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RESEARCH ARTICLE

A Novel Hybrid Multiple Attribute Decision Making Framework for Enterprise Green Marketing Performance Management Evaluation Based on the Triangular Fuzzy Neutrosophic Sets

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ABSTRACT The performance of green marketing refers to the realistic state of green marketing activities in terms of enterprise development, consumer demand and social ecological environment. These aspects are represented by the game equilibrium between green marketing subjects. The better the game equilibrium between green marketing subjects, the better the performance of green marketing. In the real market environment, this ideal balance is often broken, and green marketing activities are difficult to carry out normally, affecting the performance of green marketing. At the same time, the characteristics of green marketing performance have its particularity. On the one hand, green marketing performance cannot be formed in a short time. Once good performance is formed, this performance can play a role in a long time; On the other hand, there are many factors involved, and the quality of performance not only depends on the improvement of the social ecological environment, but also includes the achievement of enterprise goals and consumer satisfaction. The enterprise green marketing performance management evaluation is a classical multiple attribute decision making (MADM). Recently, the TODIM and TOPSIS method has been used to cope with MADM issues. The triangular fuzzy neutrosophic sets (TFNSs) are used as a tool for characterizing uncertain information during the enterprise green marketing performance management evaluation. In this manuscript, the triangular fuzzy neutrosophic TODIM-TOPSIS (TFN-TODIM-TOPSIS) method is built to solve the MADM under TFNSs. In the end, a numerical case study for enterprise green marketing performance management evaluation is given to validate the proposed method.

INDEX TERMS Multiple attribute decision making (MADM), triangular fuzzy neutrosophic sets (TFNSs), TODIM, TOPSIS, enterprise green marketing performance.

I. INTRODUCTION

Due to the different complexity of real-world decision-making problems, peoples may not be able to express their evaluations through precise number [1], [2], [3], [4], [5], [6] and the fuzzy information may conform to human expression habits and preferences [7], [8], [9]. With the increasing complexity of the MADM problems [10], [11], [12], [13], it is of great necessity to consider the DMs' psychological factors [14]. Tversky and Kahneman [15] built the prospect theory (PT) under risk. Gomes and Lima [16] built the TODIM for MADM issues under risk. Wei, Ren and Rodriguez [17] built the hesitant fuzzy linguistic TODIM method. Wei [18] built the TODIM to solve the picture fuzzy MADM. Mishra and Rani [19] built the TODIM under IVIFSs. Pramanik and Mallick [20] constructed the TODIM strategy for MAGDM in trapezoidal neutrosophic number environment. Pramanik et al. [21] constructed the TODIM for neutrosophic cubic MAGDM. Lai, Liu and Hwang [22] defined the TOPSIS method. Ye, Zhang, Wu and

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Xing [23] defined the q-Rung orthopair fuzzy TOPSIS for information service quality evaluation. Zulqarnain, Xin and Saeed [24] defined the TOPSIS method under intuitionistic fuzzy hypersoft setting. Biswas, Pramanik and Giri [25] constructed the TOPSIS method for MAGDM under single-valued neutrosophic environment. Pramanik et al. [26] constructed the TOPSIS for single valued neutrosophic soft expert set based MADM. Mondal et al. [27] constructed the TOPSIS for rough neutrosophic MAGDM. Pramanik et al. [28] constructed the TOPSIS for neutrosophic cubic MADM. Biswas et al. [29] constructed the TOPSIS for trapezoidal neutrosophic MADM. Pramanik et al. [30] constructed the Neutrosophic BWM-TOPSIS model under SVNS Environment. However, TODIM method and TOPSIS method have their own drawbacks, but Lourenzutti and Krohling [31] defined the Hellinger distance in MADM based on the TOPSIS and TODIM which combined the two methods to avoid weaknesses and avoid the limitations of single method. Lourenzutti, Krohling and Reformat [32] defined the Choquet based TOPSIS and TODIM for heterogeneous MADM. Krohling, Pacheco and dos Santos [33] defined the TODIM and TOPSIS for MADM with Z-numbers. Xu and Peng [34] defined the TODIM and TOPSIS for MADM with multi-valued neutrosophic sets. Seker and Kahraman [35] proposed the Pythagorean cubic fuzzy method based on TOPSIS and TODIM for software selection.

In the 21st century, people's consumption concept has changed. The concept of ecology environmental protection, health and sustainable development has been gradually deepened in economic activities [36], [37]. As a mainstream marketing model in the 21st century, green marketing is sweeping the world. At the International marketing Seminar held in Hong Kong in November 1992, domestic scholars first came into contact with this concept and began to study it. Chen and Chen [38] put forward a comprehensive definition of green marketing and believed that green marketing is to take corresponding measures in the whole process of product development, development, production, sales and after-sales service to achieve sustainable consumption of consumers, sustainable production of enterprises Balancing the three aspects of sustainable development for the entire society. Due to the increasingly serious global environmental problems and the strong impact of the green movement, Chinese enterprises have gradually realized the inevitable trend of the development of green marketing, introduced the concept of green marketing in marketing practice, invested a lot of human, material and financial resources, and implemented green marketing [39], [40], [41]. However, in the process of implementing green marketing, it has faced a series of challenges, such as the lack of green concept, low level of green consumption, etc. Correct understanding and evaluation of green marketing performance is related to the survival and development of enterprises. Our enterprises have a long way to go to implement green marketing [42], [43], [44]. Green marketing emphasizes the balance of sustainable consumption of consumers, sustainable production of enterprises and sustainable development of the whole society. It requires balancing the goals of promoting social harmony and sustainable development, pursuing maximum corporate profits, and meeting consumer needs; It also requires people to coordinate their immediate interests with long-term interests, and their own interests with the interests of future generations. This balanced process is actually a complex long-term game process in green marketing [45], [46]. In the game process of green marketing, the main players that enterprises participate in the game of green marketing are the government, enterprises and consumers. The government is the highest spokesman for social interests. In order to ensure the safety of human environment and the sustainable development of society and maintain ecological balance, the government has the obligation to advocate green marketing, encourage enterprises and consumers to participate in green marketing, organize, guide and supervise enterprises to implement green marketing, and create a strong atmosphere of green marketing in the whole society [47], [48]. As the implementer of green marketing, enterprises play an important role in producing green products, guiding green consumption and protecting the living environment in green marketing [49], [50]. By providing green products and services, enterprises gain public trust and support, increase market profit opportunities, and ensure their survival and development. Consumers are buyers and consumers of green products, with the purpose of obtaining satisfactory green products and services, healthy consumption, and improving the quality of the living environment. Because their responsibilities and interests in green marketing are different, their behavior is also quite different, so they are playing a fierce game in the unity of opposites. The performance of green marketing refers to the realistic state of green marketing activities in terms of enterprise development, consumer demand and social ecological environment. These aspects are represented by the game equilibrium between green marketing subjects. The better the game equilibrium between green marketing subjects, the better the performance of green marketing. In the real market environment, this ideal balance is often broken, and green marketing activities are difficult to carry out normally, affecting the performance of green marketing [51], [52], [53]. At the same time, the characteristics of green marketing performance have its particularity. On the one hand, green marketing performance cannot be formed in a short time [54], [55], [56]. Once good performance is formed, this performance can play a role in a long time; On the other hand, there are many factors involved, and the quality of performance not only depends on the improvement of the social ecological environment, but also includes the achievement of enterprise goals and consumer satisfaction. To sum up, the introduction and implementation of green marketing is based on the "win-win" of enterprises, consumers and society [57], [58], [59]. Only when the "win-win" of the three can be achieved, can enterprises achieve game balance in green marketing activities, and can enterprises improve their green marketing performance [59], [60], [61]. Therefore, to build an enterprise green marketing performance evaluation system, on the basis of green marketing performance characteristics, we should focus on the performance of green marketing activities to enterprises, consumers and society [62], [63].

The enterprise green marketing performance management evaluation is classical MADM. Recently, the TODIM method [16] and TOPSIS method [22] method has been used to cope with MADM issues. The TFNSs [64] are used as a tool for characterizing uncertain information during the enterprise green marketing performance management evaluation. In this study, two well-known MADM techniques (TODIM and TOPSIS) are integrated and constructed as a new extended hybrid MADM technique using triangular fuzzy neutrosophic sets (TFNSs) to manage complex MADM issues. The implementation process of the new hybrid MADM technique with TFNSs isn't difficult due to easy adaptable of TFNSs to the new hybrid technique. To the best of the authors' knowledge, this hybrid technique is introduced as the first time in the literature under TFNSs. TODIM is applied to handle situations where the DMs' bounded rationality is taken into consideration. TOPSIS is applied in the ranking of alternatives since it employed Euclidean distances to measure the alternatives with their positive ideal solution (PIS) and negative ideal solution (NIS). Thus, In this paper, the TFN-TODIM-TOPSIS method is designed to solve the MADM under TFNSs. In the end, a numerical case study for enterprise green marketing performance management evaluation is given to validate the proposed method.

The structure of this paper is listed below. In Section II, the TFNSs are introduced. In Section III, TFN-TODIM-TOPSIS method is designed under TFNSs with entropy. Section IV gives an illustrative case for enterprise green marketing performance management evaluation and some comparative analysis. Some remarks are given in Section V.

II. PRELIMINARIES

Biswas, Pramanik and Giri [64] designed the TFNSs.

Definition 1 ([64]): Let Θ be a fix set, the TFNSs VV are defined as:

$$VV = \{(\theta, VA(\theta), VB(\theta), VC(\theta)) | \theta \in \Theta\} \tag{1}$$

where $VA(\theta), VB(\theta), VC(\theta) \in [0,1]$ represent the truth membership, indeterminacy membership and falsity membership with triangular fuzzy numbers. (2)–(4), as shown at the bottom of the page. We let $VV = \{(VA^L, VA^M, VA^U), (VB^L, VB^M, VB^U), (VC^L, VC^M, VC^U)\}$ be a TFNN, $0 \le VA^U + VB^U + VC^U \le 3$.

Definition 2 ([64]): There are three TFNNs

$$VV_1 = \left\{\left(VA_1^L, VA_1^M, VA_1^U\right), \left(VB_1^L, VB_1^M, VB_1^U\right), \left(VC_1^L, VC_1^M, VC_1^U\right)\right\},$$
$$VV_2 = \left\{\left(VA_2^L, VA_2^M, VA_2^U\right), \left(VB_2^L, VB_2^M, VB_2^U\right), \left(VC_2^L, VC_2^M, VC_2^U\right)\right\} \text{ and}$$
$$VV = \left\{\left(VA^L, VA^M, VA^U\right), \left(VB^L, VB^M, VB^U\right), \left(VC^L, VC^M, VC^U\right)\right\},$$

the operation laws of them are designed, as shown in the equation at the bottom of the page.

$$VA(\theta) = \left(VA^L(\theta), VA^M(\theta), VA^U(\theta)\right), 0 \le VA^L(\theta) \le VA^M(\theta) \le VA^U(\theta) \le 1 \tag{2}$$
$$VB(\theta) = \left(VB^L(\theta), VB^M(\theta), VB^U(\theta)\right), 0 \le VB^L(\theta) \le VB^M(\theta) \le VB^U(\theta) \le 1 \tag{3}$$
$$VC(\theta) = \left(VC^L(\theta), VC^M(\theta), VC^U(\theta)\right), 0 \le VC^L(\theta) \le VC^M(\theta) \le VC^U(\theta) \le 1 \tag{4}$$

$$(1)\ VV_1 \oplus VV_2 = \left\{\begin{array}{l}\left(VA_1^L + VA_2^L - VA_1^L VA_2^L, VA_1^M + VA_2^M - VA_1^M VA_2^M, VA_1^U + VA_2^U - VA_1^U VA_2^U\right),\\ \left(VB_1^L VB_2^L, VB_1^M VB_2^M, VB_1^U VB_2^U\right), \left(VC_1^L VC_2^L, VC_1^M VC_2^M, VC_1^U VC_2^U\right)\end{array}\right\};$$

$$(2)\ VV_1 \otimes VV_2 = \left\{\begin{array}{l}\left(VA_1^L VA_2^L, VA_1^M VA_2^M, VA_1^U VA_2^U\right),\\ \left(VB_1^L + VB_2^L - VB_1^L VB_2^L, VB_1^M + VB_2^M - VB_1^M VB_2^M, VB_1^U + VB_2^U - VB_1^U VB_2^U\right),\\ \left(VC_1^L + VC_2^L - VC_1^L VC_2^L, VC_1^M + VC_2^M - VC_1^M VC_2^M, VC_1^U + VC_2^U - VC_1^U VC_2^U\right)\end{array}\right\};$$

$$(3)\ \lambda VV = \left\{\begin{array}{l}\left(1-\left(1-VA^L\right)^\lambda, 1-\left(1-VA^M\right)^\lambda, 1-\left(1-VA^U\right)^\lambda\right),\\ \left(\left(VB^L\right)^\lambda, \left(VB^M\right)^\lambda, \left(VB^U\right)^\lambda\right),\\ \left(\left(VC^L\right)^\lambda, \left(VC^M\right)^\lambda, \left(VC^U\right)^\lambda\right)\end{array}\right\}, \lambda > 0;$$

$$(4)\ VV^\lambda = \left\{\begin{array}{l}\left(\left(VA^L\right)^\lambda, \left(VA^M\right)^\lambda, \left(VA^U\right)^\lambda\right),\\ \left(1-\left(1-VB^L\right)^\lambda, 1-\left(1-VB^M\right)^\lambda, 1-\left(1-VB^U\right)^\lambda\right),\\ \left(1-\left(1-VC^L\right)^\lambda, 1-\left(1-VC^M\right)^\lambda, 1-\left(1-VC^U\right)^\lambda\right)\end{array}\right\}, \lambda > 0.$$

It's clear that the operation laws have following given properties (5)–(7), as shown at the bottom of the page.

Definition 3 ([64]): Let

$$VV=\left\{\begin{array}{l}\left(VA^L,VA^M,VA^U\right),\left(VB^L,VB^M,VB^U\right),\\ \left(VC^L,VC^M,VC^U\right)\end{array}\right\}$$

be a TFNN, the score and accuracy functions are:

$$SF\left(VV\right)=\frac{1}{12}\left[\begin{array}{l}8+\left(VA^L+2VA^M+VA^U\right)\\ -\left(VB^L+2VB^M+VB^U\right)\\ -\left(VC^L+2VC^M+YV^U\right)\end{array}\right],$$
$$SF\left(VV\right)\in[0,1] \tag{8}$$

$$AF\left(VV\right)=\frac{1}{4}\left[\left(VA^L+2VA^M+VA^U\right)-\left(VB^L+2VB^M+VB^U\right)\right],AF\left(VV\right)\in[-1,1] \tag{9}$$

For two TFNNs VV_1 and VV_2, based on the given Definition 3, we have as shown in the equation at the bottom of the page.

Definition 4 ([65]): Let

$$VV_1=\left\{\begin{array}{l}\left(VA_1^L,VA_1^M,VA_1^U\right),\left(VB_1^L,VB_1^M,VB_1^U\right),\\ \left(VC_1^L,VC_1^M,VC_1^U\right)\end{array}\right\}$$

$$\text{and } VV_2=\left\{\begin{array}{l}\left(VA_2^L,VA_2^M,VA_2^U\right),\left(VB_2^L,VB_2^M,VB_2^U\right),\\ \left(VC_2^L,VC_2^M,VC_2^U\right)\end{array}\right\}$$

be two TFNNs, the normalized Hamming distance is defined:

$$HD\left(VV_1,VV_2\right)=\frac{1}{9}\left(\begin{array}{l}\left|VA_1^L-VA_2^L\right|+\left|VA_1^M-VA_2^M\right|\\ +\left|VA_1^U-VA_2^U\right|+\left|VB_1^L-VB_2^L\right|\\ +\left|VB_1^M-VB_2^M\right|+\left|VB_1^U-VB_2^U\right|\\ +\left|VC_1^L-VC_2^L\right|+\left|VC_1^M-VC_2^M\right|\\ +\left|VC_1^U-VC_2^U\right|\end{array}\right) \tag{10}$$

III. TFN-TODIM-TOPSIS METHOD FOR MAGDM WITH ENTROPY WEIGHT

A. TFN-MAGDM ISSUES DESCRIPTION

In this section, TFN-TODIM-TOPSIS method is designed for MAGDM. Let $VA=\{VA_1,VA_2,\cdots,VA_m\}$ be alternatives, and the attributes set $VG=\{VG_1,VG_2,\cdots,VG_n\}$ with weight vw, where $vw_j\in[0,1]$, $\sum_{j=1}^{n}vw_j=1$ and a set of invited experts $VE=\left\{VE_1,VE_2,\cdots,VE_q\right\}$,let expert's weight be $\{v\omega_1,v\omega_2,\cdots,v\omega_t\}$.

Then, TFN-TODIM-TOPSIS is designed for MAGDM. The calculating steps are depicted:

Step 1. Build the TFNN-matrix $VV=\left[VV_{ij}\right]_{m\times n}$:

$$VV=\left[VV_{ij}\right]_{m\times n}=\begin{array}{c} \\ VA_1\\ VA_2\\ \vdots\\ VA_m\end{array}\begin{array}{c}\begin{array}{cccc}VG_1 & VG_2 & \ldots & VG_n\end{array}\\ \left[\begin{array}{cccc}VV_{11} & VV_{12} & \ldots & VV_{1n}\\ VV_{21} & VV_{22} & \ldots & VV_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ VV_{m1} & VV_{m2} & \ldots & VV_{mn}\end{array}\right]\end{array}$$

$$VV_{ij}=\left\{\begin{array}{l}\left(\left(VA_{ij}^L\right),\left(VA_{ij}^M\right),\left(VA_{ij}^U\right)\right),\\ \left(\left(VB_{ij}^L\right),\left(VB_{ij}^M\right),\left(VB_{ij}^U\right)\right),\\ \left(\left(VC_{ij}^L\right),\left(VC_{ij}^M\right),\left(VC_{ij}^U\right)\right)\end{array}\right\} \tag{11}$$

Step 2. Normalize the $VV=\left[VV_{ij}\right]_{m\times n}$ into $NV=\left[NV_{ij}\right]_{m\times n}$.

For benefit attributes:

$$NV_{ij}=\left\{\begin{array}{l}\left(\left(NVA_{ij}^L\right),\left(NVA_{ij}^M\right),\left(NVA_{ij}^U\right)\right),\\ \left(\left(NVB_{ij}^L\right),\left(NVB_{ij}^M\right),\left(NVB_{ij}^U\right)\right),\\ \left(\left(NVC_{ij}^L\right),\left(NVC_{ij}^M\right),\left(NVC_{ij}^U\right)\right)\end{array}\right\}=\left\{\begin{array}{l}\left(\left(VA_{ij}^L\right),\left(VA_{ij}^M\right),\left(VA_{ij}^U\right)\right),\\ \left(\left(VB_{ij}^L\right),\left(VB_{ij}^M\right),\left(VB_{ij}^U\right)\right),\\ \left(\left(VC_{ij}^L\right),\left(VC_{ij}^M\right),\left(VC_{ij}^U\right)\right)\end{array}\right\} \tag{12}$$

For cost attributes:

$$NV_{ij}=\left\{\begin{array}{l}\left(\left(NVA_{ij}^L\right),\left(NVA_{ij}^M\right),\left(NVA_{ij}^U\right)\right),\\ \left(\left(NVB_{ij}^L\right),\left(NVB_{ij}^M\right),\left(NVB_{ij}^U\right)\right),\\ \left(\left(NVC_{ij}^L\right),\left(NVC_{ij}^M\right),\left(NVC_{ij}^U\right)\right)\end{array}\right\}=\left\{\begin{array}{l}\left(\left(VC_{ij}^L\right),\left(VC_{ij}^M\right),\left(VC_{ij}^U\right)\right),\\ \left(\left(VB_{ij}^L\right),\left(VB_{ij}^M\right),\left(VB_{ij}^U\right)\right),\\ \left(\left(VA_{ij}^L\right),\left(VA_{ij}^M\right),\left(VA_{ij}^U\right)\right)\end{array}\right\} \tag{13}$$

$$(1)\ VV_1\oplus VV_2=VV_2\oplus VV_1,\ VV_1\otimes VV_2=VV_2\otimes VV_1,\ \left(\left(VV_1\right)^{\lambda_1}\right)^{\lambda_2}=\left(VV_1\right)^{\lambda_1\lambda_2}; \tag{5}$$

$$(2)\ \lambda\left(VV_1\oplus VV_2\right)=\lambda VV_1\oplus\lambda VV_2,\ \left(VV_1\otimes VV_2\right)^{\lambda}=\left(VV_1\right)^{\lambda}\otimes\left(VV_2\right)^{\lambda}; \tag{6}$$

$$(3)\ \lambda_1VV_1\oplus\lambda_2VV_1=\left(\lambda_1+\lambda_2\right)VV_1,\ \left(VV_1\right)^{\lambda_1}\otimes\left(VV_1\right)^{\lambda_2}=\left(VV_1\right)^{\left(\lambda_1+\lambda_2\right)}. \tag{7}$$

$$(1)\ if\ SF\left(VV_1\right)\prec SF\left(VV_2\right),\ then\ VV_1\prec VV_2;$$
$$(2)\ if\ SF\left(VV_1\right)=SF\left(VV_2\right),AF\left(VV_1\right)\prec AF\left(VV_2\right),\ then\ VV_1\prec VV_2;$$
$$(3)\ if\ SF\left(VV_1\right)=SF\left(VV_2\right),AF\left(VV_1\right)=AF\left(VV_2\right),\ then\ VV_1=VV_2.$$

B. COMPUTE THE ATTRIBUTES WEIGHT BY USING INFORMATION ENTROPY

The weight is important for MAGDM. Many scholars focused on to obtain the weight information under different environment [66], [67], [68], [69], [70]. Entropy [71] is a conventional theory to derive weight. Firstly, the normalized TFNN-matrix NNV_{ij} is obtained:

$$NNV_{ij} = \frac{SF\begin{Bmatrix}\left(\left(NVA_{ij}^{L}\right),\left(NVA_{ij}^{M}\right),\left(NVA_{ij}^{U}\right)\right),\\ \left(\left(NVB_{ij}^{L}\right),\left(NVB_{ij}^{M}\right),\left(NVB_{ij}^{U}\right)\right),\\ \left(\left(NVC_{ij}^{L}\right),\left(NVC_{ij}^{M}\right),\left(NVC_{ij}^{U}\right)\right)\end{Bmatrix}}{\sum_{i=1}^{m} SF\begin{Bmatrix}\left(\left(NVA_{ij}^{L}\right),\left(NVA_{ij}^{M}\right),\left(NVA_{ij}^{U}\right)\right),\\ \left(\left(NVB_{ij}^{L}\right),\left(NVB_{ij}^{M}\right),\left(NVB_{ij}^{U}\right)\right),\\ \left(\left(NVC_{ij}^{L}\right),\left(NVC_{ij}^{M}\right),\left(NVC_{ij}^{U}\right)\right)\end{Bmatrix}}, \tag{14}$$

Then, the Shannon entropy $TFNSE = (TFNSE_1, TFNSE_2, \cdots, TFNSE_n)$ is derived by Eq. (15):

$$TFNSE_j = -\frac{1}{\ln m}\sum_{i=1}^{m} NNV_{ij}\ln NNV_{ij} \tag{15}$$

and $NNV_{ij}\ln NNV_{ij} = 0$ if $NNV_{ij} = 0$.

Then, the weights $vw = (vw_1, vw_2, \cdots, vw_n)$ is derived:

$$vw_j = \frac{1 - TFNSE_j}{\sum_{j=1}^{n}\left(1 - TFNSE_j\right)}, \quad j = 1, 2, \cdots, n. \tag{16}$$

C. TFN-TODIM-TOPSIS METHOD FOR MAGDM

In such section, the TFN-TODIM-TOPSIS method is built for MAGDM.

(1) Define relative weight of VG_j as:

$$rvw_j = vw_j \big/ vw_j^*, \tag{17}$$

vw_j^* is the maximum weight of the attributes, and $0 \le vw_j \le 1$.

(2) The dominance degree $VDD_j(VA_i, VA_t)$ of VA_i over VA_t for VG_j is obtained with Eqs.(18), as shown at the bottom of the page. The values of α, β is determined according to the Ref [15].

The dominance degree matrix $VDD_j(VA_i)$ $(j = 1, 2, \cdots, n)$ with respect to VG_j is defined, as shown in the equation at the bottom of the page, where the parameter θ means the risk factor for the gain and loss.

(3) Produce the overall dominance degree of VA_i over other ones for VG_j:

$$VDD_j(VA_i) = \sum_{t=1}^{m} VDD_j(VA_i, VA_t) \tag{19}$$

with all dominance degree of VG_j calculated, the overall dominance matrix is defined, as shown in the equation at the bottom of the page.

(4) Produce the TFN positive ideal solution (TFNPIS) and TFN negative ideal solution (TFNNIS):

$$TFNPIS = (TFNPIS_1, TFNPIS_1, \cdots, TFNPIS_n) \tag{20}$$

$$TFNNIS = (TFNNIS_1, TFNNIS_1, \cdots, TFNNIS_n) \tag{21}$$

$$TFNPIS_j = \max_{j=1}^{n} VDD_{ij}, TFNNIS_j = \min_{j=1}^{n} VDD_{ij} \tag{22}$$

$$VDD_j(VA_i, VA_t) = \begin{cases} \dfrac{rvw_j \times \left(HD\left(NY_{ij}, NY_{tj}\right)\right)^{\alpha}}{\sum_{j=1}^{n} rvw_j} & \text{if } SF\left(NV_{ij}\right) > SF\left(NV_{tj}\right) \\ 0 & \text{if } SF\left(NV_{ij}\right) = SF\left(NV_{tj}\right) \\ -\dfrac{1}{\theta}\dfrac{\sum_{j=1}^{n} rvw_j \times \left(HD\left(NY_{ij}, NY_{tj}\right)\right)^{\beta}}{rvw_j} & \text{if } SF\left(NV_{ij}\right) < SF\left(NV_{tj}\right) \end{cases} \tag{18}$$

$$VDD_j(VA_i) = \left[VDD_j(VA_i, VA_t)\right]_{m\times m}$$

$$= \begin{array}{c} \\ VA_1 \\ VA_2 \\ \vdots \\ VA_m \end{array} \begin{array}{c} \begin{array}{cccc} VA_1 & VA_2 & \cdots & VA_m \end{array} \\ \begin{bmatrix} 0 & VDD_j(VA_1, VA_2) & \cdots & VDD_j(VA_1, VA_m) \\ VDD_j(VA_2, VA_1) & 0 & \cdots & VDD_j(VA_2, VA_m) \\ \vdots & \vdots & \cdots & \vdots \\ VDD_j(VA_m, VA_1) & VDD_j(VA_m, VA_2) & \cdots & 0 \end{bmatrix} \end{array}$$

$$VDD = \left(VDD_{ij}\right)_{m\times n} = \begin{bmatrix} & VG_1 & VG_2 & \cdots & VG_n \\ VA_1 & \sum_{t=1}^{m} VDD_1(VA_1, VA_t) & \sum_{t=1}^{m} VDD_2(VA_1, VA_t) & \cdots & \sum_{t=1}^{m} VDD_n(VA_1, VA_t) \\ VA_2 & \sum_{t=1}^{m} VDD_1(VA_2, VA_t) & \sum_{t=1}^{m} VDD_2(VA_2, VA_t) & \cdots & \sum_{t=1}^{m} VDD_n(VA_2, VA_t) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ VA_m & \sum_{t=1}^{m} VDD_1(VA_m, VA_t) & \sum_{t=1}^{m} VDD_2(VA_m, VA_t) & \cdots & \sum_{t=1}^{m} VDD_n(VA_m, VA_t) \end{bmatrix}$$

TABLE 1. The TFNN information.

	VG_1	VG_2
VA_1	$\{(0.45,0.59,0.71),(0.26,0.39,0.67),(0.28,0.45,0.59)\}$	$\{(0.56,0.72,0.83),(0.36,0.45,0.57),(0.29,0.32,0.45)\}$
VA_2	$\{(0.39,0.52,0.78),(0.27,0.48,0.59),(0.36,0.47,0.69)\}$	$\{(0.63,0.74,0.82),(0.49,0.51,0.63),(0.59,0.65,0.73)\}$
VA_3	$\{(0.37,0.56,0.83),(0.43,0.58,0.71),(0.36,0.47,0.53)\}$	$\{(0.43,0.56,0.67),(0.23,0.41,0.52),(0.39,0.52,0.65)\}$
VA_4	$\{(0.25,0.36,0.63),(0.22,0.34,0.61),(0.19,0.31,0.65)\}$	$\{(0.43,0.52,0.63),(0.53,0.61,0.72),(0.38,0.49,0.56)\}$
VA_5	$\{(0.45,0.53,0.72),(0.49,0.51,0.67),(0.29,0.33,0.51)\}$	$\{(0.35,0.53,0.62),(0.47,0.63,0.74),(0.46,0.52,0.65)\}$
	VG_3	VG_4
VA_1	$\{(0.34,0.45,0.51),(0.36,0.62,0.76),(0.39,0.43,0.61)\}$	$\{(0.43,0.54,0.67),(0.37,0.46,0.58),(0.46,0.61,0.74)\}$
VA_2	$\{(0.19,0.32,0.43),(0.23,0.46,0.58),(0.56,0.61,0.73)\}$	$\{(0.17,0.31,0.45),(0.45,0.51,0.66),(0.65,0.74,0.79)\}$
VA_3	$\{(0.27,0.51,0.63),(0.45,0.51,0.62),(0.43,0.52,0.65)\}$	$\{(0.36,0.43,0.56),(0.37,0.46,0.53),(0.29,0.43,0.52)\}$

TABLE 1. *(Continued.)* The TFNN information.

VA_4	$\left\{\begin{array}{l}(0.63,0.71,0.82),\\(0.66,0.74,0.81),\\(0.59,0.63,0.73)\end{array}\right\}$	$\left\{\begin{array}{l}(0.58,0.62,0.74),\\(0.39,0.45,0.62),\\(0.32,0.42,0.51)\end{array}\right\}$
VA_5	$\left\{\begin{array}{l}(0.43,0.61,0.74),\\(0.53,0.62,0.71),\\(0.26,0.33,0.62)\end{array}\right\}$	$\left\{\begin{array}{l}(0.43,0.46,0.52),\\(0.37,0.43,0.52),\\(0.26,0.38,0.43)\end{array}\right\}$

(5) Calculate the Euclidean distance and the TFN closeness coefficient (TFNCC) to the TFNPIS. The alternative has the maximum TFNCC value named as the most desirable alternative.

$$TFNED\,(VA_i, TFNPIS) = \sqrt{\sum_{j=1}^{n}\left(VDD_{ij} - TFNPIS_j\right)^2} \tag{23}$$

$$TFNED\,(VA_i, TFNNIS) = \sqrt{\sum_{j=1}^{n}\left(VDD_{ij} - TFNNIS_j\right)^2} \tag{24}$$

$$TFNCC\,(VA_i, TFNPIS) = \frac{TFNED\,(VA_i, TFNNIS)}{TFNED\,(VA_i, TFNPIS) + TFNED\,(VA_i, TFNPIS)} \tag{25}$$

IV. AN EMPIRICAL EXAMPLE AND COMPARATIVE ANALYSIS

A. AN EMPIRICAL EXAMPLE

The concept of green marketing is a new marketing concept that emerged in the 1980s to meet the requirements of social and economic sustainable development. Under the requirements of the concept of sustainable development of human society, enterprises take corresponding measures to guide and meet the green consumption of consumers in the whole process of product development, development, production, sales and after-sales service from the perspective of social responsibility, environmental protection, full use of resources, etc, Activities that promote sustainable production of enterprises and achieve their marketing goals. In recent years, Chinese enterprises have introduced the concept of green marketing in marketing practice, invested a lot of human, material and financial resources, and implemented green marketing. However, the performance of green marketing is often lack of systematic evaluation and control. Therefore, the evaluation index system of enterprises' green marketing performance is constructed, and green marketing performance is evaluated and controlled accordingly, so as to scientifically guide enterprises' green marketing activities, Improving the performance of green marketing is one of the important tasks for modern enterprises to implement green marketing strategies. For traditional enterprise marketing performance, it is often required that the marketing investment of the enterprise be as low as possible, while the marketing output indicators such as sales volume, sales volume, and market share should be as high as possible. However, the enterprise's green marketing performance has greater particularity. On the one hand, the investment scope of green marketing is larger. The investment of green marketing activities not only includes the marketing budget of enterprises to sell products and expand the market (enterprises generally hope that the less the investment is, the better or appropriate), but also includes the green consumption demand of consumers to meet the sustainable development of social economy, environmental protection and sustainable use of resources The increased investment for the long-term development goals of the enterprise and various compensations to reduce the adverse impact of marketing activities on stakeholders (in the game process between the enterprise and stakeholders, stakeholders generally require the enterprise to increase this investment as much as possible). On the other hand, the output of green marketing has multiple objectives. The output of green marketing should not only pursue the maximization of market goals such as higher corporate profits and market share, but also achieve the social performance and environmental performance goals such as the minimum adverse impact of corporate marketing activities on stakeholders, and pursue the immediate marketing behavior and long-term marketing strategy of enterprises and social, economic, ecological, environmental The organic coordination of resource utilization and its positive impact on the long-term development of enterprises. The enterprise green marketing performance management evaluation is a classical MADM issue. Therefore, the enterprise green marketing performance management evaluation is presented to demonstrate the approach developed in this paper. There is a panel with five potential express enterprises $VA_i\,(i = 1, 2, 3, 4, 5)$ to choose. The experts select four

TABLE 2. The normalized TFNN information.

	VG_1	VG_2
VA_1	$\{(0.45,0.59,0.71),(0.26,0.39,0.67),(0.28,0.45,0.59)\}$	$\{(0.56,0.72,0.83),(0.36,0.45,0.57),(0.29,0.32,0.45)\}$
VA_2	$\{(0.39,0.52,0.78),(0.27,0.48,0.59),(0.36,0.47,0.69)\}$	$\{(0.63,0.74,0.82),(0.49,0.51,0.63),(0.59,0.65,0.73)\}$
VA_3	$\{(0.37,0.56,0.83),(0.43,0.58,0.71),(0.36,0.47,0.53)\}$	$\{(0.43,0.56,0.67),(0.23,0.41,0.52),(0.39,0.52,0.65)\}$
VA_4	$\{(0.25,0.36,0.63),(0.22,0.34,0.61),(0.19,0.31,0.65)\}$	$\{(0.43,0.52,0.63),(0.53,0.61,0.72),(0.38,0.49,0.56)\}$
VA_5	$\{(0.45,0.53,0.72),(0.49,0.51,0.67),(0.29,0.33,0.51)\}$	$\{(0.35,0.53,0.62),(0.47,0.63,0.74),(0.46,0.52,0.65)\}$

	VG_3	VG_4
VA_1	$\{(0.34,0.45,0.51),(0.36,0.62,0.76),(0.39,0.43,0.61)\}$	$\{(0.43,0.54,0.67),(0.37,0.46,0.58),(0.46,0.61,0.74)\}$
VA_2	$\{(0.19,0.32,0.43),(0.23,0.46,0.58),(0.56,0.61,0.73)\}$	$\{(0.17,0.31,0.45),(0.45,0.51,0.66),(0.65,0.74,0.79)\}$

TABLE 2. *(Continued.)* The normalized TFNN information.

VA_3	$\begin{Bmatrix}(0.27,0.51,0.63),\\(0.45,0.51,0.62),\\(0.43,0.52,0.65)\end{Bmatrix}$	$\begin{Bmatrix}(0.36,0.43,0.56),\\(0.37,0.46,0.53),\\(0.29,0.43,0.52)\end{Bmatrix}$
VA_4	$\begin{Bmatrix}(0.63,0.71,0.82),\\(0.66,0.74,0.81),\\(0.59,0.63,0.73)\end{Bmatrix}$	$\begin{Bmatrix}(0.58,0.62,0.74),\\(0.39,0.45,0.62),\\(0.32,0.42,0.51)\end{Bmatrix}$
VA_5	$\begin{Bmatrix}(0.43,0.61,0.74),\\(0.53,0.62,0.71),\\(0.26,0.33,0.62)\end{Bmatrix}$	$\begin{Bmatrix}(0.43,0.46,0.52),\\(0.37,0.43,0.52),\\(0.26,0.38,0.43)\end{Bmatrix}$

TABLE 3. The VDD matrix $VDD = (VDD_{ij})_{5\times4}$.

	VG_1	VG_2	VG_3	VG_4
VA_1	-0.3922	-0.9955	-0.0113	-0.7622
VA_2	0.2729	0.8085	-0.3904	-0.1624
VA_3	0.3577	0.2211	-1.3066	0.2927
VA_4	0.7568	0.6278	-0.3237	-0.3305
VA_5	-0.8789	-0.8433	0.6319	-0.6146

TABLE 4. The TFNPIS and TFNNIS.

	VG_1	VG_2	VG_3	VG_4
TFNPIS	0.7568	0.8085	0.6319	0.2927
TFNNIS	-0.8789	-0.9955	-1.3066	-0.7622

attributes to assess the five potential express enterprises: ① VG_1 is enterprise performance; ② VG_2 is ecological environment performance; ③VG_3 is consumer performance; ④VG_4 is social performance. All are beneficial one. The five possible express enterprises VA_i $(i = 1, 2, 3, 4, 5)$ are to be evaluated with TFNNs with the four criteria. The TFN-TODIM-TOPSIS method is used to solve the enterprise green marketing performance management evaluation.

Step 1. Build the TFNN matrix $VV = [VV_{ij}]_{5\times4}$ (See Table 1).

Step 2. Normalize the matrix $VV = [VV_{ij}]_{5\times4}$ to $NV = [NV_{ij}]_{5\times4}$(See Table 2).

Step 3. Compute the weight:

$vw_1 = 0.1877, vw_2 = 0.3145, vw_3 = 0.2623, vw_4 = 0.2355.$

Step 4. Produce the relative weight:

$rvw = \{0.5968, 1.0000, 0.8340, 0.7488\}$

TABLE 5. The $TFNED(VA_i, TFNPIS)$, $TFNED(VA_i, TFNNIS)$ and $TFNCC(VA_i, TFNPIS)$.

Alternative	$TFNED(VA_i, TFNPIS)$	$TFNED(VA_i, TFNNIS)$	$TFNCC(VA_i, TFNPIS)$	Order
VA_1	2.4700	1.3837	0.3591	5
VA_2	1.2192	2.4042	0.6635	2
VA_3	2.0645	2.0303	0.4958	3
VA_4	1.1551	2.5423	0.6876	1
VA_5	2.4954	1.9501	0.4387	4

TABLE 6. Order of different methods.

	Ordering
TFNNWA operator[64]	$VA_4 > VA_2 > VA_3 > VA_5 > VA_1$
TFNNWG operator[64]	$VA_4 > VA_2 > VA_5 > VA_3 > VA_1$
TFN-VIKOR method [72]	$VA_4 > VA_2 > VA_3 > VA_5 > VA_1$
TFN-MABAC method [65]	$VA_4 > VA_2 > VA_3 > VA_5 > VA_1$
TFN-EDAS method [73]	$VA_4 > VA_2 > VA_3 > VA_5 > VA_1$

Step 5. Obtain the VDD matrix $VDD = \left(VDD_{ij}\right)_{5\times4}$(See table 3):

Step 6. Calculate the TFNPIS and TFNNIS (See table 4).

Step 7. Calculate the $TFNED(VA_i, TFNPIS)$, $TFNED(VA_i, TFNNIS)$ and $TFNCC(VA_i, TFNPIS)$ (See table 5).

Thus, the best of alternatives is VA_4.

B. COMPARATIVE ANALYSIS

Then, the TFN-TODIM-TOPSIS method is compared with TFNNWA operator and TFNNWG operator [64], TFN-VIKOR [72], TFN-MABAC [65] and TFN-EDAS [73]. The comparative decision results are shown in Table 6.

From the above detailed analysis, it could be seen that these six decision models have the same optimal choice and these five methods' order are slightly different. This verifies the TFN-TODIM-TOPSIS method is reasonable and effective. Thus, the main advantages of the proposed TFN-TODIM-TOPSIS method are outlined: (1) the proposed TFN-TODIM-TOPSIS not only handles the uncertainty in real MADM issues, but also portrays the DMs' psychological behavior during the enterprise green marketing performance management evaluation. (2) the proposed TFN-TODIM-TOPSIS analyze the behavior of the TODIM and TOPSIS as MADM methods when they are hybridized.

V. CONCLUSION

The check and balance mechanism of the enterprise's green marketing performance system refers to a kind of interdependent and mutually restricting force between the various elements that constitute the green marketing performance system. This force keeps the green marketing performance system in constant motion, while maintaining a certain stability of the movement. The environmental supersystem of enterprise green marketing is in the position of external control and guidance. The marketing activities of enterprises should first follow its requirements and internalize it into the enterprise's green marketing concept. At the same time, the operation of the green marketing performance system has an impact on the environmental supersystem. The environmental supersystem should constantly put forward new requirements for the enterprise's green marketing activities to correct the enterprise's green marketing activities; The concept system of green marketing is at the criterion level within the whole green marketing performance system, which guides the implementation system and control system of green marketing and is the criterion that must be followed by enterprise marketing activities; The green marketing execution system and control system are specific actions taken under the guidance of the green marketing concept, and their effects further strengthen and solidify the enterprise's green marketing concept; At the same time, there is also a certain relationship between the implementation system of green marketing and the control system. The implementation effect of the green marketing implementation system directly affects the input of the control system. The better the implementation effect is, the smaller the control input is; On the contrary, the control system is the feedback to the execution system, and the quality of the control effect affects the execution effect of the next phase. Such repeated cycles have formed a benign operation of the enterprise's green marketing performance system and continuously improved the enterprise's green marketing performance. The enterprise green marketing performance management evaluation is MADM. Recently, the TODIM-TOPSIS method has been used to solve MADM. The TFNSs are used as a tool for characterizing uncertain information during the enterprise green marketing performance management evaluation. In this manuscript, we design the TFN-TODIM-TOPSIS model to solve the MADM under TFNSs. finally, a numerical case study for enterprise green marketing performance management evaluation is given to validate the proposed method. This study may have some limitations which should be explored in our future studies:(1) The MADM techniques proposed haven't investigate the consensus issues of DMs and applied consensus theory to MAGDM with TFNSs is a worthwhile research topic [74], [75], [76]; (2) In subsequent decision studies, the MADM techniques of TFNSs need to be investigated in any other uncertain environment [77], [78], [79], [80], [81], [82].

Compliance with ethical standards

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Conflict of interest

The authors declare that they have no conflict of interest.

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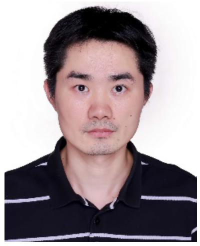

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