validated using real data in the food industry of green service Food Company in Shahrekord. This research encouraged innovation in creating a hierarchy for the supplier selection and order allocation to a favorite supplier. A summary of activities and contracts of green service company in Shahrekord has been registered in Cheharmahal and Bakhtiyari province in 2002. It has concluded 28 contracts with the public organizations for providing some services such as preparing, cooking, distributing, and supplying manpower. The following contracts from the respectable employers have been applied successfully.

A list of effective criteria in evaluation and selection of green suppliers in the company has been considered. Finally, nine major criteria were identified after interviewing with experts of raw materials selection and experts of food industries. These criteria are as follows: price, quality, transportation cost, fulfillment of the order, distance, environmental compatibility, defect, flexibility, technology, and timely delivery. There are different suppliers for each food raw material. Totally, there are 28 suppliers for 9 food raw materials in this study. The name of food raw materials are: 1) meat, 2) chicken, 3) schnitzel, 4) rice, 5) fish, 6) tomato paste, 7) lemon juice, 8) tomato, and 9) yoghurt.

4-1. Hierarchical System for MADM

The steps of the proposed method for the first raw material have been explained. These steps have been considered for other raw materials. The steps of the proposed method are as follows:

Step 1: construction hierarchical tree

Five alternatives were studied for selection of an appropriate supplier of the first raw material in a food company. Moreover, five criteria have been considered for selection of an appropriate alternative: c1: price, c2: transport cost, c3: flexibility, c4: technology, c5: quality. The hierarchical structure is shown in Figure 2.

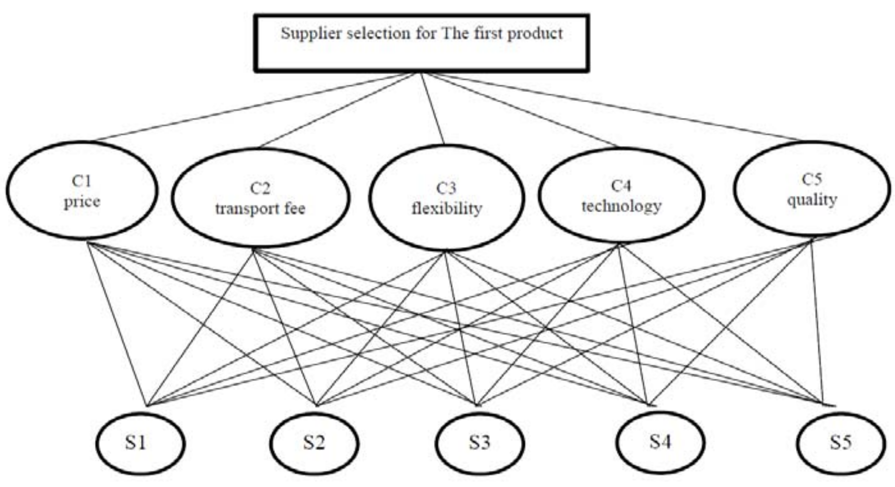

Fig. 2.The hierarchical structure of the AHP

Step 2: Pairwise comparisons At first, the pairwise comparison matrix has been constructed to determine an appropriate criterion by AHP. You can see this matrix in Table 1. Consider that indicator n (X_j) has been compared in relation to decision-making purpose in a MADM by DM as pairwise. The following scaled sections have been obtained from its comparisons.

Tab. 1. The pairwise comparison of each criterion for the meat

	C1	C2	C3	C4	C5
C1	1	5	9	7	6
C2	0.2	1	7	5	1
C3	0.111	0.142	1	3	2
C4	0.142	0.2	0.333	1	3
C5	0.166	1	0.5	0.333	1

Step 3: obtaining weights from decision matrix
The weight vector should be obtained for each pairwise comparison matrix to determine the score of each alternative. Row set method was used in this case study. Table 2 shows criteria weights for the first raw material. In the row sum method, elements sum of each row would be written in one vector, and this vector would be normalized (i.e., all the elements are divided into the largest element of each vector).

Tab. 2. Determination of the weights of criteria

	W1	W2	W3	W4	W5
W1	0.498869	0	0	0	0
W2	0	0.252998	00	0	0
W3	0	0.111408	0	0	
W4	0	0	0	0.083293	0
W5	0	0	0	0	0.053432

4.2. Using fuzzy TOPSIS for evaluating suppliers
Due to the subjective uncertainty of managers, fuzzy numbers are used to determine the best supplier. The linguistic variables for rating alternative are shown in Table 3. The fuzzy information is expressed in Table 4 based on these linguistic variables. Table 5 shows normalized fuzzy decision matrix. All the calculations have been done using Ms Excel. In this step, weighted normalized decision matrix can be obtained through Equation 3 (Table 6).

Tab. 3. Linguistic variables for rating criteria

Fuzzy numbers	Linguistic variable
(0,0,1)	(VL)Very low
(0,1,3)	low (L)
(1,3,5)	Medium low (ML)
(3,5,7)	medium (M)
(5,7,9)	Medium high (MH)
(7,9,10)	(H) High
(9,10,10)	Very high (VH)

Tab. 4. Ratings of the suppliers by DMs under various criteria linguistic variable for rating of criteria for meat

suppliers	price	transport fee	flexibility	technology	quality
S1	(1,3,5)	(9,10,10)	(0,0,1)	(0,0,1)	(0,0,1)
S2	(7,9,10)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)
S3	(5,7,9)	(9,10,10)	(5,7,9)	(0,1,3)	(0,1,3)
S4	(3,5,7)	(5,7,9)	(3,5,7)	(3,5,7)	(5,7,9)
S5	(9,10,10)	(7,9,10)	(0,1,3)	(5,7,9)	(5,7,9)

Tab. 5. Fuzzy normalized ratings criteria

Suppliers	price	transport fee	flexibility	technology	quality

S1	(0.2, 0.33, 1)	(0.5, 0.5, 0.55)	(0, 0, 0.1)	(0, 0, 0.1)	(0, 0, 0.1)
S2	(0.1, 0.11, 0.14)	(0.5, 0.55, 0.77)	(0.9, 1, 1)	(0.9, 1, 1)	(0.9, 1, 1)
S3	(0.11, 0.14, 0.2)	(0.5, 0.5, 0.55)	(0.5, 0.7, 0.9)	(0, 0.1, 0.3)	(0, 0.1, 0.3)
S4	(0.14, 0.2, 0.33)	(0.55, 0.714, 1)	(0.3, 0.5, 0.7)	(0.3, 0.5, 0.7)	(0.5, 0.7, 0.9)
S5	(0.1, 0.1,0.11)	(0.5, 0.55, 0.71)	(0, 0.1, 0.3)	(0.5, 0.7, 0.9)	(0.5, 0.7, 0.9)

Tab. 6. Fuzzy weighted normalized ratings

Suppliers	V_1	V_2	V_3	V_4	V_5
s1	(0.18, 0.33, 1)	(0.35,0.45, 0.55)	(0,0, 0.07)	(0, 0, 0.09)	(0,0, 0.1)
s2	(0.09,0.111, 0.142)	(0.35,0.495, 0.77)	(0.27,0.5, 0.7)	(0.45, 0.7, 0.9)	(0.63, 0.9, 1)
s3	(0.0999,0.142, 0.2)	(0.35, 0.45, 0.55)	(0.15, 0.35, 0.63)	(0, 0.07, 0.27)	(0, 0.09, 0.3)
s4	(0.1278, 0.2, 0.33)	(0.385, 0.6426, 1)	(0.09, 0.25, 0.49)	(0.15, 0.35, 0.63)	(0.35, 0.63, 0.9)
s5	(0.09, 0.1, 0.111)	(0.35,0.495, 0.71)	(0, 0.05, 0.21)	(0.25, 0.49, 0.81)	(0.35,0.63, 0.9)

We can calculate the fuzzy PIS and the fuzzy NIS by Equations 3-7. Table 7 shows the distance of each alternative suppliers from the positive ideal and negative ideal solutions $\left(S_1^-, S_1^+\right)$. Finally, closeness coefficients of the alternatives are determined through Equation 7, and similar calculation has been done for other alternatives.

CC1=0.182986907 CC2=0.523831845 CC3=0.218226254 CC4=0.427944857 CC5=0.354111808

Tab. 7. The *PIS* and the *NIS*

supplier	$d(S_k^+)$	$d(S_k^-)$
S1	3.683712	0.825043
S2	2.158753	2.37484
S3	3.46224	0.966458
S4	2.644803	1.978533
S5	2.905796	1.593119

Tab. 8. Supplier evaluation

Preferred order of the suppliers	Raw material
$S_2 > S_4 > S_5 > S_3 > S_1$	Meat
$S_7 > S_8 > S_6$	Chicken
$S_{10} > S_9 > S_7 > S_8$	Schnitzel
$S_{12} > S_{11} > S_{13}$	Rice
$S_{14} > S_{15} > S_{16}$	Fish
$S_{19} > S_{17} > S_{18}$	Tomato paste
$S_{20} > S_{21} > S_{22}$	Lemon juice
$S_{23} > S_{24} > S_{25}$	Tomato
$S_{26} > S_{28} > S_{27}$	Yoghurt

4-4. MOLP Model for Order Allocation

After prioritization of suppliers and calculation of supplier importance in raw materials, the proposed mathematical model has been solved by goal programming method and Lingo software. The proposed model will turn into the following model to solve the multi-objective model by goal programming method:

$$\min Z = W_1(d_1^+ + d_1^-) + W_2(d_2^+ + d_2^-) + W_3(d_3^+ + d_3^-)$$

$$s.t:$$

$$TC - d_1^+ + d_1^+ = g_1$$

$$TV - d_2^+ + d_2^+ = g_2$$

$$L - d_3^+ + d_3^+ = g_3$$

$$d_1^+, d_1^-, d_2^+, d_2^-, d_3^+, d_3^- \geq 0$$

$$and (4) to (10)$$

In the case study, we have: $w_1 = w_2 = w_3$, $g_1 = 20000000000, g_2 = 421065, g_3 = 0$. By solving the mathematical model, the optimal order allocation to each supplier of any raw materials was specified, and the best solution was determined for order allocation. In the optimal solution, the objective function values are 25801550000, 4117365, and 0, respectively. The value of unmet demand is zero regarding the optimal solution, but cost and value of purchasing from desirable suppliers have a deviation from the goals. Table 9 shows the value of purchasing raw materials from each supplier.

5. Conclusion

One of the important competitive factors in the organizations is supply chain management which includes different activities. In the initial steps, supplier selection process is very important, which its goal is a selection of the best supplier. In this article, supplier selection problem has been considered with several suppliers and raw materials. The proposed integrated method is composed of analytic hierarchy process, fuzzy TOPSIS, and integer programming model. Supplier selection criteria were obtained after interviewing with industry experts. These criteria were different about the selection of each type of raw material. This model was applied in Green Service Food Company to evaluate the proposed model and its results were expressed. This study is an integrated approach to green supplier selection and order allocation problem in order to improve initiatives of green supply chain management.

Tab. 9. The order allocation of raw material from the suppliers

Supplier	Meat	Chicken	Schnitzel	Rice	Fish	Tomato paste	Lemon juice	Tomato	Yoghurt
s2	5184000								
s3	9764000								
s5	7500000								
s7		2392200	1696500						
s8		6951900	1992700						
s9			2550000						
s10			4040000						
s11				1519900					
s14					5819000				
s15					1122000				
s16					9000000				
s17						4500000			
s18						6290000			
s19						7680000			
s20							9270000		
s22							1350000		
s24								1880200	
s25								3000000	
s26									2370340
s28									1064930

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