2nd International IFS Conference, Mersin, Turkey, 14–18 Oct. 2015
Notes on Intuitionistic Fuzzy Sets
ISSN 1310–4926
Vol. 21, 2015, No. 4, 69–75

Selection of vendor based on intuitionistic fuzzy linguistic hedges

Prabjot Kaur* and Madhumita Pal

Department of Mathematics, Birla Institute of Technology
Mesra, Ranchi, India
e-mail: tinderbox_fuzzy@yahoo.com

* Corresponding author

Abstract: Vendor selection problem is selection of a suitable vendor that performs optimally on various desired dimensions such as cost, quality, delivery and service. Individual vendors may have different performance characteristics for different dimensions, so selection of a suitable vendor is a tedious task with so many complex factors used for evaluation. In this paper we propose selection of vendor based on linguistic hedges under intuitionistic fuzzy environment. We propose intuitionistic fuzzy sets (IFS) to represent the data dimensions of various vendors and intuitionistic fuzzy hedges to modify the various dimensions to approximate values. Also hedges are compatible with IFS and IFS help decision makers to describe and character the fuzzy sets with another parameter called non-membership function. The above process ensures that vendors are carefully and systematically evaluated and are satisfactory suppliers. A numerical example illustrates our proposed methodology.
Keywords: Intuitionistic fuzzy set, Linguistic hedge.
AMS Classification: 03E72.

1 Introduction

Vendor selection problem are of two types: one in which a single vendor is selected by a single decision made by the decision maker. The second one being selecting more than one vendor and more than one decision is made for selection and order allocation. The advantage of single sourcing is in terms of a continuing relationship between a vendor and buyer (organization). With the advent of just-in-time (JIT) purchasing, strategies which call for ordering smaller lot-size are more practical and feasible [6]. With vendor rating system the single best source can be selected keeping in mind companies priorities, activities and competencies.

The first study on vendor/supplier selection was done by Dickson in the year 1966. Dickson in his study stated that there are 23 criteria on the basis of which the vendor is

selected. He rated and ranked the criteria on the information provided by 170 purchasing managers. Since then a number of literature reviews of criteria and various methodologies have been carried out (Weber et al. (1991), De Boer et al. (2001), William Ho et al. (2010), Om Pal et al. (2013)). Literature is rich in various methodologies for single sourcing supplier selection problem. Some are linear weighting method (Lamberson et al. 1976, Timmerman 1986, Wind and Robinson 1968)), Analytical Hierarchy Process (Narasimhan 1983, Hill and Nydick 1992)), Matrix method (Gregory 1986)). Although these approaches are very simple, they heavily depend on human judgment and proper scaling of criteria values [7]. The best way to evaluate the vendors by proper scaling of criteria can be done by fuzzy sets. The advantage of fuzzy sets is that it helps to characterize indetermination with respect to vendor rating context. Even more advantageous is IFS, they consider not only the degree of membership to a given set, but also the degree of rejection such that the sum of both values is less than one. In IFS, DM may provide his/her preferences with a degree of doubt in a more realistic form. IFS have found applications in many areas of research [8, 9, 12–14].

Guo, Qi and Zhao (2010) used intuitionistic fuzzy topsis to deal with supplier selection problem. Boran et al (2009) used multicriteria intuitionistic fuzzy group decision making for supplier selection with Topsis method. Shahrokhi et al. (2011) used a combination of intuitionistic fuzzy set and linear programming for supplier selection problem. Kaur (2014a) gave an intuitionistic fuzzy multiobjective approach to vendor selection problem and in another paper Kaur (2014b) triangular intuitionistic fuzzy number based approach for the vendor selection problem using analytical hierarchy process.

In our paper we propose to use a linear weighting method of intuitionistic fuzzy linguistic hedges. The uniqueness of the method lies in use of intuitionistic fuzzy sets, single sourcing in order to implement JIT strategy. The advantage of our approach is that from strategic point of view our suppliers are manageable and ideal for final choice of selection. To develop a vendor rating tool based on intuitionistic fuzzy sets.

This paper has been organized as follows: Section 2 gives a brief description of intuitionistic fuzzy sets. Section 3 the methodology of vendor selection problem. In Section 4 a numerical example illustrates our methodology and finally section 5 gives the results and conclusions.

2 Preliminaries

Intuitionistic fuzzy set theory is an extension of fuzzy set theory introduced by Atanassov in 1983 (see, e.g. [26]), which is a suitable way to deal with vagueness.

Definition 1: An intuitionistic fuzzy set (IFS, for short) A on a universe U is defined as an object of the following form: $A = \{ (x, \mu_A(x), \nu_A(x)) \mid x \in U\}$ where the functions $\mu_A : U \rightarrow [0, 1]$ and $\nu_A : U \rightarrow [0, 1]$ define the degree of membership and the degree of non-membership of the elements $x \in U$ in A, respectively, and for every $x \in U : 0 \leq \mu_A(x) + \nu_A(x) \leq 1$.

Definition 2: The value of $\pi_A(x) = 1 - \mu_A(x) - \nu_A(x)$ represents the degree of hesitation (or uncertainty) associated with the membership of elements $x \in U$ in IFS A. We call it intuitionistic fuzzy index of A with respect of element $x \in U$.

Definition 3: The concentration [15] of an intuitionistic fuzzy set A of the universe U, is denoted by CON (A) and is defined by $\mathrm{CON}(A) = \{x, \mu_{\mathrm{CON}(A)}(x), \nu_{\mathrm{CON}(A)}(x) \mid x \in U\}$ where

$$\mu_{\mathrm{CON(A)}}(x) = [\mu_A(x)]^2, \tag{1}$$

$$\nu_{\mathrm{CON(A)}}(x) = 1 - [1 - \nu_A(x)]^2, \tag{2}$$

i. e. the operation of concentration is defined by $\mathrm{CON}(A) = A^2$.

Definition 4: The dilation [15] of an intuitionistic fuzzy set A of the universe U, is denoted by DIL (A) and is defined by $\mathrm{DIL}(A) = \{x, \mu_{\mathrm{DIL}(A)}(x), \nu_{\mathrm{DIL}(A)}(x) \mid x \in U\}$, where

$$\mu_{\mathrm{DIL(A)}}(x) = [\mu_A(x)]^{1/2}, \tag{3}$$

$$\nu_{\mathrm{DIL(A)}}(x) = 1 - [1 - \nu_A(x)]^{1/2}. \tag{4}$$

In other words, dilation of an intuitionistic fuzzy set is defined by $\mathrm{DIL}(A) = A^{1/2}$.

Definition5: Let $\tilde{A} = (\mu, \nu)$ be an intuitionistic set, an accuracy function H (see [24]) of an intuitionistic fuzzy value can be represented as follows:

$$H(A) = [\mu_A(x) + \nu_A(x)]. \tag{5}$$

3 Methodology

Step 1: A list of possible vendors is compiled. A request for proposal or request for quotation is sent to vendors. The vendors are short listed with respect to criteria.

Step 2: The construction of membership and non-membership [27] is given as follows: Construct the membership and non-membership function for i^{th} vendor $\langle \mu_i, \nu_i \rangle$,

$$\mu_i, \nu_i \in [0, 1], \mu_i + \nu_i \leq 1,$$

$$\mu_i = \frac{f_i}{f_{max}} \tag{6}$$

$$\upsilon_i = \begin{cases} \frac{f_{\min} - f_i}{f_{max}}, f_{min} \geq f_i \\ 0, f_{min} < f_i \end{cases} \tag{7}$$

Step 3: Dilation and centralization for each criteria. We use concentrator on Price, Lead time and delivery because the lesser their values the better it is. In case of Quality, Technology and service we dilate their values because the more the value the better it is for selection of vendor. The Quantity is kept constant.

Step 4: How the decision of selecting the vendor is made. We use Chen and Tan's technique to find an evaluation function E to measure the degrees to which the alternative Mi satisfies and does not satisfy the decision-maker's requirement.

$$E(M_i) = ((\mu_{ij}, \nu_{ij}) \wedge (\mu_{ik}, \nu_{ik}) \wedge \ldots \wedge (\mu_{ip}, \nu_{ip})) \vee (\mu_{is}, \nu_{is}) \tag{8}$$

where $\wedge$ and $\vee$ denote the infimum operator and the supremum operator defined on

$$L^* = \{(a_1, a_2) \mid a_1, a_2 \in [0, 1], a_1 + a_2 \leq 1\},$$

resp., and $\mu_{Mi} = \max((\min(\mu_{ij}, \mu_{ik}, \ldots, \mu_{ip}), \mu_{is})$ and $\nu_{Mi} = \min((\max(\nu_{ij}, \nu_{ik}, \ldots, \nu_{ip}), \nu_{is})$.

Step 5: We use equation (5) to get a crisp ranking of vendors for final selection of vendors.

Step 6: By cluster analysis [30] we obtain two groups of vendors A and B.

4 Numerical example

Following [28], consider FBK Industries, a firm looking for a supplier to act as one of two sole source vendors for a commodity group from which the firm consumes random quantities of between 10,000 and 20,000 units per month, depending on demand. One vendor will be contracted for supply of items. At present ten potential suppliers have been identified, all with strong reputations in at least one area, FBK has identified the five rights as fundamental criteria for selecting vendors. In addition, the firm has determined that it is important for supplier firms to be advanced with information technology in order that ordering, billing, tracking, etc. might be streamlined, FBK also considers service and responsiveness a necessary criterion for its vendors, so that must also be incorporated into the decision. Hence, seven criteria are to be used in selecting a vendor. Table 1 summarizes the raw score data for the ten firms being considered for the sole-sourcing contract. The steps for evaluation and selection of vendors are as follows:

Vendor	Price	Quality	Lead time	Quantity	Delivery	Tech	Service
1	8.75	7	3	6	6	3	5
2	7.25	2	2	4	4	4	4
3	10.24	6	4	2	7	3	4
4	11.28	6	2	1	6	7	5
5	11.20	7	2	4	3	7	6
6	11.73	7	4	4	6	4	7
7	6	3	4	5	4	5	4
8	9.77	5	2	7	1	5	6
9	11.10	6	3	3	2	7	4
10	8.91	5	3	7	7	4	6

Table 1. Vendor data for FBK industries

Step 1: Using equations (6) and (7), we construct IFS (Table 2) for data given in Table 1.

Vendor	Price	Quality	Lead time	Quantity	Delivery	Tech	Service
1	(.746,.217)	(1, 0)	(.75,.125)	(.857,.07)	(.857,.071)	(.428,.357)	(.714,.214)
2	(.618,.345)	(.286,.643)	(.5,.25)	(.571,.357)	(.571,.357)	(.571,.214)	(.571,.357)
3	(.873,.094)	(.857,.071)	(1, 0)	(.286,.643)	(1, 0)	(.428,.357)	(.571,.357)
4	(.962,.001)	(.857,.071)	(.5,.25)	(.143,.786)	(.857,.071)	(1, 0)	(.714,.214)
5	(.955,.008)	(1, 0)	(.5,.25)	(.571,.357)	(.428,.5)	(1, 0)	(.857,.071)
6	(1, 0)	(1, 0)	(.25,.5)	(.571,.357)	(.857,.071)	(.571,.214)	(1, 0)
7	(.511,.452)	(.428,.5)	(1, 0)	(.714,.214)	(.571,.357)	(.714,.071)	(.571,.357)
8	(.833,.130)	(.714,.214)	(.5,.25)	(1, 0)	(.143,.786)	(.714,.071)	(.857,.071)
9	(.946,.017)	(.857,.071)	(.75,.125)	(.428,.5)	(.286,.643)	(1, 0)	(.571,.357)
10	(.759,.204)	(.714,.214)	(.75,.125)	(1, 0)	(1, 0)	(.571,.214)	(.857,.071)

Table 2. Intuitionistic fuzzy Score matrix

Step 2: To the matrix in Table 2 we apply concentrate/dilate operation on each criteria by using equations 1–4. Table 3 shows the scores of matrix after concentration and dilation.

Vendor	Price	Quality	Lead time	Quantity	Delivery	Tech	Service
1	(.556,.387)	(1, 0)	(.562,.234)	(.925,.198)	(.925,.036)	(.654, 0.198)	(.845,.113)
2	(.382,.571)	(.535,.402)	(.25,.437)	(.756,.113)	(.756,.198)	(.756,.113)	(.756, .198)
3	(.762,.179)	(.925,.036)	(1, 0)	(.534,.036)	(1, 0)	(.654, .198)	(.756, .198)
4	(.925,.001)	(.925,.036)	(.25,.437)	(.378, 0)	(.925,.036)	(1, 0)	(.845,.113)
5	(.912,..016)	(1, 0)	(.25,.437)	(.756,.113)	(.654,.293)	(1, 0)	(.925,.036)
6	(1, 0)	(1, 0)	(.0625, 0.75)	(.756,.113)	(.925,.036)	(.756,.113)	(1, 0)
7	(.261, 0.7)	(.654,.293)	(1, 0)	(.844,.115)	(.756,.198)	(.845,.036)	(.756,.198)
8	(.694,.243)	(.845,.113)	(.25,.437)	(1,.244)	(.378, .537)	(.845,.036)	(.925,.036)
9	(.895,.033)	(.925,.036)	(.562,.234)	(.654,.074)	(.535,.402)	(1, 0)	(.756,.198)
10	(.576,.366)	(.845,.113)	(.5625,.234)	(1, 0)	(1, 0)	(.756,.113)	(.925,.036)

Table 3.

Vendor	$E(M_i)$	$H(M_i)$
1	(.857,.07)	.927
2	(.571,.357)	.928
3	(.654,.198)	.852
4	(.25,.437)	.687
5	(.571,.357)	.928
6	(.571,.357)	.928
7	(.714, 0.214)	.928
8	(1, 0)	1
9	(.535,.402)	.937
10	(1, 0)	1

Table 4.

Step 3: The evaluation function $E(M_i)$ is obtained by using equation (8) and a crisp value for final evaluation and selection of vendor is obtained by equation (5).

Step 4: The largest value of $H(M_i)$ is selected for final vendor selection.

Step 5: By cluster analysis we obtain two clusters i. e cluster $A = \{v_1, v_2, v_7, v_8 \text{ and } v_{10}\}$ and cluster $B = \{v_3, v_4, v_5, v_6, v_9\}$.

5 Conclusions

Our approach of intuitionistic fuzzy linguistic hedges for selection of vendors main advantage being that linguistic hedges are compatible with IFS. The hedges are more to do with people's subjective judgment. The results show that vendor seems to be suitable for selection as single source of suppliers, though we found the ranking of 8^{th} and 10^{th} vendors as same and highest. The reason for two vendors getting highest ranking is due to thin profit margins, higher

expectation of quality products and short lead times. We select the vendor 10 because its cost is the lowest, quality is good enough, though not excellent, and best delivery time. In terms of service it is also very good. Again by cluster analysis we see vendors 8 and 10 fall in same cluster along with vendors 1, 2 and 7. The advantage of selecting vendor 10 is its best delivery status, good service and reasonable quality. Its lead time is same as vendor 8 and vendor 1. Others criteria rating are reasonable and company can make a decision for its selection as a single source. This paper can be further extended for a mathematical model and how much order allocation can be done for selected vendors.

Reference

[1] Om Pal, Amit Kumar Gupta, & R. K. Garg (2013) Supplier Selection Criteria and Methods in SupplyChains: A Review, *International Journal of Social, Management, Economics and Business Engineering*, 7(10).

[2] Ho, W. Xiaowei Xu & Prasanta K. Dey (2010) Multi-criteria decision making approaches for supplier evaluation and selection: A literature review, *European Journal of Operational Research*, 202, 16–24.

[3] Weber, C. A., J. R. Current &, W. C. Benton (1991) Vendor selection criteria and methods. *European Journal of Operational Research*, 50(1), 2–18.

[4] De Boer, L., E. Labro & P. Morlacchi (2001) A review of methods supporting supplier selection, *European Journal of Purchasing & Supply Management*, 7, 75–89.

[5] Dickson, G. W. (1966) An analysis of vendor selection system and decisions. *Journal of purchasing*, 2(1), 28–41.

[6] Soeini, R. A., L. Tashakor, J. T. Bafghi, M. Mokhtari, A. Vakili (2012) Supplier selection based on multiple criteria, *International Journal on New Computer Architectures and Their Applications*, 2(1), 258–273.

[7] Mendoza, A., E. Santiago & A. Ravi Ravindran (2008) A three phase multicriteria method to the supplier selection problem, *International Journal of Industrial Engineering*, 15(2), 195–210.

[8] Szmidt, E. & J. Kacprzyk (2001) Intuitionistic Fuzzy Sets in Some Medical Applications, *Notes on Intuitionistic Fuzzy Sets*, 7(4), 58–64.

[9] Kaur, P. & M. Deb (2015) An Intuitionistic Approach for Price Breaks in EOQ from Buyer's Perspective, *Applied Mathematical Sciences*, 9(71), 3511–3523.

[10] Kaur, P. (2014a) An Intuitionistic Fuzzy Multi-Objective Vendor Selection Problem, *Applied Mathematical Sciences*. 8(149), 7443–7452.

[11] Kaur, P. (2014b) Selection of Vendor Based on Intuitionistic Fuzzy Analytical Hierarchy Process, *Advances in Operations Research*, 2014b, Article ID 987690, 10 pages.

[12] Mukherjee, S. & K. Basu (2011) Solving intuitionistic fuzzy assignment problem by using similarity measures and score functions, *Int. J. Pure, Science Technology*, 2(1), 118.

[13] Wang, P. (2009) QoS-aware web services selection with intuitionistic fuzzy set under consumer's vague perception, *Expert Systems with Applications*, 36, 4460–4466.

[14] Boran, F. E. (2011) An integrated intuitionistic fuzzy multicriteria decision making method for facility location selection, *Mathematical and Computational Applications*, 16 (2), 487–496.

[15] Kumar De, S., R. Biswas & A. R. Roy (2000) Some operations on intuitionistic fuzzy sets, *Fuzzy Sets and Systems*, 114, 477–484.

[16] Lamberson, L. R., D. Diederivh, & J. Wuoriu (1976) Quantitative vendor evaluation, *J. of Purchasing and Materials Management*, 12, 19–28.

[17] Timmerman, E. (1986) An approach to vendor performance evaluation, J. of Purchasing and Materials Management, 22(4), 2–8.

[18] Wind, Y. & P. J. Robinson (1968) The determinants of vendor selection: The evaluation function approach, *J. of Purchasing and Materials Management*, 4(3), 29–41.

[19] Narsimhan, R. (1983) An analytical approach to supplier selection, J. *of Purchasing and Materials Management*, 19(4), 27–32.

[20] Nydick, R. L. & R. P. Hill (1992) Using the analytic hierarchy process to structure the supplier selection procedure, *J. of Purchasing and Materials Management*, 25(2), 31–36.

[21] Gregory, R. E. (1986) Source selection: A matrix approach, *J. of Purchasing and Materials Management*, 22(2), 24–29.

[22] Boran, F. E., S. Genc, M. Kurt & D. Akay (2009) A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method, *Expert Systems with Applications*, 36, 11363–11368.

[23] Shahrokhi, M., A. Bernard & H. Shidpour (2011) An integrated method using intuitionistic fuzzy set and linear programming for supplier selection problem, *Proc. of 18th IFAC World Congress Milano* (Italy) August 28 – September 2, 6391–6395.

[24] Hua-Wen Liu & Guo-Jun Wang (2007) Multi-criteria decision-making methods based on intuitionistic fuzzy sets, *European Journal of Operational Research*, 179, 220–233.

[25] Guo, Z., M. Qi & X. Zhao (2010) A new approach based on intuitionistic fuzzy set for selection of suppliers, *Proc. of 6th International Conference on Natural Computation* (ICNC 2010), 3715–3718.

[26] Atanassov, K. (1986) Intuitionistic fuzzy sets. *Fuzzy Sets and Systems*, 20, 87–96.

[27] Sotirova, E., A. Shannon, S. Sotirov & M. Krawczak (2014) Intuitionistic fuzzy estimation of the doctoral comprehensive examination, *Notes on Intuitionistic Fuzzy Sets*, 20(2), 119–125.

[28] Seydel, J. (2005) Supporting the paradigm shift in vendor selection: Multicriteria methods for sole sourcing. *Managerial Finance*, 31(3).

[29] Chen, S. M. & J. M. Tan (1994) Handling multi-criteria fuzzy decision-making problems based on vague set theory, *Fuzzy Sets and Systems*, 67(2), 163–172.

[30] Hartigan, J. A. (1975) *Clustering Algorithms*, Wiley.