A New Decision Model Based on Interval Valued 2-Tuple Linguistic Preferences for Evaluating Green Supplier's Performance

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Abstract

Under conditions of expanding environmental importance from business sectors, organizations in supply chains have perceived the significance of greening their supply chain within green supplier development programs. Different articles have begun to investigate the between connections between green supply chain management and supplier performance. Much of this performance can be accomplished only with suppliers inclusion in green supplier development programs. However, the studies concentrating on green supplier development programs is very limited. To address this gap in the literature, we present a new decision model based on interval valued 2-Tuple linguistic preferences and compromise solution for evaluating green supplier's performance. Due to the supply chain-experts' different backgrounds and preferences, some of which may be imprecise and uncertain. Then, a case study from the recent literature in the manufacturing industry is presented and solved by the proposed decision model under uncertain conditions.

Keywords:
Interval Valued 2-Tulpe, Linguistic Preferences, Decision Model, Evaluation, Green Supplier's Performance.

Introduction

Nowadays, individuals know about the solid connections between the economy and the environment. In the fields of business and administration, association faces more greater responsibilities to reduce their impacts on the environment. One part of this obligation incorporates actualizing proactive ways to deal with environmental performance as greening the supply chain [1-3].

Environmental management is regarded as predictable arrangement of managerial and operational approaches and practices that considers the insurance of the environment through the alleviation of environmental effects and harm coming about because of planning, implementation, operation, expansion, reallocation or deactivation of ventures or activities by considering all of the product's life cycle phases [4]. For chosen ideas of environmental management allude to Jabbour and Jabbour [4]. Organizations have embraced shifting environmental management systems (EMS), for example, BS 7750, ISO 14000 frameworks of standards in order to regard environmental challenges [5]. EMS and green supply chain management (GSCM) have risen as a path for firms to accomplish benefit and piece of the overall industry goals by bringing down natural effects and expanding environmental effectiveness [6]. While literature identified with supplier evaluation is abundant, the considering green supplier evaluation that take account of environmental factors are somewhat constrained [6-9].

Regarding the recent literature, Shen et al. [10] investigated the GSCM to present a fuzzy multi-criteria approach for green suppliers' evaluation. Dou et al. [11] presented a grey analytical network process (grey ANP)-based model to distinguish green supplier development programs that can successfully enhance suppliers' performance. Ghorabaee et al. [12] extended incorporated approach in light of weighted aggregated sum product assessment (WASPAS) technique to manage multi-criteria group decision-making problems with interval type-2 fuzzy sets (IT2FSs) for the green supplier selection. Awasthi and Kannan [13] regarded the issue of evaluating green supplier development programs and presented a fuzzy NGT-VIKOR based arrangement approach. The literature review denotes that the majority of researchers focused on decision methods for the GSCM by utilizing linguistic values by using fuzzy logic to deal with the uncertainty in real situations. Therefore, an approximation process can be regarded to describe the results in the initial expression area because the computation results may be not exactly match any of the initial linguistic variables [14-16]. Whereas the interval 2-tuple linguistic information [17,18], Lui [19] can handle the previously mentioned limitations. The advantages of the decision approach are that supply

chain-experts can express their evaluations by the use of linguistic term sets with several granularities of uncertainty, and their opinions can be described with an interval valued 2-tuple from the predefined linguistic term set. Hence, the proposed decision approach based on the interval valued 2-tuple linguistic information is more flexible and precise to handle linguistic terms in solving the green supplier's performance evaluation problems in the SCM.
In this paper, an evaluation approach green supplier's performance is presented with a new decision-making model by interval valued 2-tuple linguistic and compromise solution concepts. For this purpose, a new version of technique for order preference by similarity to ideal solution (TOPSIS) is introduced to solve the performance evaluation problem. A new ranking index with interval valued 2-tuple linguistic is presented for the evaluation process of the green supplier's performance. Then, a case study from the recent literature [10] in the manufacturing industry is presented and solved by proposed decision model under uncertainty.
The structure of our research incorporates five sections. The rest of this paper is organized as follows. Section 2 reviews some recent works on interval valued 2-tuple linguistic information and proposed decision model are presented in Section 3. Then, a case study is given in Section 4. Some concluding remarks are reported in Section 5.

Preliminaries

Tuple linguistic variables: The 2-tuple linguistic representation model was firstly introduced by Herrera and Martínez [14] 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 $(s_i,\alpha_i), s_i \in S$, 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 [14], 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.

Definition 1. Let $S = \{s_0, s_1, \dots, s_g\}$ be a linguistic term set and $\beta \in [0,1]$ a value describing the result of a symbolic aggregation operation. Then, the generalized translation function Δ used to determine the 2-tuple linguistic variable equivalent to β can be presented as follows [20]:

$$\Delta: [0,1] \rightarrow S \times \left[-\frac{1}{2g}, \frac{1}{2g}\right) \quad (1)$$

$$\Delta(\beta) = (s_i,\alpha), with \begin{cases} s_i, & i = round(\beta.g) \\ \alpha = \beta + \frac{i}{g}, & \alpha \in \left[-\frac{1}{2g}, \frac{1}{2g}\right) \end{cases} \quad (2)$$

where round $(\cdot)$ is the usual rounding operation, s_i has the closest index label to β, and α can be the value of the symbolic translation. The interval of α can be defined by the number of linguistic terms in S. For instance, if S contains five linguistic terms, then $g = 4$ and $\alpha \in [-0.125, 0.125)$.

Definition 2. Let $S = \{s_0, s_1, \dots, s_g\}$ be a linguistic term set and (s_i,α) be a 2-tuple. There exists a function Δ^{-1}, which is able to transform a 2-tuple linguistic variable into its equivalent numerical value $\beta \in [0,1]$. The reverse function Δ^{-1} is presented as follows [20]:

$$\Delta^{-1}: S \times \left[-\frac{1}{2g}, \frac{1}{2g}\right) \rightarrow [0,1], \quad (3)$$

$$\Delta^{-1}(s_i,\alpha) = \frac{i}{g} + \alpha = \beta. \quad (4)$$

The conversion of a linguistic term into a linguistic 2-tuple includes regarding a value 0 as symbolic translation [14]:

$$s_i \in S \Rightarrow (s_i, 0) \quad (5)$$

The comparison of linguistic information represented by 2-tuples is performed based on an ordinary lexicographic order.

Definition 3. Let (s_k,α_1) and (s_l,α_2) be two 2-tuples, then [14]:
1. If $k < l$, then (s_k,α_1) is smaller than (s_l,α_2);
2. If $k = l$, then:
a. If $\alpha_1 = \alpha_2$, then (s_k,α_1) is equal to (s_l,α_2);
b. If $\alpha_1 < \alpha_2$, then (s_k,α_1) is smaller than (s_l,α_2); and
c. If $\alpha_1 > \alpha_2$, then (s_k,α_1) is bigger than (s_l,α_2).

In the processes of 2-tuple linguistic operation, both functions Δ and Δ^{-1} are applied to ensure that the operation of 2-tuple linguistic variables can be a 2-tuple without any information loss.

Definition 4. Let $X = \{(r_1, \alpha_1), (r_2, \alpha_2), \dots, (r_n, \alpha_n)\}$ be a set of 2-tuples and $w = (w_1, w_2, \dots, w_n)^T$ be their associated weights, with $w_i \in [0,1]$, $i = 1,2,\dots,n$, $\sum_{i=1}^{n} w_i = 1$. The 2-tuple weighted average (TWA) is presented as [14]:

Interval 2-tuple linguistic variables: Based on the definitions in Zhang [17] put forward an interval 2-tuple

$$TWA(X) = \Delta\left(\frac{1}{n}\sum_{i=1}^{n} w_i \Delta^{-1}(r_i, \alpha_i)\right) = \Delta\left(\frac{1}{n}\sum_{i=1}^{n} w_i \beta_i\right) \quad (6)$$

linguistic representation model, as a generalization of the 2-tuple linguistic variable.

Definition 5. 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 $i \le j$ and $\alpha_1 \le \alpha_2$ 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 $[\beta_1,\beta_2](\beta_1,\beta_2\in[0,1],\beta_1\le\beta_2)$ is proposed by the following function [17,18]:

$$\Delta[\beta_1,\beta_2]=[(s_i,\alpha_1),(s_j,\alpha_2)],\quad with\begin{cases} s_i, & i=round(\beta_1.g)\\ s_j, & i=round(\beta_2.g)\\ \alpha_1=\beta_1-\dfrac{i}{g}, & \alpha_1\in\left[-\dfrac{1}{2g},\dfrac{1}{2g}\right)\\ \alpha_2=\beta_2-\dfrac{i}{g}, & \alpha_2\in\left[-\dfrac{1}{2g},\dfrac{1}{2g}\right)\end{cases}\tag{7}$$

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:

$$\Delta^{-1}[(s_i,\alpha_1),(s_j,\alpha_2)]=\left[\alpha_1+\frac{i}{g},\alpha_2+\frac{i}{g}\right]=[\beta_1,\beta_2]\tag{8}$$

If $s_i=s_j$ and $\alpha_1=\alpha_2$, then the interval 2-tuple linguistic variable decrease to a 2-tuple linguistic variable.

Definition6. Let $\tilde{A}=\{[(r_1\ ,\alpha_1),(t_1\ ,\varepsilon_1)],\ldots,[(r_n\ ,\alpha_n),(t_n\ ,\varepsilon_n)]\}$ be a set of interval 2-tuples and $w=(w_1,w_2,\ldots,w_n)^T$ be the related weights, with $w_i\in[0,1]$, $i=1,2,\ldots,n$, $\sum_{i=1}^{n}w_i=1$. The interval 2-tuple weighted average (ITWA) operator is presented as follows [17,18]:

$$\mathrm{ITWA}([(r_1\ ,\alpha_1),(t_1\ ,\varepsilon_1)],\ldots,[(r_n\ ,\alpha_n),(t_n\ ,\varepsilon_n)])=\Delta\left[\frac{1}{n}\sum_{i=1}^{n}w_i\Delta^{-1}(r_i\ ,\alpha_i),\frac{1}{n}\sum_{i=1}^{n}w_i\Delta^{-1}(t_i\ ,\varepsilon_i)\right]\tag{9}$$

Definition 7. Let a $\tilde{a}=[(r_1,\alpha_1),(t_1,\varepsilon_1)]$ and $\tilde{b}=[(r_2,\alpha_2),(t_2,\varepsilon_2)]$ be two interval 2-tuples, then

$$d(\tilde{a},\tilde{b})=\Delta\sqrt{\frac{1}{2}\left[\left(\Delta^{-1}(r_1\ ,\alpha_1)-\Delta^{-1}(r_2\ ,\alpha_2)\right)^2+\left(\Delta^{-1}(t_1\ ,\varepsilon_1)-\Delta^{-1}(t_2\ ,\varepsilon_2)\right)^2\right]}\tag{10}$$

is named the normalized Euclidean distance between $\tilde{a}$ and $\tilde{b}$.

Proposed green supplier's evaluation model

In this section, we develop a new decision approach for evaluating green suppliers with interval 2-tuple linguistic variables. For an evaluation problem, suppose there are p members $DM_k(k\ =\ 1,2,\ldots,p)$ in supply chain-experts responsible for the assessment of m green suppliers candidates X_i $(i\ =\ 1,2,\ldots,m)$ in terms of n factors or criteria C_j $(j\ =\ 1,2,\ldots,n)$. 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 green suppliers 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 ; $t_{ij}^k\in\ S;\ S=\{s_i|\ i=0,1,2,\ldots,g\ \}$ and $r_{ij}^k\le t_{ij}^k$.
Regarded that DM_k describes the assessments in a set of five linguistic terms and the linguistic term set is presented a $S\ =\ \{s_0=Very\ low,s_1=\ Low,s_2=\ Moderate,s_3=\ High,s_4=\ Very\ high\}$.

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

$$\begin{aligned}\tilde{r}_{ij}&=[(r_{ij}\ ,\alpha_{ij}),(t_{ij}\ ,\varepsilon_{ij})]\\&=ITWA([(r_{ij}^1\ ,0),(t_{ij}^1\ ,0)],[(r_{ij}^2\ ,0),(t_{ij}^2\ ,0)],\\&\ldots,[(r_{ij}^p\ ,0),(t_{ij}^p\ ,0)])\\&=\Delta\left[\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(r_{ij}^k\ ,0),\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(t_{ij}^k\ ,0)\right],\\&i=1,\ldots,m\quad and\ \ j=1,\ldots,n\end{aligned}\tag{11}$$

and,

$$\begin{aligned}&(w_j,\alpha_{wj})\\&=ITWA([(r_{ij}^1\ ,0),(t_{ij}^1\ ,0)],[(r_{ij}^2\ ,0),(t_{ij}^2\ ,0)],\\&\ldots,[(r_{ij}^p\ ,0),(t_{ij}^p\ ,0)])\\&=\Delta\left[\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(r_{ij}^k\ ,0),\sum_{k=1}^{p}\vartheta_k\Delta^{-1}(t_{ij}^k\ ,0)\right],\\&i=1,\ldots,m\quad and\ \ j=1,\ldots,n\end{aligned}\tag{12}$$

Consequently, the comparative sequences can be generated based on the collective interval valued 2-tuple linguistic decision matrix provided by Equation (12).

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 $\widetilde{R'}=\left(\tilde{r}'_{ij}\right)_{m\times n}$ are provided, we have:

$$\tilde{r}'_{ij} = [(r'_{ij}, \alpha'_{ij}), (t'_{ij}, \varepsilon'_{ij})] = (w_j, \alpha_{wj}) \times [(r_{ij}, \alpha_{ij}), (t_{ij}, \varepsilon_{ij})] = \Delta[\Delta^{-1}(w_j, \alpha_{wj}).\Delta^{-1}(r_{ij}, \alpha_{ij}), \Delta^{-1}(w_j, \alpha_{wj}).\Delta^{-1}(t_{ij}, \varepsilon_{ij})], \quad i = 1, \ldots, m \quad and \quad j = 1, \ldots, n \tag{13}$$

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

$$A^+ = [(r_1^+, \alpha_1^+), (r_2^+, \alpha_2^+), \ldots, (r_n^+, \alpha_n^+)] \tag{14}$$

$$A^- = [(r_1^-, \alpha_1^-), (r_2^-, \alpha_2^-), \ldots, (r_n^-, \alpha_n^-)] \tag{15}$$

where

$$(r_j^+, \alpha_j^+) = \begin{cases} \max_i\{(t_{ij}, \varepsilon_{ij})\}, & \text{for benefit criteria} \\ \min_i\{(r_{ij}, \alpha_{ij})\}, & \text{for cost criteria} \end{cases} \tag{16}$$

$$(r_j^-, \alpha_j^-) = \begin{cases} \min_i\{(r_{ij}, \alpha_{ij})\}, & \text{for benefit criteria} \\ \max_i\{(t_{ij}, \varepsilon_{ij})\}, & \text{for cost criteria} \end{cases} \tag{17}$$

Where $j = 1, \ldots, n$

Step 5: Provide the separation measures.
The separation measures, D_i^+ and D_i^-, of each green 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:

$$D_i^+ = \Delta\sqrt{\sum_{j=1}^{n}\left[\left(\Delta^{-1}(r'_{ij}, \alpha'_{ij}) - \Delta^{-1}(r_j^+, \alpha_j^+)\right)^2 + \left(\Delta^{-1}(t'_{ij}, \varepsilon'_{ij}) - \Delta^{-1}(r_j^-, \alpha_j^-)\right)^2\right]} \quad i = 1, \ldots, m \tag{18}$$

and,

$$D_i^- = \Delta\sqrt{\sum_{j=1}^{n}\left[\left(\Delta^{-1}(r'_{ij}, \alpha'_{ij}) - \Delta^{-1}(r_j^-, \alpha_j^-)\right)^2 + \left(\Delta^{-1}(t'_{ij}, \varepsilon'_{ij}) - \Delta^{-1}(r_j^-, \alpha_j^-)\right)^2\right]} \quad i = 1, \ldots, m \tag{19}$$

Step 6: Compute the relative closeness coefficient ξ_i to the 2-tuple linguistic ideal solution.
The relative closeness coefficient of each alternative A_i is:

$$\xi_i = \Delta\left(\sqrt{\left[\Delta^{-1}(D_i^+) - \min_i\left(\Delta^{-1}(D_i^+)\right)\right]^2 + \left[\Delta^{-1}(D_i^-) - \max_i\left(\Delta^{-1}(D_i^-)\right)\right]^2}\right), \forall i \tag{20}$$

Step 7: Rank the green supplier's performance alternatives.
According to the relative closeness coefficient to the ideal alternative, the less the ξ_i the better is the green supplier's performance alternative A_i. Thus, all the alternatives A_i $(i = 1, 2, \ldots, m)$ can be prioritized based on ascending order of their relative closeness values.

Application

Manufacturing operations majorly affect environmental pollution at different stages in the product life cycle, from resource extraction to manufacturing, use, reuse, recycling and disposal. There has been weight on automobile manufacturers to actively enhance their supply chain environmental performance and to lessen environmental impacts (Olugu et al., 2011). Automobile manufacturing companies must start to actualize green practices at all phases of the assembling procedure to accomplish benefit and piece of the overall industry targets by bringing down their natural effects and expanding their biological effectiveness. This change is key on the grounds that many automobile parts are outsourced to suppliers, and selecting suppliers as indicated by their environmental criteria will enhance the organization's natural execution. The proposed decision approach comprises of three stages including the determination of assessment criteria, the choice of best providers utilizing proposed criteria, and leading an affectability examination to decide the impact of criteria weights on the decision making.
Criteria or factors for choosing and evaluating green suppliers [10,12,13]:

- C_1: Pollution production
- C_2: Resource consumption
- C_3: Eco-design
- C_4: Eco-design
- C_5: Environmental management system
- C_6: Commitment of GSCM from managers
- C_7: Use of environmentally friendly technology
- C_8: Use of environmentally friendly materials
- C_9: Staff environmental training

The three supply chain-experts employ different linguistic term sets to assess the potential green supplier's performance alternatives in terms of the nine evaluation factors. Specifically, DM_1 describes the assessments in the set of five labels, A; DM_2 describes the assessments in the set of seven labels, B; DM_3 describes the assessments in the set of nine labels, C. In addition, the relative importance of the evaluation factors is determined by the experts with a set of five linguistic terms, D. These linguistic term sets are presented as follows:

$$A = \{a_0 = very\ low\ (VL), a_1 = low\ (L), a_2 = moderately\ low(ML), a_3 = moderate(M)\ , a_4 = moderately\ high\ (MH), a_5 = high(H), and\ a_6 = very\ high\ (VH)\}$$

$$B = \{b_0 = very\ low\ (VL), b_1 = low\ (L), b_2 = moderate(M), b_3 = high\ (H), and\ b_4 = very\ high\ (VH)\}$$

$$C = \{c_0 = extremely\ \ low(EL), c_1 = very\ \ low\ \ (VL), c_2 = low\ \ (L), c_3 = moderately\ \ low(ML), c_4 = moderate(M)\ \ , c_5 = moderately\ \ high\ \ (MH), c_6 = high(H), c_7 = very\ \ high(VH), and\ \ c_8 = extreme\ \ high\ \ (EH)\}$$

$$D = \{d_0 = very\ \ low\ \ (VL), d_1 = low\ \ (L), d_2 = medium\ \ low(ML), d_3 = medium(M)\ \ , d_4 = medium\ \ high\ \ (MH), d_5 = high(H), and\ \ d_6 = very\ \ high\ \ (VH)\}$$

According to the steps of the proposed decision model based on interval valued 2-Tuple linguistic preferences for evaluating green supplier's performance, linguistic green 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 distances 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 green 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 green supplier performance evaluation

Criteria	Supplier X_1			Supplier X_2			Supplier X_3		
	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3	DM_1	DM_2	DM_3
C_1	M	M	ML	H	M	VH, EH	MH	M	H
C_2	M, MH	VL, L	M	H	L, M	H	MH	VL, L	MH
C_3	MH	M	ML ,M H	M	M	MH	H	L, M	H
C_4	M	VL	ML	MH	VL, L	M		L, M	ML
C_5	MH	M	M	VH	H	MH	MH ,H	M	MH
C_6		VL	ML	M	VL, L	MH	ML	VL	M
C_7	ML	VL, L	M	MH ,H	VH	H,V H	MH	H	MH
C_8	ML	M	ML	M		MH	H	M	M
C_9	M	VL, L	ML	H	VH	H	MH	H	MH ,EH

Table 2 - Linguistic for criteria weights

Criteria	Decision makers		
	DM_1	DM_2	DM_3
C_1	VH	VH	H
C_2	MH	H	H
C_3	H	H	VH
C_4	MH	M	M
C_5	M	MH	H
C_6	M	M	M
C_7	M	M	MH
C_8	H	MH	MH
C_9	MH	M	M

Table 3 - Aggregated interval 2-tuple decision matrix and aggregated weights of criteria

Criteria	Supplier X_1	Supplier X_2	Supplier X_3	Weight
C_1	Δ[0.458, 0.458]	Δ[0.736, 0.778]	Δ[0.639, 0.639]	Δ[0.944]
C_2	Δ[0.333, 0.472]	Δ[0.611, 0.694]	Δ[0.431, 0.514]	Δ[0.778]
C_3	Δ[0.514, 0.597]	Δ[0.542, 0.542]	Δ[0.611, 0.694]	Δ[0.889]
C_4	Δ[0.292, 0.292]	Δ[0.389, 0.472]	Δ[0.208, 0.625]	Δ[0.556]
C_5	Δ[0.556, 0.556]	Δ[0.794, 0.792]	Δ[0.597, 0.653]	Δ[0.667]
C_6	Δ[0.125, 0.458]	Δ[0.375, 0.458]	Δ[0.278, 0.278]	Δ[0.500]
C_7	Δ[0.278, 0.361]	Δ[0.806, 0.903]	Δ[0.681, 0.681]	Δ[0.556]
C_8	Δ[0.403, 0.403]	Δ[0.375, 0.708]	Δ[0.611, 0.611]	Δ[0.722]
C_9	Δ[0.292, 0.375]	Δ[0.861, 0.861]	Δ[0.681, 0.806]	Δ[0.556]

Table 4 - Distance from positive and negative ideal solutions

Green Suppliers candidates	D_i^+	D_i^-	ξ_i	Ranking by proposed method	Ranking by Conventional Fuzzy TOPSIS
X_1	Δ[0.820]	Δ[0.577]	Δ[0.387]	3	3
X_2	Δ[0.640]	Δ[0.772]	Δ[0.154]	2	2
X_3	Δ[0.485]	Δ[0.697]	Δ[0.075]	1	1

Conclusion

Creating environmental performance of suppliers is significant for green supply chain management. Associations are putting resources into different green supplier development programs to upgrade their supplier performances. The choice to make the right program for green suppliers' development is frequently a challenging choice because of absence of related knowledge, restricted quantitative data, particular setting of the association, and changing supplier foundations. This paper presents a new decision model based on interval valued 2-Tuple linguistic preferences and compromise solution for evaluating green supplier's performance. For this purpose, a new decision-making process under an interval valued 2-Tuple linguistic information environment was introduced based on new version of technique for order of preference by similarity to ideal solution (TOPSIS) method. A new ranking index with interval valued 2-tuple linguistic was provided for the evaluation process of the green supplier's performance. Then, a case study from the recent literature in the manufacturing industry was solved by the proposed decision model under uncertainty. The third green supplier performance alternative was selected as the best one. The results have been confirmed and compared with the conventional fuzzy TOPSIS method.

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