A Fuzzy Supplier Selection Model considering Social Responsibility in Supply Chain

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Abstract

Due to high importance of supplier selection in supply chain management issues and also taking into consideration the fact that organizations are giving more and more attention to their responsibilities in the society; this paper considers supplier selection as a multi-objective decision making problem. It inserts social responsibility (SR) parameter into the model and ensures that specification of each supplier's allocated quota from a total order uses such criterion. In supplier selection problem, objectives such as cost minimization, quality maximization and on-time delivery maximization have been generally studied. In order to effectively consider SR, we also take note of other objectives such as suppliers' SR maximization, distance minimization, etc. Due to its linear dependency property, SR observance by the suppliers can lead to higher quality level (products and services) and on-time delivery. Thus the proposed approach also incorporates quality and on-time delivery objectives into SR parameter. Furthermore, it uses a triangular fuzzy number regarding uncertainty and ambiguity in the SR observance level at the end of each period. On top of a mathematical model for a multi-product structure, numerical examples that employ fuzzy multi objective decision making method, are presented so as to justify the approach as well as its values.

Keywords: Supply Chain Management, Social Responsibility, Supplier Selection, fuzzy multi objective decision making

1. Introduction

In recent years the concept of SR has been given a significant attention and the issue that for whom or what organizations are responsible has become very important. Based on ISO26000 international standard (2010), the seven principles of SR can be expressed as: Accountability, Transparency, Ethical behavior, Respect for stakeholder interests, Respect for the rule of law, Respect for international norms of behavior and Respect for human rights. The core components of SR in this international standard consist of: Organizational governance, Human rights, Labor practices, The Environment, Fair operating practices, Consumer issues and Community involvement and development. In order to abide by SR, organizations have now social, economical, legal and environmental responsibilities on top of their traditional responsibility for their stakeholders. Nowadays supply chain management makes a fundamental basis for constitution of businesses in the world. In the global competition, various products should be available to customers in terms of their requirements, which are high quality of products and services, on-time delivery, fair price, observing environmental issues and being respectful to social subjects. This matter now leads to more pressure on organizations, something which was less felt in the past, if ever. Considering the complex nature of the issue, organizations are now forced to conduct surveillance and management tasks on external resources and external partner's production in addition to their own production and internal resources. It should, however, be emphasized that such activities help organizations to achieve and maintain their competitive advantage in the market. As the supply chains emerge in the society and efforts for gaining profit consumes social resources, observing all or at least a part of their social responsibilities can support the strategic and functional interrelationship among supply chain members. Observance of SR by suppliers will become more important in supply chain management while they are evaluated not only by common criteria such as cost, quality and on-time delivery but also by observance of SR criterion before being selected as partners in a chain. Although great efforts have been made to develop a clear definition for corporate social responsibility (CSR or simply SR), there is still no standard definition for the concept and global organizations give different definitions. Dahlsrud (2008) gathered and presented different definitions of SR in his research. In the last decade, SR has become an important issue for organizations from business point of view and the field of SR has increasingly developed. There are too many organizations that decidedly tried to employ the principles of SR or CSR in all aspects of their business. World Business Council for Sustainable Development (WBCSD) defines SR as “Business’ commitment to contribute to sustainable economic development, working with employees, their families, the local community, and larger associations of the society in order to improve the quality of life.” Business for Social Responsibility (BSR) defines SR as “Achieving commercial success in ways that honor ethical values and respect people, communities, and the natural environment.” The International Chamber of Commerce (ICC) maintains that SR is the voluntary commitment by business to manage its activities in a responsible way. The American Society for Quality (ASQ) defines social responsibility as “people and organizations behaving and conducting business ethically and with sensitivity toward social, cultural, economic, and environmental issues. Striving for SR helps individuals, organizations and governments have a positive impact on development of business, and society”. ISO 26000 International standard (2010) defines SR as “responsibility of an organization for the impacts of its decisions and activities on society and the environment, through transparent and ethical behavior that

- Contributes to sustainable development, including health and the welfare of society.
- Takes into account the expectations of stakeholders.
- Is in compliance with applicable law and consistent with international norms of behavior, and
- Is integrated throughout the organization and practiced in its relationships.

  Note that Activities include products, services and processes and Relationships refer to an organization's activities within its sphere of influence. ”

2. Literature Review

CarterandJennings (2002) surveyed the interrelationship among supply chain and social responsibility. They described the challenges of purchasing managers having social responsibility and the potential effects that observing social responsibility, may have on supply chain. Their findings indicate that observing social responsibility has direct and positive influence on supplier performances. Levis (2006) has surveyed acceptance of CSR instructions by multinational corporations. In this research it is noticed that multinational corporations are increasingly advertising their commitment to CSR and informing others about the instructions. Heslinand Ochoa (2008)presented seven strategic CSR principles including 1-cultivate the needed talent 2- develop new markets 3- protect labor welfare 4- reduce your environmental footprint 5- profit from by-products 6- involve customers 7- green your supply chain. O’Connor and Spangenberg (2008) presented a methodology for reporting CSR. Galbreath (2008) presented the procedure of creation of CSR as a part of organization’s strategy. Cruz (2008) developed a dynamic framework for the modeling and analysis of supply chain networks with CSR through integrated environmental decision-making considering profit maximization, and pollution and risk minimization. Cruzand Wakolbinger (2008) surveyed multi-level effects of CSR on supply chain networks, trade costs, emissions, and supply chain risk. Hsuehand Chang (2008) presented equilibrium analysis and CSR for supply chain integration. Results of this research cleared that, while taking social responsibility by organization, total profit of supply chain would increase with or without cooperation. Dahlsrud (2008) gathered 37 definitions of CSR in the appendix of his paper. Teraji (2009) presented a model for organization’s social performance related to social consent and moral behavior. In this paper, organization’s social performance is discussed noting customers and managers. Holmqvist (2009) presented CSR as a social control of organization. Cruzand Matsypura (2009) developed a framework for modeling and analysis of supply chain network with CSR through integrated environmental decision making. They presented multi-criteria decision making behavior of different decision makers (i.e. suppliers, producers, assemblers, distributors, retailers and customers) that consists of maximization of network returns, minimization of emissions (waste), and risk. Lin*et al*. (2009) surveyed CSR effects on financial performance of organization. Cruz (2009) surveyed influence of CSR on supply chain management that has multi-criteria decision making approach. Debing&

Li (2010) surveyed allocation of SR in two echelon supply chain. Kabir (2011) studied CSR activities of hotel industry of Switzerland. The results of his survey shows that organizations tend to engage in SR activities in order to build a better and more acceptable organizational image and to become social organizations. Pop *et al.*(2011) surveyed promotion of CSR in green economy and creative careers. Beatrice Kogg and Oksana Mont (2012) studied environmental and social responsibility in supply chains and presented the practice of choice and inter-organizational management in their survey. Cruz J. M. (2013) developed a framework for the modeling and analysis of a complex global supply chain network with CSR through integrated environmental decision-making and risk management. Croom*et al*. (2000) presented an analytic framework for critical literature review in supply chain. Ghodsypour*et al*. (2001) offered a model for contemplating total cost of logistics in supplier selection under conditions of multiple sourcing, multiple criteria and capacity constraint. Tan (2001) presented a framework for supply chain management literature, with two strategic and holistic approaches. This research discusses strategies of supply chain management and circumstances that lead to supply chain management. De Boer *et al*. (2001) presented a review of methods supporting supplier selection in which different decision making methods are cited. Kouvelis*et al*.(2006) reviewed the researches and the procedures in supply chain management. In this paper he studied books and researches on supply chain management from 1992 to 2006. Chen *et al*. (2006) suggested a fuzzy method for evaluating and choosing suppliers in supply chain management. They presented a fuzzy decision making method for the issue of choosing suppliers in supply chain system. Amid *et al*. (2006) presented a fuzzy multi-objective linear model for supplier selection in a supply chain. Amid *et al*. (2009) suggested a weighted fuzzy multi-objective model for the supplier selection problem under price breaks in a supply Chain. Giunipero*et al*. (2008) surveyed the concepts of literature of supply chain historically in the past, present, and future. Ko*et al*. (2010) reviewed the soft computing applications in supply chain management. They presented different techniques of soft computing such as fuzzy logic and genetic algorithm in developing efficiency and effectiveness of different issues of supply chain management. Boran*et al*. (2009) presented a multi-criteria intuitive fuzzy group decision making for supplier selection with TOPSIS method. Lee *et al*. (2009) presented a green supplier selection model for high-tech industries. Wang (2010) presented a fuzzy linguistic computing approach to supplier evaluation. Ho *et al*. (2010) reviewed Multi-criteria decision making approaches for supplier evaluation and selection. They analyzed the related papers from 2000 to 2008.Kilincci&Onal(2011) presented an AHP fuzzy method for supplier selection in a laundry machine producer organization. Amin *et al.*(2011) surveyed supplier selection and order allocation on the basis of analytical fuzzy SWOT and fuzzy linear programming. Feng*et al.*(2011) presented a decision making method for supplier selection in multi-service outsourcing. Amid *et al.*(2011) studied a weighted max-min model for fuzzy multi-objective supplier selection in a supply chain. Pishvaee *et al.* (2012)presented a robust possibilistic programming for socially responsible supply chain network design. They considered cost and CSR objectives, and demand and capacity constraint. Cruz (2013) studied the relationship of globalized supply chain and CSR. He measured the impact of globalization on supply chains' CSR decision-making and analyzed the effects of CSR on price, product-flow and the global supply chain efficiency and found that SR conscious global supply chain networks have more efficiency than others. Hsueh (2014) integrated CSR into a two-echelon supply chain consisting of a manufacturer and retailer. In this model, the manufacturer invests in CSR and charges the retailer a wholesale price; the retailer sells products and it returns a ratio of its revenue to the manufacturer. Mathematically, the model determines optimal CSR investment, wholesale price, and revenue sharing ratio so as to achieve channel coordination. Ağan *et al.* (2016) presented a research the aim of which is to deepen the understanding of environmental supplier development (ESD), through developments of suppliers to manufacturers for the purpose of environmental performance. CSRwas examined as the precedent of ESD in this research. Using a survey method, 314 responses were collected from Turkish manufacturing plants with more than 250 employees. The results indicated that CSR is positively related to ESD and that ESD has a positive influence on the financial performance and competitive advantage of the participating firms. Feng *et al.* (2017) developed a systematic study quantitatively depicting the knowledge structure and the intellectual progress of CSR for supply chain management (SCM). This research systematically evaluated the CSR-related publications for SCM. Key findings for researchers include "(1) an analytical discussion of the five sub-fields that constitute the intellectual structure of CSR for SCM; (2) Theoretical and conceptual research significantly dominate in this field; (3) The topics of sustainable development and economic and social effects are more frequently discussed among scholars; (4) Key research gaps include lacking of practical and normative modeling research, and considering from the supplier perspectives in emerging economies".

3. Problem Definition

Organization's strategy plays an important role in selecting suppliers since it can specify the objectives and also supplier selection and evaluation criteria. As such, suppliers which are capable of providing the organization with its requirements are specified and eventually some of them are selected through a ranking procedure. Quota is then allocated to each of them in such a way that the best one satisfies the objectives that are specified by the strategies. In this research, supplier selection is considered as a fuzzy multi-objective problem and observance level of SR (organizations generally acclaim it in percentage)is inserted into the model as a mathematical parameter. The proposed model aims to select and specify order quota of suppliers that not only satisfy common objectives of this relation but also maximizes the SR level of related suppliers.
In addition to formerly studied objectives such as cost minimization, quality maximization and maximization of on time delivery for supplier selection, this research incorporates a number of additional objectives such as maximization of supplier social responsibility, minimization of total distance to suppliers, and maximization of probability to purchase from domestic suppliers in order to create jobs (according to ISO26000 standard). This approach can lead to economic improvement of the society wherein buyer organization and suppliers are making the transactions. Constraints of demand and suppliers' capacity, as well as all the fundamental issues and observance of seven principles of SR by the organization are considered in SR observance parameter. Since SR observance linearly increases quality and on-time delivery level of organizations, we take care of this matter in the quality and the on-time delivery objective function. The presented model is linear programming, integer programming and in multi-product state. We assume that the buyer organization intends to buy from existing suppliers and also total demand is taken as constant and definite. Each supplier can provide all or a part of raw material that buyer organization requires. Production capacity of each supplier is taken limited, definite and constant for providing the buyer organization with its requirements. Considering the fact that in real world the expected level of SR of each supplier is ambiguous and introduced as linguistic phrases and that suppliers cannot report the exact and definite percentage of their SR observance and so on, level of SR observance of suppliers are taken as triangular fuzzy numbers. Since reporting level of SR observance of suppliers depends on such factors, it becomes easier to realize its indefinite nature. However, SR observance by the suppliers can lead to improve organization's performance regarding its internal procedures. Performance improvement may consist of improvement in the performance of product quality as well as on-time delivery of demanded items. Jennings and Carter (2002) survey shows that social responsibility observance is linearly related to performance improvement of product quality and on-time delivery. In our research, evaluation and selection of suppliers is done during a specific period of time. Each supplier has its own initial performance regarding quality level and on-time delivery percentage. SR observance by the suppliers is one of the important factors that can linearly increase the performance of these two subjects. As SR observance increases quality level and on-time delivery to a certain amount and that there are other factors influencing these parameters, their maximum increment percentage are bound in terms of experts' viewpoint and are represented by parameters β and γ. This means that β and γ are the maximum amount of increment for quality level and on-time delivery. For example, suppose a supplier has a product quality level of seventy percent in a survey time and based on expert's option, its maximum increment of quality level could be fifty percent higher if SR is fully observed. This implies that β would increase fifty percent during the remaining thirty percent quality level phase and could result in a total product quality level of eighty five percent for this supplier under full SR observance. In the absence of full observance, linear relation between SR observance and quality level can beused to extract its exact total amount.

3.1. Parameters and Variables

i :Supplier index

j :Product index

k :Objective function index

D_j : Demand for product j

C_{ij}: Production capacity of supplier i for product j

F_{ij}: Percentage of on time delivery of product j by supplier i

Q_{ij}: Percentage of quality level of product j provided by supplier i

P_{ij} : Unit cost of product j provided by supplier i

n: Number of suppliers

f_i :Distance of supplier i from the buyer organization

T_{ij} : Unit cost of shipment of product j of supplier i in distance unit

α_i^0 : Initial level of CSR of supplier *i* (at the beginning of the period)
$\tilde{\alpha}_i^1$: Final level of fuzzy CSR for supplier *i* (at the end of the period)
β_{ij} : Maximum percentage of increase in F_{ij} regarding fuzzy CSR for supplier i at the end of the period (with due regard to experts)
γ_{ij} : Maximum percentage of increase in Q_{ij} regarding fuzzy CSR for supplier i at the end of the period (with due regard to experts)
μ_k: Importance scale of objective function k
I:Utility of supplying raw materials from domestic suppliers
E:Utility of supplying raw materials from external suppliers
O_i :Cost of ordering to and cooperating with supplier i
$K_i : \begin{cases} 1 & \text{supplier i is domestic} \\ 0 & \text{otherwise} \end{cases}$
$0 \le \alpha_i^0 < 1$
$0 \le \tilde{\alpha}_i^1 \le 1$
$Y_i : \begin{cases} 1 & \text{supplier i is selected} \\ 0 & \text{otherwise} \end{cases}$
X_{ij} : amount of allocated order of product j to supplier i

3.2. Mathematical Formulation

$$Z_1 = \sum_{i=1}^{n}\sum_{j=1}^{m} P_{ij}X_{ij} + \sum_{i=1}^{n} O_iY_i + \sum_{i=1}^{n}\sum_{j=1}^{m}(f_iT_{ij})X_{ij} \quad (1)$$

$$Z_2 = \sum_{i=1}^{n}\sum_{j=1}^{m}[(\left(\frac{\gamma_{ij}(\tilde{\alpha}_i^1-\alpha_i^0)}{(1-\alpha_i^0)}\right)(1-Q_{ij})) + Q_{ij}]\,X_{ij} \quad (2)$$

$$Z_3 = \sum_{i=1}^{n}\sum_{j=1}^{m}[(\left(\frac{\beta_{ij}(\tilde{\alpha}_i^1-\alpha_i^0)}{(1-\alpha_i^0)}\right)(1-F_{ij})) + F_{ij}]\,X_{ij} \quad (3)$$

$$Z_4 = \sum_{i=1}^{n} IK_iY_i + \sum_{i=1}^{n} E(1-K_i)Y_i \quad (4)$$

$$Z_5 = \sum_{i=1}^{n}\sum_{j=1}^{m} \tilde{\alpha}_i^1 X_{ij} \quad (5)$$

$$Z_6 = \sum_{i=1}^{n} f_iY_i \quad (6)$$

s.t.

$$X_{ij} \le C_{ij} \times Y_i \quad (7)$$

$$\sum_{i=1}^{n} x_{ij} = D_j \quad (8)$$

$$X_{ij} \ge 0 \quad (9)$$

$$Y_i : \begin{cases} 1 & \text{supplier i is selected} \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

Equation (1) gives all the costs of buying, ordering and shipment of products, i.e., its first term is sum total cost of buying products from suppliers, the second term is sum total cost of ordering to all the suppliers and the third term is sum total cost of product shipment from suppliers; this objective function is to be minimized. Equation (2) is the sum total percentage products quality level that is bought from suppliers. According to the equation above, if the supplier i reaches to maximum level of SR observance that is ($\tilde{\alpha}_i^1 = 1$) then percentage of current quality level of product j that is bought from this supplier will at most increase to [$\gamma_{ij}(1 - Q_{ij})$+Q_{ij}]. This objective function is to be maximized. Equation (3) is the sum total percentage of products on-time delivery level that is bought from suppliers. Based on the above equation, if the supplier i reaches to maximum level of SR observance that is ($\tilde{\alpha}_i^1 = 1$) then percentage of current on-time delivery level of product j that is bought from this supplier will at most increase to [$\beta_{ij}(1 - F_{ij}) + F_{ij}$],this objective function is to be maximized. Equation (4) is the sum total utility of buying products from domestic and external suppliers. In this objective function we have E<I and it is in accordance with the SR of the organization and helps create jobs and increase employment rate; this objective function is considered

maximum. Equation (5) is the weighted sum total of suppliers' expected SR observance at the end of the period that is considered according to buying amount from suppliers. SR observance consists of all the principles and fundamental issues that is presented in ISO26000 international standard, this objective function is to be maximized. Equation (6) is the sum total distance of buyer organization from suppliers. Minimizing the selected supplier's distances to the buyer organization can reduce the fuel consumption amount for transportation and environmental pollution, which implies observance of environmental issues, reduction of global warming and reduction of fossil fuel consumption which are some of most important subjects of CSR. Constraint (7) gives limitation of production capacity of product j by the supplier i. If a supplier is chosen, it means (Y_i =1), then the amount of product j that is allocated to this supplier is at best up to its production capacity. Constraint (8) gives limitation of demand for the product j. Constraint (9) gives positive state of variable X. Constraint (10) gives state of variable Y. If a supplier is chosen, it means (Y_i =1), otherwise (Y_i =0).

4. Resolution Methods

We use two different approaches to convert fuzzy numbers into non-fuzzy numbers for solving this mathematical programming model. In the first approach, fuzzy coefficient is converted into crisp coefficient by using average method and then the problem is solved by L-P Metric method. In the second approach, we use fuzzy approach for converting (conversion of a fuzzy objective function into several crisp objective functions) and then the problem is solved by using min-max method.

4.1. Average Method - Triangular Fuzzy Numbers

Fuzzy number is a fuzzy set $\tilde{A}$ on real numbers if the following clauses are confirmed:

$\tilde{A}$ is a normal fuzzy set.

A_α should be a closed bound on each value of(α ∈ (0, 1]).

Supporting set for $\tilde{A}$ should be limited.

Triangular fuzzy numbers (a, b, c) are fuzzy numbers that have membership function as equation (11)

$$\begin{cases} \frac{x-a}{b-a} & a \le x \le b \\ 1 & x = b \\ \frac{c-x}{c-b} & b \le x \le c \end{cases} \tag{11}$$

General form of linear programming model with fuzzy coefficients for objective function variables is shown in equation (12).

$$\max z = \tilde{C}x \tag{12}$$

s.t.

$$AX \le b \tag{13}$$

$$X \ge 0 \tag{14}$$

If $\tilde{C}$ is defined as triangular fuzzy number $\tilde{C} = (C^p, C^m, C^o)$ then its fuzzy programming model will be as equation (15).

$$\max z = \sum_{j=1}^{n} (C^p, C^m, C^o) x_j \tag{15}$$

s.t.

$$AX \le b \tag{16}$$

$$X \ge 0 \tag{17}$$

According to average method, fuzzy numbers are converted to crisp numbers by equation (18) and programming problem with fuzzy coefficients is converted to programming problem with crisp coefficients.

$$C = \frac{C^p + 4C^m + C^o}{6} \tag{18}$$

4.2. Fuzzy Approach

In this method if the coefficients of fuzzy objective function is assumed as triangular fuzzy numbers $\tilde{C} = (C^p, C^m, C^o)$ and the objective function is maximum, then the objective function will be as equation (19).

$$max\, z = (C^p, C^m, C^o)X \quad (19)$$

In such condition, we maximize the value of $(C^m X)$, minimize the value of $((C^m - C^p)X)$ and maximize the value of $((C^o - C^m)X)$, so the objective function of equation (18) with triangular fuzzy numbers is converted to three objective functions with crisp coefficients as equations (20), (21), (22).

$$min\, Z_1 = (C^m - C^p)X \quad (20)$$

$$maxZ_2 = C^m X \quad (21)$$

$$max\, Z_3 = (C^o - C^m)X \quad (22)$$

If the objective function is minimization then the objective function will be as equation (23).

$$min\, z = (C^p, C^m, C^o)X \quad (23)$$

We minimize the value of $(C^m X)$, maximize the value of $((C^m - C^p)X)$ and minimize the value of $((C^o - C^m)X)$, so the objective function of equation (23) with triangular fuzzy numbers is converted to three objective functions with crisp coefficients as equations (24), (25), (26).

$$max\, Z_1 = (C^m - C^p)X \quad (24)$$

$$minZ_2 = C^m X \quad (25)$$

$$min\, Z_3 = (C^o - C^m)X \quad (26)$$

The problem is then solved by min-max approach. In this approach we turn all the objective functions to minimum form, contemplate the ideal value for each of them and then solve the problem by minimizing maximum of functions. Naturally to non-scale the functions, we are better off to contemplate the ideal for each of them.

5. Numerical Example

As shown in Table (1) we aim to provide three products from four suppliers among which, three are domestic S_1, S_2, S_3 (K_1=K_2=K_3=1) and one is external S_4 (K_4=0). We are supposed to select the suppliers and allocate quota of each product to them. It is assumed that supplier one can supply product type one and three, supplier two can supply product type two and three, supplier three can supply all three types of product and supplier four can supply product type one and two. It is further assumed that total demand amount for product one is 350 units, for product two 250 units, and for product three 300 units. Parameters I=1 and E=0.3 are considered for utility of domestic and external suppliers.$\beta_{ij}$and $\gamma_{ij}$are regarding the observance level of SR and experts opinion assumed to be fifty percent on $\beta_{ij}$and sixty percent on γ_{ij}.

Table1. Parameters value

Param.	i, j	1	2	3
C_{ij}	1	400	0	200
	2	0	250	75
	3	150	200	350
	4	250	200	0
F_{ij}	1	0.6	0	0.5
	2	0	0.7	0.55
	3	0.6	0.45	0.6
	4	0.4	0.7	0
Q_{ij}	1	0.6	0	0.4
	2	0	0.5	0.6
	3	0.55	0.6	0.5
	4	0.7	0.45	0
P_{ij}	1	170	0	200
	2	0	180	200
	3	180	150	250
	4	200	150	0

T_{ij}	1	150	0		150
	2	0	150		200
	3	200	150		200
	4	150	150		0
β_{ij}	1	0.5	0		0.5
	2	0	0.5		0.5
	3	0.5	0.5		0.5
	4	0.5	0.5		0
γ_{ij}	1	0.6	0		0.6
	2	0	0.6		0.6
	3	0.6	0.6		0.6
	4	0.6	0.6		0
Param.	i		Param.	i	
O_i	1	500	f_i	1	250
	2	500		2	200
	3	600		3	200
	4	1500		4	2000
α_i^0	1	0.7	$\tilde{\alpha}_i^1$	1	(0.6, 0.9,0.97)
	2	0.2		2	(0.3, 0.5,0.7)
	3	0.5		3	(0.6, 0.8,0.95)
	4	0.6		4	(0.5, 0.75,0.95)

5.1. Solving by Average Method

By using equation (18) we converted objective functions with fuzzy coefficients to objective functions with crisp coefficients. The problem is solved after converting objective functions with fuzzy coefficients to objective functions with crisp coefficients by means of L-P metric method. In this approach, each objective function is initially solved without taking other objective functions into consideration and the optimum value for each of objective functions is obtained. Under such condition, the values of Z_1^*, Z_2^*, Z_3^*, Z_4^*, Z_5^*, Z_6^* are also obtained. Consequently, by using equations (27) and (28) we contemplate the values of variables and objective functions.

$$\text{Min } U = \left\{\sum_{k=1}^{l} \mu_k \left[\frac{Z_k^* - Z_k}{Z_k^*}\right]^p\right\}^{1/p} \quad if \quad Z \to max\, Z \tag{27}$$

$$\text{Min } U = \left\{\sum_{k=1}^{l} \mu_k \left[\frac{Z_k - Z_k^*}{Z_k^*}\right]^p\right\}^{1/p} \quad if \quad Z \to min\, Z \tag{28}$$

The problem was solved by LINGO8 and the obtained values for Z_1^*, Z_2^*, Z_3^*, Z_4^*, Z_5^*, Z_6^* are presented in Table (2).

Table2.Optimum values of each objective functions

Z_1^*	Z_2^*	Z_3^*	Z_4^*	Z_5^*	Z_6^*
32286350	648.925	655.7	3.3	747.9	650

To obtain an answer for decision making and also for simplicity, we assumed values of μ_k and p to be equal to one. The problem is solved by LINGO8 and the obtained results are presented in Table (3). In Table (4) the results are compared with their ideal values.

Table3.Obtained results

$\mathbf{x_{11}} = 350$	$\mathbf{x_{13}} = 0$	$\mathbf{x_{22}} = 50$	$\mathbf{x_{23}} = 0$	$\mathbf{x_{31}} = 0$	$\mathbf{x_{42}} = 0$	$\mathbf{x_{32}} = 200$	$\mathbf{x_{33}} = 300$	$\mathbf{x_{41}} = 0$
$\mathbf{y_1} = 1$	$\mathbf{y_2} = 1$	$\mathbf{y_3} = 1$	$\mathbf{y_4} = 0$					
$\mathbf{U}^* = 0.21$								

As can be observed from Table 3, suppliers 1,2 and 3 are selected and 350 units of product one is provided by supplier one and 50 units of product two is provided by supplier two and 200 units of product two is provided by supplier three and 300 units of product three is provided by supplier three.

Table4.Compared results

Z_1^*	Z_2^*	Z_3^*	Z_4^*	Z_5^*	Z_6^*
32286350	648.925	655.7	3.3	747.9	650
Z_1	Z_2	Z_3	Z_4	Z_5	Z_6
32800100	633.3	725.9	3	721.85	650

5.2. Solving by Fuzzy Approach Method

In this approach, equations (19) to (26) are utilized to transform the problem into a multi-objective crisp one and solve the problem by min-max method. To carry out the process, each of the objective function is solved by LINGO8 without taking other objective functions into consideration. Table (5) shows obtained value of each objective function.

Table5.Optimum results of each objective function

Z_1^*	Z_{21}^*	Z_{22}^*	Z_{23}^*	Z_{31}^*	Z_{32}^*	Z_{33}^*	Z_4^*	Z_{51}^*	Z_{52}^*	Z_{53}^*	Z_6^*
32286350	77.8	651.9	94.35	65.85	661.55	81.65	3.3	190	772.5	163.75	650

Subsequently, the problem is converted to a single-objective one and solved by LINGO8. The obtained results are presented in Table (6).In Table (7) the results are compared with their ideal values.

Table6.Gained results

$x_{11} = 200$	$x_{13} = 200$	$x_{22} = 50$	$x_{23} = 0$	$x_{31} = 150$	$x_{32} = 200$	$x_{33} = 100$	$x_{41} = 0$	$x_{42} = 0$
$y_1 = 1$	$y_2 = 1$	$y_3 = 1$	$y_4 = 0$					
$\theta^* = 0$								

As can be observed from Table 6, suppliers 1,2, and 3 are selected and 200 units of product one and 200 units of product three is provided by supplier one and 50 units of product two is provided by supplier two and 150 units of product one and 200 units of product two and 100 units of product three is provided by supplier three.

Table7.Compared results

Z_1^*	Z_{21}^*	Z_{22}^*	Z_{23}^*	Z_{31}^*	Z_{32}^*	Z_{33}^*	Z_4^*	Z_{51}^*	Z_{52}^*	Z_{53}^*	Z_6^*
32286350	77.8	651.9	94.35	65.85	661.55	81.65	3.3	190	772.5	163.75	650
Z_1	Z_{21}	Z_{22}	Z_{23}	Z_{31}	Z_{32}	Z_{33}	Z_4	Z_{51}	Z_{52}	Z_{53}	Z_6
32666600	131.15	634.2	67.3	103.67	620.2	54.5	3	220	745	105.5	650

6. Conclusion

In the recent years, supplier selection and evaluation has become one of the most important issues in supply chain management and organizations have great concerns about CSR observance. This paper proposed a mathematical model that incorporates SR on top of other traditional parameters such as cost minimization, quality maximization, on-time delivery maximization, etc. A multi-objective model having six objective functions of cost, quality, on-time delivery, utility, SR and distance for suppliers, developed as a linear and integer programming, was presented. Selection of suppliers were carried out by minimizing their cost and distance objective functions and maximizing their quality, on-time delivery, utility and SR objective functions. Considering the mathematical complexity of the proposed model, we also demonstrated the selection process via numerical examples using our two different approaches for converting fuzzy numbers into non-fuzzy numbers. Although each conversion approach resulted in a different answer, something which is related to the fuzzy nature of the problem, both approaches selected suppliers that had higher SR under various states. In summary, this research not only integrated a very important social concept for supplier selection and evaluation, i.e., SR observance according ISO26000 standard, but also showed that such activity can even help organizations to achieve and maintain their competitive advantage in the market.

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