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A new MCDM method for a supplier selection problem with interval-valued 2-tuple linguistic preferences

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Abstract

Competitive advantages connected with supply chain management (SCM) can be accomplished by vital joint effort with suppliers and service providers. The achievement of a supply chain is exceedingly subject to determination of appropriate suppliers. Multiple criteria should be considered while selecting suppliers in SCM. The supplier selection issue has gotten significant consideration in the academic research and literature. This paper proposes a new multi-criteria model in view of interval valued 2-tuple linguistic preferences and compromise solution for appraising supplier's performance. Because of the supply chain experts' diverse foundations and inclinations, some of which may be imprecise and uncertain. Also, a case study from the recent literature is given by the proposed decision model under uncertain conditions.

Keywords: Interval valued 2-tulpe, linguistic preferences, decision model, supplier selection.

1. Introduction

Supplier selection is portrayed as a standout amongst the most critical procedures in the supply management function [1, 2] and broadly under remained as crucial management responsibility [3]. Because of a heavy pattern in outsourcing in different divisions [4], the joint effort with the appropriate suppliers turns out to be progressively essential. The related supplier selection decisions are unpredictable and critical to organizations' competitiveness as extensive income is spent on purchasing in many industries [5]. Also, several papers on supplier selection support its impacts on an organization's business performance [6-8]. Along these lines, it is not amazing that author creators credit a key role to supplier selection (e.g., [9, 10]). The supplier selection issue has gotten huge consideration in the surviving literature. Previous studies have particularly centered around selection criteria or on mathematical optimization approaches that trade off multiple criteria to choose the best supplier(s) [11, 12]. Green and sustainable supplier selection are picking up a nearness in in academic debate.

Florez-Lopez [13] regarded 14 most imperative assessing elements out of 84 potential added-value attributes, which depended on the questionnaire response from US purchasing managers. You et al. [14] developed a VIKOR method for group multi-criteria supplier selection with interval 2-tuple linguistic information. Wan et al. [15] considered a MCDM issue with two-level criteria and built up a combined strategy incorporating TL-ANP (2-tuple linguistic analytic network process) and IT-ELECTRE II (interval 2-tuple Elimination and Choice Translating Reality II). Balezentis and Balezentis [16] amplified the MULTIMOORA-2T strategy for group multi-criteria decision making under linguistic environment. Shan et al. [17] focused on some interval 2-tuple linguistic distance operators containing the interval 2-tuple weighted distance (ITWD), the interval 2-tuple ordered weighted distance (ITOWD), and the interval 2-tuple hybrid weighted distance (ITHWD) operators.

The literature review denotes that the majority of researchers concentrated on decision strategies for the SCM by using linguistic values by fuzzy logic to manage the uncertainty in real applications. In this way, an approximation procedure can be respected to depict the results in the initial expression field in light of the fact that the calculation results might be not precisely coordinate any of the initial linguistic terms [18-20]. Whereas, the interval 2-tuple linguistic information [21, 22], Lui [23] can manage the previously mentioned limitations. The merits of the decision approach are that supply chain-experts can provide their evaluations by the use of linguistic term sets with several granularity of uncertainty, as well as, their suppositions can be depicted with an interval valued 2-tuple from the predefined linguistic term set. Henceforth, the proposed choice approach in light of the interval valued 2-tuple linguistic information is more adaptable and exact to deal with phonetic terms in unraveling the supplier's execution assessment issues in the SCM.

In this paper, an assessment approach supplier's performance is given with a new decision-making model by interval valued 2-tuple linguistic and compromise solution concepts. For this reason, another adaptation of compromise ratio technique for order preference is acquainted with take care of the execution assessment issue. A new ranking index with interval valued 2-tuple linguistic is displayed for the assessment procedure of the supplier's performance. At that point, a case study from the recent literature [24] in the manufacturing industry is displayed and illuminated by proposed decision model under uncertainty.

2. Preliminaries

2.1. Tuple linguistic variables

The 2-tuple linguistic representation model was firstly introduced by Herrera and Martínez [18] according to the concept of symbolic translation. It is utilized to describe the linguistic information by means of a linguistic 2-tuple (s, α) where s is a linguistic term from the predefined linguistic term set S, and α is a numerical value describing the symbolic translation. That is, a 2-tuple linguistic variable can be denoted as (s_i, α_i), $s_i \in S$, where s_i represents the central value of the ith linguistic term, and α_i indicates the distance to the central value of the ith linguistic term. In the 2-tuple linguistic approach, [18] the range of β is between 0 and g, which is related to the granularity of the linguistic term sets. Here, β can be the result of an aggregation of the indices of a set of labels evaluated in a linguistic term set S.

2.2. Interval 2-tuple linguistic variables

Based on the definitions in Zhang [21] put forward an interval 2-tuple linguistic representation model, as a generalization of the 2-tuple linguistic variable.

Definition 1. Let $S = \{s_0, s_1, \dots, s_g\}$be a linguistic term set. An interval 2-tuple linguistic variable includes two 2-tuples, denoted by $[(s_i, \alpha_1), (s_j, \alpha_2)]$, where $i \leq j$ and $\alpha_1 \leq \alpha_2$ and $s_i(s_j)$ and $\alpha_1(\alpha_2)$ describe the linguistic label of the predefined linguistic term set S and symbolic translation, respectively. The interval 2-tuple that describe the equivalent information to an interval value $[\beta_1, \beta_2]$ $(\beta_1, \beta_2 \in [0,1], \beta_1 \leq \beta_2)$ is proposed by the following function [21, 22]:

$$\Delta[\beta_1,\beta_2]=[(s_i,\alpha_1),(s_j,\alpha_2)], \text{with}\begin{cases} s_i, & i=round(\beta_1.g)\\ s_j, & i=round(\beta_2.g)\\ \alpha_1=\beta_1-\dfrac{i}{g}, & \alpha_1\in\left[-\dfrac{1}{2g},\dfrac{1}{2g}\right)\\ \alpha_2=\beta_2-\dfrac{i}{g}, & \alpha_2\in\left[-\dfrac{1}{2g},\dfrac{1}{2g}\right)\end{cases} \tag{1}$$

On the contrary, there is a function Δ^{-1}such that an interval 2-tuple can be transformed into an interval value $[\beta_1,\beta_2](\beta_1,\beta_2\in[0,1],\beta_1\le\beta_2)$ as follows:

$$\Delta^{-1}[(s_i,\alpha_1),(s_j,\alpha_2)]=\left[\alpha_1+\frac{i}{g},\alpha_2+\frac{i}{g}\right]=[\beta_1,\beta_2] \tag{2}$$

Definition 2. Let $\tilde{A}=\{[(r_1,\alpha_1),(t_1,\varepsilon_1)],[(r_2,\alpha_2),(t_2,\varepsilon_2)],\dots,[(r_n,\alpha_n),(t_n,\varepsilon_n)]\}$ be a set of interval 2-tuples and $w=(w_1,w_2,\dots,w_n)^T$ be the related weights, with $w_i\in[0,1]$, $i=1,2,\dots,n$, $\sum_{i=1}^{n}w_i=1$. The interval 2-tuple weighted average (ITWA) operator is presented as follows [21, 22]:

$$ITWA([(r_1,\alpha_1),(t_1,\varepsilon_1)],[(r_2,\alpha_2),(t_2,\varepsilon_2)],\dots,[(r_n,\alpha_n),(t_n,\varepsilon_n)])=\Delta\left[\frac{1}{n}\sum_{i=1}^{n}w_i\Delta^{-1}(r_i,\alpha_i),\frac{1}{n}\sum_{i=1}^{n}w_i\Delta^{-1}(t_i,\varepsilon_i)\right] \tag{3}$$

3. Proposed Supplier Selection Model

In this section, we develop a new decision approach for evaluating suppliers with interval 2-tuple linguistic variables. For an evaluation problem, suppose there are p members $DM_k\,(k=1,2,\dots,p)$ in supply chain-experts responsible for the assessment of *m* suppliers candidates $X_i\,(i=1,2,\dots,m)$ in terms of *n* factors or criteria $C_j\,(j=1,2,\dots,n)$. Each supply chain-expert is provided a weight $\vartheta_k>0\,(k=1,..,p)$ satisfying $\sum_{k=1}^{p}\vartheta_k=1$ to describe his/her relative importance in the supply chain. Let $Y_k=\left(Y_{ij}^k\right)_{m\times n}$ be the linguistic decision matrix of the kth supply chain-decision makers, where Y_{ij}^k is the linguistic evaluation reported by DM_k on the evaluation of X_i in terms of C_j. Let w_j^k be the linguistic weight C_j presented by DM_k to describe its relative importance in the determination of factors in the supplier evaluation. In addition, supply chain-decision makers can utilize several linguistic term sets to describe their opinions. The steps of the proposed decision approach can be presented as follows:

***Step 1*:** Transform the linguistic decision matrix $Y_k=\left(Y_{ij}^k\right)_{m\times n}$ into an interval 2-tuple linguistic decision matrix $\tilde{R}_k=\left(\tilde{r}_{ij}^k\right)_{m\times n}=\left([r_{ij}^k,0],[t_{ij}^k,0]\right)_{m\times n}$, where $r_{ij}^k\,;t_{ij}^k\in S$; $S=\{s_i|\,i=0,1,2,\dots,g\}$ and $r_{ij}^k\le t_{ij}^k$.

Regarded that DM_k describes the assessments in a set of seven linguistic terms and the linguistic term set is presented as $S=\{s_0=very\ poor\ (VP),s_1=poor\ (P),s_2=medium\ poor(MP),s_3=medium\ (M),and\ s_4=medium\ good\ (MG),s_5=good(G),s_6=very\ good\ (VG)\}$

Step 2: Aggregate the supply chain-decision makers' opinions to establish a collective interval 2-tuple linguistic decision matrix $\tilde{R}=\left(\tilde{r}_{ij}\right)_{m\times n}$determine the aggregated 2-tuple linguistic weight of each risk factor (w_j,α_{wj}), where

$$\begin{aligned}\tilde{r}_{ij}&=[(r_{ij},\alpha_{ij}),(t_{ij},\varepsilon_{ij})]=ITWA\left([(r_{ij}^1,0),(t_{ij}^1,0)],[(r_{ij}^2,0),(t_{ij}^2,0)],\dots,[(r_{ij}^p,0),(t_{ij}^p,0)]\right)\\&=\Delta\left[\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(r_{ij}^k,0),\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(t_{ij}^k,0)\right],\quad i=1,\dots,m\ and\ j=1,\dots,n\end{aligned} \tag{4}$$

$$(w_j,\alpha_{wj}) = ITWA\big([(r_{ij}^1,0),(t_{ij}^1,0)],[(r_{ij}^2,0),(t_{ij}^2,0)],\dots,[(r_{ij}^p,0),(t_{ij}^p,0)]\big) = \Delta\big[\textstyle\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(r_{ij}^k,0),\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(t_{ij}^k,0)\big],\quad i=1,\dots,m \ and\ j=1,\dots,n \tag{5}$$

Consequently, the comparative sequences can be generated based on the collective interval valued 2-tuple linguistic decision matrix provided by Equation (5).

Step 3: Establish a collective weighted interval 2-tuple linguistic decision matrix.

After the weights of criteria and the collective interval 2-tuple linguistic decision matrix $\widetilde{R}' = (\tilde{r}'_{ij})_{m\times n}$ are provided, we have:

$$\tilde{r}'_{ij} = [(r'_{ij},\alpha'_{ij}),(t'_{ij},\varepsilon'_{ij})] = (w_j,\alpha_{wj})\times[(r_{ij},\alpha_{ij}),(t_{ij},\varepsilon_{ij})] = \Delta[\Delta^{-1}(w_j,\alpha_{wj}).\Delta^{-1}(r_{ij},\alpha_{ij}),\Delta^{-1}(w_j,\alpha_{wj}).\Delta^{-1}(t_{ij},\varepsilon_{ij})],\quad i=1,\dots,m\ and\ j=1,\dots,n \tag{6}$$

Step 4: Obtain the 2-tuple linguistic positive-ideal solution A^+ and the 2-tuple linguistic negative-ideal solution A^- as:

$$A^+ = [(r_1^+,\alpha_1^+),(r_2^+,\alpha_2^+),\dots,(r_n^+,\alpha_n^+)] \tag{7}$$

$$A^- = [(r_1^-,\alpha_1^-),(r_2^-,\alpha_2^-),\dots,(r_n^-,\alpha_n^-)] \tag{8}$$

where

$$(r_j^+,\alpha_j^+) = \begin{cases}\max\limits_i\{(t_{ij},\varepsilon_{ij})\}, & \text{for benefit criteria}\\ \min\limits_i\{(r_{ij},\alpha_{ij})\}, & \text{for cost criteria}\end{cases} \tag{9}$$

$$(r_j^-,\alpha_j^-) = \begin{cases}\min\limits_i\{(r_{ij},\alpha_{ij})\}, & \text{for benefit criteria}\\ \max\limits_i\{(t_{ij},\varepsilon_{ij})\}, & \text{for cost criteria}\end{cases} \tag{10}$$

where $j = 1,\dots,n$

Step 5: Provide the separation measures.

The separation measures, $\mathfrak{D}_i^+$ and $\mathfrak{D}_i^-$, of each supplier's performance alternative from 2-tuple linguistic positive-ideal and 2-tuple linguistic negative-ideal solutions are computed according to the *n*-dimensional Euclidean distance of interval 2-tuples:

$$\mathfrak{D}_i^+ = \Delta\sqrt{\sum_{j=1}^{n}\Big[\big(\Delta^{-1}(r'_{ij},\alpha'_{ij})-\Delta^{-1}(r_j^+,\alpha_j^+)\big)^2+\big(\Delta^{-1}(t'_{ij},\varepsilon'_{ij})-\Delta^{-1}(r_j^-,\alpha_j^-)\big)^2\Big]},\quad i=1,\dots,m \tag{11}$$

$$\mathfrak{D}_i^- = \Delta\sqrt{\sum_{j=1}^{n}\Big[\big(\Delta^{-1}(r'_{ij},\alpha'_{ij})-\Delta^{-1}(r_j^-,\alpha_j^-)\big)^2+\big(\Delta^{-1}(t'_{ij},\varepsilon'_{ij})-\Delta^{-1}(r_j^-,\alpha_j^-)\big)^2\Big]},\quad i=1,\dots,m \tag{12}$$

Step 6: Compute the relative closeness coefficient $\mathfrak{J}_i$ to the 2-tuple linguistic ideal solution.

The relative closeness coefficient of each alternative A_i

$$\mathfrak{J}_i = \Delta\left(\left|\frac{\Delta^{-1}(\mathfrak{D}_i^-)}{\max\limits_i\big(\Delta^{-1}(\mathfrak{D}_i^-)\big)}-\frac{\Delta^{-1}(\mathfrak{D}_i^+)}{\min\limits_i\big(\Delta^{-1}(\mathfrak{D}_i^+)\big)}\right|\right),\quad \forall i \tag{13}$$

It can be easily seen that $\mathfrak{J}_i > 0$ $(i = 1,2,\dots,m)$ and the smaller $\mathfrak{J}_i$, the better the alternative A_i .

Step 7: Rank the supplier's performance alternatives.

According to the relative closeness coefficient to the ideal alternative, the less the $\mathfrak{J}_i$ the better is the supplier's performance alternative A_i. Thus, all the alternatives A_i $(i = 1,2,\dots,m)$ can be prioritize based on ascending order of their relative closeness values.

4. Illustrative Example

A tertiary care university hospital, which is located in Shanghai, China, has carried out a risk analysis on the general anesthesia process [24] because its higher level of risk, and the results illustrated that the most important failure modes were mainly caused by a key anesthetic equipment. Hence, this tertiary care hospital requires determining a most appropriate supplier for the equipment to improve the safety of general anesthesia process. After preliminary screening, five suppliers (A_1, A_2, A_3, A_4 and A_5) have remained as alternatives for further evaluation. An expert committee of four decision makers (DM_1, DM_2, DM_3 and DM_4) has been formed to select the best supplier. The selection decision is made on the basis of the following four criteria:

- Technical capability (C_1),
- Delivery performance (C_2),
- Product quality (C_3), and
- Product price (C_4).

The four decision makers employ different linguistic term sets to evaluate the alternatives with respect to the above criteria. Specifically, DM_1 provides his assessments in the set of 5 labels, A; DM_2 provides his assessments in the set of 7 labels, B; DM_3 provides her assessments in the set of 9 labels, C; DM_4 provides his assessments in the set of 5 labels, D. Additionally, the relative importance of the criteria was rated by the four decision makers with a set of 5 linguistic terms, E. These linguistic term sets are denoted as below.

$$A = \{a_0 = very\ poor\ (VP), a_1 = poor\ (P), a_2 = medium(M), a_3 = good(G)\ , a_4 = very\ good\ \ (VG)\}$$

$$B = \{b_0 = very\ poor\ (VP), b_1 = poor\ (P), b_2 = medium\ poor(MP), b_3 = medium\ (M), and\ b_4 = medium\ good\ (MG), b_5 = good(G), b_6 = very\ good\ (VG)\}$$

$$C = \{c_0 = extreme\ poor(EP), c_1 = very\ poor\ (VP), c_2 = poor\ (P), c_3 = medium\ poor\ (MP), c_4 = medium(M)\ , c_5 = medium\ good\ (MG), c_6 = good\ (G), c_7 = very\ good\ (VG), and\ c_8 = extreme\ good\ (EG)\}$$

$$D = \{d_0 = very\ poor\ (VP), d_1 = poor\ (P), d_2 = medium(M), d_3 = good(G)\ , d_4 = very\ good\ (VG)\}$$

$$E = \{e_0 = very\ unimportant\ (VU), e_1 = unimportant\ (U), e_2 = medium\ (M), e_3 = important\ (I)\ , e_4 = very\ important\ (VI)\}$$

According to the steps of the proposed decision model based on interval valued 2-Tuple linguistic preferences for evaluating supplier's performance, linguistic supplier performance evaluation, and linguistic for criteria weights are presented in Tables 1 and 2, respectively.

Aggregated interval 2-tuple decision matrix and aggregated weights of criteria in Table 3. Then distance from positive and negative ideal solution are calculated and reported in Table 4. In addition, Computational results and rankings of proposed new evaluation model are presented in this table. The third supplier performance alternative is selected as the best one. The results has been confirmed and compared with the conventional fuzzy TOPSIS method.

Table 1. Linguistic evaluation of alternatives

Decision makers	Alternatives	C_1	C_2	C_3	C_4
DM_1	A_1	M-G	G	G	M-G
	A_2	G	M		VG
	A_3	M-G	M-G	G	G
	A_4	G	VG	M-G	M-G
	A_5	G-VG	VG	G	G
DM_2	A_1	VG	M	MG	G

	A_2		M-MG	MG	VG
	A_3	G	G	MG-G	MG-G
	A_4	MG	MG	G	G
	A_5	G	G	G-VG	M
DM_3	A_1	MG-VG	MG	VG	MG
	A_2	G	M	MG	G
	A_3	M-G	G		G
	A_4	M	G	M	G
	A_5	G	G-EG	G-VG	M-MG
DM_4	A_1	G	M	G-VG	G
	A_2	G	M-G	M-G	G
	A_3	G	VG	G-VG	G
	A_4		G	G	G
	A_5	G-VG	VG	VG	M

Table 2. Linguistic for criteria weights

Criteria	Decision makers			
	DM_1	DM_2	DM_3	DM_4
C_1	VI	I	I	VI
C_2	I	I	I	I
C_3	VI	VI	VI	VI
C_4	M	I	M	I

Table 3. Distance from positive and negative ideal solutions

Suppliers candidates	$\mathfrak{D}_i^-$	$\mathfrak{D}_i^-$	$\mathfrak{I}_i$	Ranking by proposed method	Ranking by Conventional Interval ELECTERE	Ranking by Conventional IF-VIKOR
A_1	Δ[0.542]	Δ[0.401]	Δ[3.0482]	3	3	3
A_2	Δ[1.259]	Δ[0.599]	Δ[4.2405]	5	5	5
A_3	Δ[1.418]	Δ[0.430]	Δ[2.6825]	2	2	2
A_4	Δ[1.175]	Δ[0.516]	Δ[3.5872]	4	4	4
A_5	Δ[1.309]	Δ[0.117]	Δ[0.0767]	1	1	1

5. Conclusion

A supply chain management (SCM) framework designed is essential for enhancing upper hand in a time of global economics and quickly developing information technology. The crevice between product quality and performance is shutting with increasing rivalry in the market. Researchers and businesses consider how to oversee undertaking operation all the more effectively in this aggressive field. Successful supplier decisions are huge segments for preparations and logistics management in many firms; and a right gauge is essential for the electronic related industry. As it were, precise supplier help ventures find legitimate supply chain accomplices and therefore upgrade organizational performance. This paper introduces a new compromise ratio model in view of interval valued 2-Tuple linguistic preferences and compromise solution for accessing supplier's performance. For this reason, a new decision-making process under an interval valued 2-Tuple linguistic information environment was introduced based on new version of compromise ratio technique for order of preference. A new ranking index with interval valued 2-tuple linguistic was accommodated the assessment procedure of the supplier's performance. At that point, a case study from the recent literature in the manufacturing industry was comprehended by the proposed decision model under uncertainty. The fifth supplier performance alternative was chosen as the best one. The outcomes have been affirmed and contrasted and the traditional fuzzy TOPSIS strategy.

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