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FOREWORD BY DEPUTY RECTOR OF RESEARCH, INDUSTRIAL LINKAGES & ALUMNI

Since 2018, the INSIGHT JOURNAL (IJ) from Universiti Teknologi MARA Cawangan Johor has come up with several biennial publications. Volume 1 and 2 debuted in 2018, followed by Volume 3 this year as well as Volume 4 with 19 published papers due to the great response from authors both in and out of UiTM. Through Insight Journal, lecturers have the ability to publish their research articles and opportunity to share their academic findings. Insight Journal is indexed in MyJurnal MCC and is now an international refereed journal with many international reviewers from prestigious universities appointed as its editorial review board members.

This volume 5 as well as volume 6 (which will be published in 2020) are special issues for the 6th International Accounting and Business Conference (IABC) 2019 held at Indonesia Banking School, Jakarta. The conference was jointly organized by the Universiti Teknologi MARA Cawangan Johor and the Indonesia Banking School Jakarta. Hence, the volumes focus mainly on the accounting and business research papers compiled from this conference, which was considered a huge success as over 66 full papers were presented.

Lastly, I would like to thank the Rector of UiTM Johor, Associate Professor Dr. Ahmad Naqiyuddin Bakar for his distinctive support, IJ Managing Editor for this issue Dr. Noriah Ismail, IJ Assistant Managing Editor, Fazdillah Md Kassim well as all the reviewers and editors who have contributed in the publication of this special issue.

Thank you.

ASSOCIATE PROF. DR. SAUNAH ZAINON
Deputy Rector of Research, Industrial Linkages & Alumni
Editor-in-Chief for INSIGHT Journal
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Fuzzy Simple Hierarchy Analysis for Supplier Selection Decision

T.Zamali[1], M. Y. Yassar [2], N.S.A Khadijah[3] and M.K. Rusnani[4]

[1]Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA Cawangan Johor
Segamat, Johor, Malaysia
zamalihj@uitm.edu.my

[2]Faculty of Computer and Mathematical Sciences
Universiti Teknologi Mara Cawangan Johor
Segamat, Johor, Malaysia

[3]Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA Cawangan Johor
Segamat, Johor, Malaysia

[4]Faculty of Computer and Mathematical Sciences
Universiti Teknologi MARA Cawangan Johor
Segamat, Johor, Malaysia

Abstract

Supplier selection problem usually involves so many ambiguity components and multi-criteria factors consideration towards achieving more precision decision. Different researchers have various approaches to overcome such problem concern. In this paper, the Fuzzy Simple Hierarchy Analysis (FSHA) was proposed to deal with the ambiguity or vague multi-criteria evaluation process which commonly exists in supplier selection decision. The technique is equipped with the linguistic variables, the so-called linguistic hedges (i.e., dilation and concentration) for decision-makers (DMs) to evaluate the criterion with ease and direct to the attributes based on their expertise and/or experiences. To show the applicability and practicality of the proposed method, the related hypothetical example was adopted. The calculation results show that the proposed method is highly beneficial and offers a unique advantage to deal with the diversified and too ill-defined in terms of input criterion. Therefore, a simple and systematic manner in evaluation process can be derived from the proposed method without loss any information.

Keywords: Fuzzy Simple Hierarchy Analysis (FSHA); Linguistic Hedge; Supplier Selection.

1. Introduction

Supplier selection is a decision-making process with the purpose of defining an order of preference among potential suppliers based on a set of evaluation criteria (Lima-Junior & Carpinetti, 2016). The process is often an overlooked issue in the procurement process that can possibly touch on effective organizations' performance. Heading into effective and trusted organizations, companies have to collaborate with outstanding suppliers that offer to provide materials in comparative excellent quality and affordable cost, and this may result in an established long-term partnership between organizations and supplier (Chang, Chang & Wu, 2011). The good cooperation between organization and supplier helps the organization to serve more customer as this can influence the revenue outcome in the long term (Lee, Chuang & Wu, 2013). Therefore, the importance of supplier selection is to determine the high potential supplier that will meet the organizations' needs consistently and helps to ensure the performance of organizations are high (Lin, 2012). Supplier selection can be influenced by a lot of factors or criteria that may help them choose the best options of supplier in order to help the sourcing process. Many criteria for supplier selection were reviewed and synthesized into small number of criteria which suit the characteristics and needs of the business to obtain greater benefits. (Sureeyatanapas et al, 2018). In other cases, some organizations become more dependent on their suppliers, resulted in poor decision making (Chan and Kumar, 2007). Some of the factors that become important in selecting the supplier are the legal, political and cultural process but not excluding the transportation problems, technologies, capacities of the production (Parkouhi & Ghadikolaei, 2017). Thus, in this decision-making process of choosing the best supplier, some criteria are important and need an evaluation.

Some studies propose using weightage on the criteria, and decisions are made based on the weightage given (Chang et al., 2011). Lima-Junior & Carpinetti (2016) suggested the multi-criteria decision making (MCDM), and it should involve the decision makers from various functional areas such as quality, logistics and product development that used to understand the priorities of the buyer company. A lot of studies have been made to identify the best criteria for supplier selection. Even though MCDM method has been applied in various situation and offers well solution, Tarmudi, Abdullah & Md Tap (2010) stated that multi-criteria solutions usually considered only positive aspects and the decision-making process are very critical. In 2012, Lin proposed a FANP which integrates FPP (Fuzzy Preference Programming) with ANP (Analytic Network Process) to identify top suppliers by considering the effects of interdependence among the selection criteria and to handle inconsistent and uncertain judgments. She found that the proposed method can handle effectively the dependence and effects under uncertainty and help firms monitor supplier without any interruption from human decision. A recent study by Abdullah et. al., (2018) was using ANP to weight on the sustainable development criteria. This method is a multi-criteria decision making method where interdependencies amongst many divers' criteria can be dealt with a network. A multi-criteria decision making techniques allow process automation and can bring efficiency and rationality to the decision-making process. Lima-Junior & Carpinetti (2016) developed a new multi-criteria decision making approach based on fuzzy QFD to aid the choice and weighting of criteria to be used in the supplier selection process. The proposed approach combines the fuzzy QFD procedure for weighting the criteria with a procedure for evaluating the difficulty of data collection to describe the criteria in the grid classification. The method helps the decision makers to choose the set of important things yet not so costly criteria to supplier selection.

Igoulalene et al, (2015) proposed two new fuzzy hybrid approaches for the strategic supplier selection problem. The first approach combines the fuzzy consensus-based possibility measure and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method. The second approach combines the fuzzy consensus-based neat

OWA and goal programming model. Both approaches use a CCSD model to compute the criteria weights by using strategic supplier selection problem and analyze the numerical results. They found a priori (TOPSIS) and progressive (GPSF) articulation of the stakeholder's preferences in order to offer satisfactory and legitimate solutions. Moreover, in 2018, Sureeyatanapas et al. extended the ability of TOPSIS method to be applicable even when the assessment data and/or the weight of criteria are uncertain and/or unavailable. This simple method facilitates and simplifies purchasing decisions under incomplete conditions, and it can be generalized to any cases of multiple criteria decision making. This method can be implemented to supplier selection problems and also capable of handling other selection problems. The finding of the research by Parkouhi and Ghadikolaei (2017) agree with Sureeyatanapas, where by using VlseKriterijuskaOptimizacija I KomoromisnoResenje (VIKOR) technique, they manage to exploit the grey method to solve vague problems and problems with incomplete information.

However, Banaeianet. al. (2018) found that Grey Relational Analysis (GRA) appears to be a preferred method in effectively handling imprecise criteria and supplier alternative data. As mentioned above, they have compared the three performances of the popular MCDM methods including TOPSIS, VIKOR and GRA when integrated with fuzzy sets to address concerns related to decision uncertainties. The result shows that fuzzy GRA has a better time complexity compared to the other two methods and generates the results in smaller number of steps and operations. Meanwhile, Tavana et al. (2016) chose to use a hybrid of ANFIS and ANN method in their research, due to believing it to work more precisely than a previous MLP-ANN method proposed by Golmohammadi. In their research, they used the feed-forward quality of both methods to provide a good predictive framework to make the decision making process in real life much easier. Researches by Chang et al. (2011) and Mirmousa and Dehnavi (2016) used the DEMATEL method to choose the most important criteria in selecting suppliers. However, these previous researches were not without problems. According to a review made by Simic, et al. (2017), some researchers who used DEA as their method encountered a few problems: the users of this method may mistake the input and output criteria, and the judgment of the criteria is subjective. This point is agreed by Parkouhi and Ghadikolaei (2017), who states that the experts who rated the criteria may have their own personal opinions on the matter.

There are a few more methods that can be used in solving supplier selection process. However, in this paper the Fuzzy Simple Hierarchy Analysis (FSHA) was proposed to deal with the vague multi-criteria evaluation process, which commonly exists in supplier selection decision making. To do so, this paper is structured as follows; Section 1 introduces and briefly discusses the literature reviews related to the supplier selection problems. Section 2 was to identify and briefly discuss the common problem facing by DMs in the decision-making process. Sections 3 and 4 both reviewed the theoretical background and methodology, and also the implementation of proposed method for illustration purposes, respectively. Finally, Section 5 contains the conclusions of this research.

2. Problem Identification

In supplier selection problems, one of the most common problems faced is the ambiguity or uncertainty that exists during the selection process. Many of the past researchers have faced this problem, and they have proposed many techniques to deal with the problem efficiently. However, the proposed techniques are quite complicated to use. In this research, the objective is to propose a simpler method to deal with the ambiguity. The proposed method is by using the Fuzzy Simple Hierarchy Analysis (FSHA) is to be used in the same problem to get the same findings. The method is also improved by equipping it with the linguistic variable approaches, which are the so-called linguistic hedges. The findings are expected to be the same as the previous researches, but with a simpler, systematic and easy to use technique without loss any information.

3. The Theoretical Concept and Methodology

3.1 Preliminaries

In this sub-section, the basic definitions and the theoretical of fuzzy sets and related concept will briefly elaborated and used throughout this paper and for reference purposes.

Definition 1 A fuzzy set *A* in a universe of discourse *X* is characterized by a membership function $\mu_A(x)$ that takes the values in the interval of [0,1]. It can be denoted as follows:

$$A = \{(\mu_A(x)/x);\ x \in X\}.$$

Definition 2 A fuzzy numbers *A* is a fuzzy subset in the universe of a real number ***R*** that is both convex and normal.

Definition 3 If $\tilde{A}$ is a fuzzy number and $a_\alpha^l > 0$ for $\alpha \in (0,1]$, then $\tilde{A}$ is called a positive fuzzy number.

Definition 4 A Triangular Fuzzy Number (TFN) $\tilde{A}$ can be defined by a triplet (a_1, a_2, a_3). The membership function $\mu_{\tilde{A}}(x)$ is defined as:

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

Definition 5 Let $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ be two triangular fuzzy numbers. If $\tilde{A} = \tilde{B}$, then $a_1 = b_1$, $a_2 = b_2$ and $a_3 = b_3$.

Definition 6 A linguistic hedges or a modifier is an operation that modifies the meaning of a term more generally, of a fuzzy set. If $\tilde{A}$ is a fuzzy set then the modifier *k* generates the (composite) term $\tilde{B} = k\left(\tilde{A}\right)$.

The modifier defined as

Concentration $\mu_{con(\tilde{A})}(a) = \left[\mu_{\tilde{A}}(a)\right]^{\alpha}$, where $\alpha > 1$ (2)

Dilation $\mu_{dil(\tilde{A})}(a) = \left[\mu_{\tilde{A}}(a)\right]^{1/\alpha}$, where $\alpha > 1$ (3)

Definition 7 The linguistic hedges and their approximate meanings are specifically classified as shown in Table 1.

Table 1 The hedge values of the specific concentration and dilation

Linguistic hedges	*Extremely Important (EI)*	*Very Important (VI)*	*Fairly important (FI)*	*Somewhat important (SI)*	*Less important (LI)*	*Between linguistic hedges*
Meaning	Intensify a fuzzy region	Contrast intensification	-	Contrast difussion	Dilate a fuzzy region	Intensify/ contrast/ dilate
Hedge values (α)	$[\mu_{EI}(x)]^3$	$[\mu_{VI}(x)]^2$	$[\mu_{FI}(x)]^1$	$[\mu_{FI}(x)]^{1/2}$	$[\mu_{FI}(x)]^{1/4}$	Between two hedges value range

Source: Cox (1994)

3.2 Fuzzy Simple Hierarchy Analysis-based Linguistic Hedges

In this study the mean of fuzzy numbers which is usually utilized in evaluation process have been ignore totally to representing the crisp values of each criterion. Here, we introduced the advantage of TFNs in linguistic variables to substitute this mean of fuzzy numbers which is believed more efficient and more representing the actual situations in terms of evaluation approaches. In addition, the linguistic hedge to derive the significant of the relative weights for each criterion has been equipped in the selection process from perspective of group DMs. For instance, the words such as 'extremely recommended', 'very recommended', 'slightly recommended', etc. have been used for rating purposes after the potential suppliers have submitted their quotation. Thus, the words such as 'extremely', 'very', 'slightly' are called linguistic hedges.

3.3 Methodology

To clarify our proposed methodology, the detail step-by-step analysis process was given as follows:

Step 1: Decomposing of actual problem was carried out in the hierarchy structure (see Figure 1) based on the criteria and its definition.

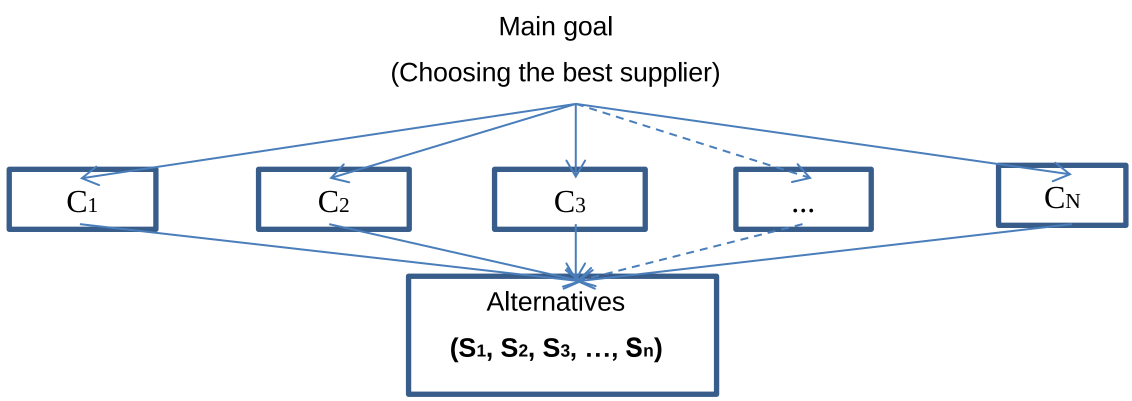

Figure 1 The hierarchy structure of the problem

Table 2 The Triangular Fuzzy Numbers (TFNs) and its linguistic variables, respectively

Linguistic variables	TFNs
Very poor (*VP*)	(0, 0, 0.1)
Poor (*P*)	(0, 0.1, 0.3)
Medium poor (*MP*)	(0.1, 0.3, 0.5)
Fair (*F*)	(0.3, 0.5, 0.7)
Medium good (*MG*)	(0.5, 0.7, 0.9)
Good (*G*)	(0.7, 0.9, 1.0)
Very good (*VG*)	(0.9, 1.0, 1.0)

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Step 2: Assign for each criterion based on DMs evaluation as respect each alternative using TFNs in Table 2. The performance scores $(\tilde{H})$ obtained as

$$\begin{array}{c} \\ \tilde{H} = \end{array} \begin{array}{c} \\ S_1 \\ S_2 \\ \ldots \\ \ldots. \\ S_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_1 & \ldots. & C_n \end{array} \\ \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \ldots & \tilde{a}_{2n} \\ \ldots. & .. & \ldots & \ldots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \ldots & \tilde{a}_{mn} \end{bmatrix} \end{array}, \tag{4}$$

where, C_i, (i = 1,2, 3, …., n) is number of criterion and S_i (i = 1,2,3, …, n) are number of an alternative (i.e., suppliers)

Step 3: Defuzzyfy $(\tilde{H}_D)$ for each vectors (a_{ij}) in fuzzy performance score using Chen (1996) based on TFNs given as

$$\tilde{H}_D = \frac{1}{4}\begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \ldots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \ldots & \tilde{a}_{2n} \\ \ldots. & .. & \ldots & \ldots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \ldots & \tilde{a}_{mn} \end{bmatrix}, \tag{5}$$

where

$$(a_{ij})_{m\times n} = \frac{1}{4}(a_1 + a_2 + a_2 + a_3)_{m\times n} \qquad (i = 1,2,3,\ldots,m;\ j = 1,2,3,\ldots,n)$$

Step 4: The power of dilation and/or concentration for each criterion was assigning based on DMs expertise/opinion/suggestions $(\tilde{H}_A^{\alpha})$ given as

$$\tilde{H}_D^{\alpha} = \begin{bmatrix} \begin{pmatrix} \mu_{11}(a) \\ \mu_{12}(a) \\ \ldots\ldots \\ \mu_{1n}(a) \end{pmatrix}^{\alpha_1} \begin{pmatrix} \mu_{12}(a) \\ \mu_{22}(a) \\ \ldots\ldots \\ \mu_{2n}(a) \end{pmatrix}^{\alpha_2} \begin{pmatrix} \ldots\ldots \\ \ldots\ldots. \\ \ldots\ldots. \\ \ldots\ldots.. \end{pmatrix}^{\alpha_{n-1}} \begin{pmatrix} \mu_{1n}(a) \\ \mu_{2n}(a) \\ \ldots\ldots\ldots \\ \mu_{m\times n}(a) \end{pmatrix}^{\alpha_n} \end{bmatrix}, \tag{6}$$

Step 5: The operator of maximin for overall criteria in descending order was employed to choose the best alternative given as

$$\mu_{H_D^{\alpha}}(S_i) = \max_i \left(\min_j \mu_{ij}^{\alpha_j} \right) \tag{7}$$

4. Implementation

In this section a case study from Mansini et al. (2012) was adopted. The evaluation was carried out based on six criteria; $C_1 \approx$ quality and technology, $C_2 \approx$ price and cost, $C_3 \approx$ supply time, $C_4 \approx$ service level, $C_5 \approx$ innovation and agility, and $C_6 \approx$ logistics and information. There are five potential suppliers (S_i, i = 1,2,3,4,5) have consider in the final stage after initial screening made thoroughly. Next, all four DMs involved evaluate the importance of each criterion based on his/her expertise/opinion (*see* Table 4). The evaluations are based on the raw input datasets using linguistic variables and quantify by TFNs as define in Table 2.

Table 3 The **raw input datasets four six criteria**

Alternative/Criteria	C_1	C_2	C_3	C_4	C_5	C_6
S_1	*G*	*G*	*VG*	*G*	*MG*	*G*
S_2	*G*	*VG*	*VG*	*G*	*VG*	*VG*
S_3	*VG*	*G*	*VG*	*G*	*G*	*G*
S_4	*MG*	*G*	*VG*	*G*	*G*	*G*
S_5	*F*	*G*	*G*	*F*	*VG*	*VG*

Here, we provide the step-by-step procedures as follows:

Step 1: Decompose the actual problem in the hierarchy structure similar in Figure 1.

Step 2: Assign for each criterion based on DMs evaluation as respect to each criterion.

Here, we obtain the overall performance scores $(\tilde{H})$ using Eq. (4) as,

$$\tilde{H} = \begin{bmatrix} (0.7,0.9,1.0) & (0.7,0.91.0) & (0.9,1.0,1.0) & (0.7,0.9,1.0) & (0.5,0.7,0.9) & (0.7,0.9,1.0) \\ (0.7,0.9,1.0) & (0.9,1.0,1.0) & (0.9,1.0,1.0) & (0.7,0.9,1.0) & (0.9,1.0,1.0) & (0.9,1.0,1.0) \\ (0.9,1.0,1.0) & (0.7,0.9,1.0) & (0.9,1.0,1.0) & (0.7,0.9,1.0) & (0.7,0.9,1.0) & (0.7,0.9,1.0) \\ (0.5,0.7,0.9) & (0.7,0.9,1.0) & (0.9,1.0,1.0) & (0.7,0.9,1.0) & (0.7,0.9,1.0) & (0.7,0.9,1.0) \\ (0.3,0.5,0.7) & (0.7,0.9,1.0) & (0.7,0.9,1.0) & (0.3,0.5,0.7) & (0.9,1.0,1.0) & (0.9,1.0,1.0) \end{bmatrix}$$

Step 3: Defuzzyfy $(\tilde{H}_D)$ for each vector in above fuzzy performance score matrix using Eq. (5) and obtain as

$$\tilde{H}_D = \begin{bmatrix} (0.875) & (0.875) & (0.975) & (0.875) & (0.700) & (0.875) \\ (0.875) & (0.975) & (0.975) & (0.875) & (0.975) & (0.975) \\ (0.975) & (0.875) & (0.975) & (0.875) & (0.875) & (0.875) \\ (0.700) & (0.875) & (0.975) & (0.875) & (0.875) & (0.875) \\ (0.500) & (0.875) & (0.875) & (0.500) & (0.975) & (0.975) \end{bmatrix}$$

Table 4 The hedges (*dilation* and *concentration*) from all DMs

DMs	C_1	C_2	C_3	C_4	C_5	C_6
DM_1	*EI*	*VI*	*EI*	*FI*	*FI*	*FI*
DM_2	*EI*	*EI*	*VI*	*VI*	*EI*	*EI*
DM_3	*VI*	*EI*	*VI*	*FI*	*VI*	*FI*
DM_4	*VI*	*FI*	*SI*	*VI*	*FI*	*EI*

Step 4: Assign the power of concentration and/or dilation for each criterion $(\tilde{H}_A^{\alpha})$ and aggregate the DMs evaluated values.

Obviously, each of DMs have their own judgment/opinion for each criterion as given in Table 4 and the average aggregated power of *concentration* and *dilation* for each criterion were calculated. Hence, from Eq. (6) we have

$$\tilde{H}_D^{\alpha} = \left[\begin{pmatrix} 0.875 \\ 0.875 \\ 0.975 \\ 0.700 \\ 0.500 \end{pmatrix}^{5/2} \begin{pmatrix} 0.875 \\ 0.975 \\ 0.875 \\ 0.875 \\ 0.875 \end{pmatrix}^{9/4} \begin{pmatrix} 0.975 \\ 0.975 \\ 0.975 \\ 0.975 \\ 0.875 \end{pmatrix}^{15/8} \begin{pmatrix} 0.875 \\ 0.875 \\ 0.875 \\ 0.875 \\ 0.500 \end{pmatrix}^{3/2} \begin{pmatrix} 0.700 \\ 0.975 \\ 0.875 \\ 0.875 \\ 0.975 \end{pmatrix}^{7/4} \begin{pmatrix} 0.875 \\ 0.975 \\ 0.875 \\ 0.875 \\ 0.975 \end{pmatrix}^{2} \right]$$

$$= \begin{bmatrix} 0.7162 & 0.7405 & 0.9536 & 0.8185 & 0.5357 & 0.7156 \\ 0.7162 & 0.9446 & 0.9536 & 0.8185 & 0.9567 & 0.9506 \\ 0.9387 & 0.7405 & 0.9536 & 0.8185 & 0.7916 & 0.7656 \\ 0.4100 & 0.7405 & 0.9536 & 0.8185 & 0.7916 & 0.7656 \\ 0.1768 & 0.7405 & 0.7785 & 0.3536 & 0.9567 & 0.9506 \end{bmatrix}$$

Step 5: Identify the best suppliers and ranked them by descending order using Eq. (7) and we have

$$\mu_{H_D^{\alpha}}(S_i) = \max\left(0.5357, 0.7162, 0.7405, 0.4100, 0.1768\right), \quad i = 1,2,3,4,5$$

Thus, it shows that S_1 = 0.5357, S_2 = 0.7162, S_3 = 0.7405, S_4 = 0.4100, and S_5 = 0.1768. Apparently, we can write as $S_3 > S_2 > S_1 > S_4 > S_5$, where S_3 is the best in terms of their overall performance scores compared to other alternatives available. The symbol '>' means 'is superior or preferred to'.

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5.0 Conclusion

In this paper we have discussed how the Fuzzy Simple Hierarchy Analysis based on linguistic hedges was employs to choose the best suppliers based on the identified criteria. The method has introduced the linguistic variables based on TFNs approach despite using common mean of fuzzy numbers. This effort is very significant in terms of evaluation approach to derive more efficient and precise results and able to representing the actual decision situations. Beside that the method also equipped with the power of dilation and concentration for DMs evaluates the importance of each criterion for weighting purposes. Also, it clearly seen that the proposed method is highly beneficial to avoid the complexity of the evaluation process and in the same time can reduce the time consuming during the analysis stages. Although the case study results may relate only for this numerical example, we can expect the similar outcomes for other real cases. Next, the proposed method has unique advantage in the sense that it can distinguish clearly for every single judgment made by DMs for choosing the best suppliers. Finally, the method also provides a systematic procedures and successful dealing with somewhat ill-defined of input criterion. Thus, it can facilitate the DMs to make decision in a systematic and simple manner. For next effort our study will focus on the possibility to equip the method with the confidence analysis using the □-cut concept. By this tool we believed that the confidence level of DMs can be measure with ease and more effective. This initiative is left for our future research work.

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