SVNN-ExpTODIM Technique for Maturity Evaluation of Digital Transformation in Retail Enterprises Under Single-Valued Neutrosophic Sets

Xiaoling Yang*
Fujian Polytechnic of Information Technology, Fujian, 350000, China

***Abstract*—The digital economy has become an important force driving the transformation of old and new driving forces in China's economy, and also provides an opportunity for retail enterprises to "overtake" by changing lanes. The evaluation of the maturity of digital transformation in retail enterprises plays an important role in their digital transformation process. Although more and more retail enterprises are realizing the important role of digital transformation in their own development, the digital transformation of retail enterprises is a complex issue that involves all aspects of retail enterprise management. There are still many retail enterprises that lack clear strategic goals and practical paths, as well as effective supporting assessments and institutional incentives in the process of digital transformation, which may further widen the digital level gap between retail enterprises. The maturity evaluation of digital transformation in retail enterprises is multiple-attribute group decision-making (MAGDM). Recently, the Exponential TODIM (ExpTODIM) technique was employed to cope with MAGDM. The single-valued neutrosophic sets (SVNSs) are presented as decision tool for characterizing fuzzy information during the maturity evaluation of digital transformation in retail enterprise. In this study, the single-valued neutrosophic number Exponential TODIM (SVNN-ExpTODIM) technique is presented to solve the MAGDM under SVNSs. At last, numerical study for maturity evaluation of digital transformation in retail enterprise is presented to validate the SVNN-ExpTODIM technique through comparative analysis.**

Keywords*—Multiple-attribute group decision-making (MAGDM); single-valued neutrosophic sets (SVNSs); information entropy; exponential TODIM; maturity evaluation of digital transformation

I. INTRODUCTION

At the G20 Summit held in Hangzhou, China in 2016, the Group of 20 members of the Forum on International Economic Cooperation proposed the concept of "digital economy". According to the level of digitization, the "digital economy" can be divided into three stages: digital information stage, digital business stage, and digital transformation stage [1-3]. The transformation of digital technology is a new stage in the current development of the digital economy [4-7]. Exponential digitization not only expands new opportunities for economic development and is conducive to sustainable economic development, but also promotes the transformation of traditional industries and the transformation of the entire society [8-11]. However, the current challenges faced by the traditional retail industry still exist. The emergence of e-commerce has led to a decrease in customer loyalty. The availability of information channels enables enterprises to have a wider range of communication channels and promotes consumer switching and brand re-selection [12-14]. On a broader environmental level, the global economic recovery is weak, and China's economy is undergoing structural adjustments [15-17]. This directly affects the stable relationship between upstream enterprises and downstream retailers. When there are severe fluctuations, there is considerable uncertainty in the total cost, profitability, and operational difficulty of retailers [12-14, 18-20]. The application of maturity model is to describe the current situation of an organization and indicate the future development direction [21-23]. Maturity model can provide a quantitative description of the process of development and maturity of things [24-26]. The digital maturity model of retail enterprises is a measure that reflects the degree of digital transformation of retail enterprises [27-29]. As the digital maturity of retail enterprises increases, the focus of their digital transformation work also varies. The establishment of a digital maturity model aims to help enterprises understand the level of digital operation within their own enterprises, refer to the practical standards that need to be achieved at higher levels, and improve their digital level in various dimensions [30-32]. This way, enterprises can optimize and manage the transformation process in a targeted manner based on their own shortcomings and needs. In the process of enhancing the digital capabilities of enterprises, they should first have an objective understanding of their own digital level[33, 34], and evaluate their development status and ability level from various dimensions; Next, compare the maturity model to determine the key areas and path methods for improvement, and finally implement improvement and transformation to enhance the digital maturity level of the enterprise itself. The emergence of e-commerce enterprises has brought enormous pressure to many traditional retail enterprises [35-37]. The dual decline in commodity prices and consumer traffic has forced retail enterprises to pay attention to the impact and impact of e-commerce, and hope to smoothly transform using digital technology. Early transformation and development focused on the combination of online and offline techniques [38-40]. In recent years, with the popularization and development of new technologies, such as big data, cloud computing and artificial intelligence, retail enterprises have seen new directions for transformation. It can be seen that with the development of "Internet plus" and wide application

*Corresponding Author.

of big data, digital transformation of traditional enterprises is the general trend of future business development.

MAGDM refers to the process in which multiple decision-makers rank and select limited options under various evaluation attributes [41-46]. Due to its ability to evaluate objectives from multiple dimensions and fully utilizing group intelligence, it has been widely applied to many practical decision-making issues such as supplier selection, community epidemic prevention management, and evaluation of waste power battery recycling technology [47-55]. Therefore, conducting in-depth research on it has significant practical significance. However, some MAGDM methods use a single type of isomorphic information for decision modeling, but the heterogeneity of decision-makers and evaluation attributes makes it difficult for single type isomorphic information to meet the needs of accurate description and decision-making of attribute values [56-59]. Therefore, using different fuzzy information such as model information is more in line with the reality of MAGDM. The maturity evaluation of digital transformation in retail enterprise is MAGDM. Recently, ExpTODIM technique ExpTODIM [60, 61] was presented to put forward MAGDM. The SVNSs [62-70] are presented as decision tool for characterizing fuzzy information during the maturity evaluation of digital transformation in retail enterprise. In this study, the SVNN-ExpTODIM approach is presented to put forward MAGDM under SVNSs. At last, numerical study for maturity evaluation of digital transformation in retail enterprise is presented to validate the SVNN-ExpTODIM through comparative analysis. The main research motivation and goal of this study is presented: (1) Entropy technique is presented to obtain the weight with SVNSs; (2) SVNN-ExpTODIM approach is presented to put forward the MAGDM under SVNSs; (3) Finally, numerical study for maturity evaluation of digital transformation in retail enterprise is presented and (4) serval comparisons are presented to show the SVNN-ExpTODIM approach.

The structure of this study is presented. In Section II, the SVNSs is introduced. In Section III, SVNN-ExpTODIM technique is presented for MAGDM under SVNSs with entropy. Section IV presents numerical study for maturity evaluation of digital transformation in retail enterprise through comparative analysis. Final remarks are presented in Section V.

II. Preliminaries

Wang et al. [62] presented the SVNSs

Definition 1 [62]. The SVNSs is presented:

$$RA=\left\{\left(\phi,RT_A(\phi),RI_A(\phi),RF_A(\phi)\right)\middle|\phi\in\Phi\right\} \tag{1}$$

where $RT_A(\phi),RI_A(\phi),RF_A(\phi)$ presents truth-membership, indeterminacy-membership and falsity-membership, $RT_A(\phi),RI_A(\phi),RF_A(\phi)\in[0,1]$ and meets $0\le RT_A(\phi)+RI_A(\phi)+RF_A(\phi)\le 3$.

The single-valued neutrosophic number (SVNN) is presented as: $RA=(RT_A,RI_A,RF_A)$, $RT_A,RI_A,RF_A\in[0,1]$, and $0\le RT_A+RI_A+RF_A\le 3$.

Definition 2 [71]. Let $RA=(RT_A,RI_A,RF_A)$ be SVNN, a score value is presented:

$$SV(RA)=\frac{(2+RT_A-RI_A-RF_A)}{3},\ SV(RA)\in[0,1] \tag{2}$$

Definition 3[71]. Let $RA=(RT_A,RI_A,RF_A)$ be SVNN, accuracy value is presented:

$$AV(PA)=PT_A-PF_A,\ AV(RA)\in[-1,1] \tag{3}$$

Peng et al. [71] presented the order for SVNNs.

Definition 4[71]. Let $RA=(RT_A,RI_A,RF_A)$ and $RB=(RT_B,RI_B,RF_B)$ be SVNNs, $SV(RA)=\frac{(2+RT_A-RI_A-RF_A)}{3}$ and $SV(RB)=\frac{(2+RT_B-RI_B-RF_B)}{3}$, and $AV(PA)=PT_A-PF_A$ and $AV(RB)=RT_B-RF_B$, then if $SV(RA)<SV(RB)$, then $RA<RB$; if $SV(RA)=SV(RB)$, then (1)if $AV(RA)=AV(RB)$, then $RA=RB$; (2) if $AV(RA)>AV(RB)$, then $RA<RB$.

Definition 5[62]. Let $RA=(RT_A,RI_A,RF_A)$ and $RB=(RT_B,RI_B,RF_B)$ be SVNNs, the operations are presented:

(1) $PA\oplus PB=(PT_A+PT_B-PT_APT_B,PI_API_B,PF_APF_B)$;

(2) $PA\otimes PB=(PT_APT_B,PI_A+PI_B-PI_API_B,PF_A+PF_B-PF_APF_B)$;

(3) $\lambda PA=\left(1-(1-PT_A)^\lambda,(PI_A)^\lambda,(PF_A)^\lambda\right),\lambda>0$;

(4) $(PA)^\lambda=\left((PT_A)^\lambda,(PI_A)^\lambda,1-(1-PF_A)^\lambda\right),\lambda>0.$

Definition 6[72]. Let $RA=(RT_A, RI_A, RF_A)$ and $RB=(RT_B, RI_B, RF_B)$, then the Hamming distance is presented:

$$HD(RA, RB)=\frac{|RT_A-RT_B|+|RI_A-RI_B|+|RF_A-RF_B|}{3} \quad (4)$$

The SVNNWA and SVNNWG technique is presented:

Definition 7[71]. Let $RA_j=(RT_j, RI_j, RF_j)$ be SVNNs, the SVNNWA technique is presented:

$$\begin{aligned}&\text{SVNNWA}_{rw}(RA_1, RA_2, \ldots, RA_n)\\ &=rw_1RA_1 \oplus rw_2RA_2 \ldots \oplus rw_nRA_n=\mathop{\oplus}_{j=1}^{n} rw_jRA_j\\ &=\left(1-\prod_{j=1}^{n}\left(1-RT_{ij}\right)^{rw_j}, \prod_{k=1}^{l}\left(RF_{ij}\right)^{rw_j}, \prod_{k=1}^{l}\left(RT_{ij}\right)^{rw_j}\right)\end{aligned} \quad (5)$$

where $rw=(rw_1, rw_2, ..., rw_n)^T$ be weight of RA_j, $rw_j>0, \sum_{j=1}^{n} rw_j=1.$

Definition 8[71]. Let $RA_j=(RT_j, RI_j, RF_j)$ be SVNNs, the SVNNWG technique is:

$$\begin{aligned}&\text{SVNNWG}_{rw}(RA_1, RA_2, \ldots, RA_n)\\ &=(RA_1)^{rw_1} \otimes (RA_2)^{rw_2}, \ldots \otimes (RA_n)^{rw_n}=\mathop{\otimes}_{j=1}^{n}(RA_j)^{rw_j}\\ &=\left(\prod_{j=1}^{n}\left(RT_{ij}\right)^{rw_j}, 1-\prod_{k=1}^{l}\left(1-RF_{ij}^k\right)^{rw_j}, 1-\prod_{k=1}^{l}\left(1-RT_{ij}^k\right)^{rw_j}\right)\end{aligned} \quad (6)$$

where $rw=(rw_1, rw_2, ..., rw_n)^T$ be weight of RA_j, $rw_j>0, \sum_{j=1}^{n} rw_j=1.$

III. SVNN-ExpTODIM Technique for MAGDM with Entropy Weight

A. SVNN-MAGDM Issues

The SVNN-ExpTODIM technique is presented for MAGDM. Let $RA=\{RA_1, RA_2, \cdots, RA_m\}$ be alternatives, and $RG=\{RG_1, RG_2, \cdots, RG_n\}$ be attributes with weight $r\omega$, where $r\omega_j \in [0,1]$, $\sum_{j=1}^{n} r\omega_j=1$ and invited experts $RE=\{RE_1, RE_2, \cdots, RE_q\}$ with expert's weight $rw=\{rw_1, rw_2, \cdots, rw_t\}$, where $rw_j \in [0,1]$, $\sum_{k=1}^{t} rw_k=1$.

Then, SVNN-ExpTODIM technique is presented for MAGDM.

1) Present the SVNN-matrix $RM^t=\left[RM_{ij}^t\right]_{m\times n}=\left(RT_{ij}^t, RI_{ij}^t, RF_{ij}^t\right)_{m\times n}$ and average matrix $RM=\left[RM_{ij}\right]_{m\times n}$:

$$RM^t=\left[RM_{ij}^t\right]_{m\times n}=\begin{array}{c}\\ RA_1\\ RA_2\\ \vdots\\ RA_m\end{array}\begin{array}{c}\begin{array}{cccc}RG_1 & RG_2 & \ldots & RG_n\end{array}\\ \begin{bmatrix}RM_{11}^t & RM_{12}^t & \ldots & RM_{1n}^t\\ RM_{21}^t & RM_{22}^t & \ldots & RM_{2n}^t\\ \vdots & \vdots & \vdots & \vdots\\ RM_{m1}^t & RM_{m2}^t & \ldots & RM_{mn}^t\end{bmatrix}\end{array} \quad (7)$$

$$RM=\left[RM_{ij}\right]_{m\times n}=\begin{array}{c}\\ RA_1\\ RA_2\\ \vdots\\ RA_m\end{array}\begin{array}{c}\begin{array}{cccc}RG_1 & RG_2 & \ldots & RG_n\end{array}\\ \begin{bmatrix}RM_{11} & RM_{12} & \ldots & RM_{1n}\\ RM_{21} & RM_{22} & \ldots & RM_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ RM_{m1} & RM_{m2} & \ldots & RM_{mn}\end{bmatrix}\end{array} \quad (8)$$

Based on SVNNWA, the $RM=\left[RM_{ij}\right]_{m\times n}=\left(RT_{ij}, RI_{ij}, RF_{ij}\right)_{m\times n}$ is presented:

$$\begin{aligned}RM_{ij}&=rw_1RM_{ij}^1 \oplus rw_2RM_{ij}^2 \oplus \cdots \oplus rw_tRM_{ij}^t\\ &=\left(1-\prod_{k=1}^{t}\left(RT_{ij}^t\right)^{rw_j}, \prod_{k=1}^{t}\left(RI_{ij}^t\right)^{rw_j}, \prod_{k=1}^{t}\left(RF_{ij}^t\right)^{rw_j}\right)\end{aligned} \quad (9)$$

2) Normalize the $RM=\left[RM_{ij}\right]_{m\times n}=\left(RT_{ij}, RI_{ij}, RF_{ij}\right)_{m\times n}$ into $RM^N=\left[RM_{ij}^N\right]_{m\times n}=\left(RT_{ij}^N, RI_{ij}^N, RF_{ij}^N\right)_{m\times n}$.

For benefit attributes:

$$RM_{ij}^N=\left(RT_{ij}^N, RI_{ij}^N, RF_{ij}^N\right)=RM_{ij}=\left(RT_{ij}, RI_{ij}, RF_{ij}\right) \quad (10)$$

For cost attributes:

$$RM_{ij}^N=\left(RT_{ij}^N, RI_{ij}^N, RF_{ij}^N\right)=\left(RF_{ij}, RI_{ij}, RT_{ij}\right) \quad (11)$$

B. Compute the Attributes Weight by using Information Entropy

Entropy [73] is presented to derive weight. Firstly, the normalized SVNN-matrix $RSVNNM_{ij}$ is presented:

$$RSVNNM_{ij} = \frac{\dfrac{\dfrac{AV\left(NPT_{ij}, NPI_{ij}, NPF_{ij}\right)+1}{2}}{\dfrac{SV\left(NPT_{ij}, NPI_{ij}, NPF_{ij}\right)+1}{2}}}{\sum_{i=1}^{m}\left(\dfrac{\dfrac{AV\left(NPT_{ij}, NPI_{ij}, NPF_{ij}\right)+1}{2}}{\dfrac{SV\left(NPT_{ij}, NPI_{ij}, NPF_{ij}\right)+1}{2}}\right)}, \quad (12)$$

Then, the SVNN Shannon entropy (SVNNSE) is presented:

$$SVNNSE_j = -\frac{1}{\ln m}\sum_{i=1}^{m} RSVNNM_{ij} \ln RSVNNM_{ij} \quad (13)$$

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

Then, the weight information $r\omega = \left(r\omega_1, r\omega_2, \cdots, r\omega_n\right)$ is presented:

$$r\omega_j = \frac{1 - SVNNSE_j}{\sum_{j=1}^{n}\left(1 - SVNNSE_j\right)}, \quad j = 1, 2, \cdots, n. \quad (14)$$

C. SVNN-ExpTODIM Approach for MAGDM

The SVNN-ExpTODIM approach is presented for MAGDM.

1) Present relative weight of PG_j:

$$rr\omega_j = r\omega_j \Big/ \max_j r\omega_j, \quad (15)$$

2) The SVNN dominance degree (SVNNDD) of RA_i over RA_t for RG_j is presented:

$$SVNNDD_j\left(RA_i, RA_t\right) = \begin{cases} \dfrac{rr\omega_j \times \left(1 - 10^{-\rho HD\left(RM_{ij}^N, RM_{tj}^N\right)}\right)}{\sum_{j=1}^{n} rr\omega_j} & \text{if } SV\left(RM_{ij}^N\right) > SV\left(RM_{tj}^N\right) \\ 0 & \text{if } SV\left(RM_{ij}^N\right) = SV\left(RM_{tj}^N\right) \\ -\dfrac{1}{r\theta}\dfrac{\sum_{j=1}^{n} rr\omega_j \times \left(1 - 10^{-\rho HD\left(RM_{ij}^N, RM_{tj}^N\right)}\right)}{rr\omega_j} & \text{if } SV\left(RM_{ij}^N\right) < SV\left(RM_{tj}^N\right) \end{cases} \quad (16)$$

where $r\theta$ is presented from Tversky and Kahneman [74] and $\rho \in [1, 5]$ [60].

The $SVNNDD_j\left(RA_i\right)\left(j = 1, 2, \cdots, n\right)$ for RG_j is presented:

$$SVNNDD_j\left(PA_i\right) = \left[SVNNDD_j\left(PA_i, PA_t\right)\right]_{m\times m}$$

$$= \begin{array}{c c} & \begin{array}{cccc} RA_1 & RA_2 & \cdots & RA_m \end{array} \\ \begin{array}{c} RA_1 \\ RA_2 \\ \vdots \\ RA_m \end{array} & \begin{bmatrix} 0 & SVNNDD_j\left(RA_1, RA_2\right) & \cdots & SVNNDD_j\left(RA_1, RA_m\right) \\ SVNNDD_j\left(RA_2, RA_1\right) & 0 & \cdots & SVNNDD_j\left(RA_2, RA_m\right) \\ \vdots & \vdots & \cdots & \vdots \\ SVNNDD_j\left(RA_m, RA_1\right) & SVNNDD_j\left(RA_m, RA_2\right) & \cdots & 0 \end{bmatrix} \end{array}$$

3) Present the $SVNNDD\left(RA_i, RA_t\right)$ of RA_i over other alternatives for RG_t:

$$SVNNDD\left(RA_i, RA_t\right) = \sum_{j=1}^{n} SVNNDD_j\left(RA_i, RA_t\right) \quad (17)$$

The $SVNNDD = SVNNDD\left(RA_i, RA_t\right)_{m\times m}$ is presented:

$$SVNNDD = SVNNDD\left(RA_i, RA_t\right)_{m\times m}$$
$$= \begin{array}{c} \\ RA_1 \\ RA_2 \\ \vdots \\ RA_m \end{array}\left[\begin{array}{cccc} RA_1 & RA_2 & \cdots & RA_m \\ \sum_{j=1}^{n} SVNNDD_j\left(RA_1, RA_1\right) & \sum_{j=1}^{n} SVNNDD_j\left(RA_1, RA_2\right) & \cdots & \sum_{j=1}^{n} SVNNDD_j\left(RA_1, RA_m\right) \\ \sum_{j=1}^{n} SVNNDD_j\left(RA_2, RA_1\right) & \sum_{j=1}^{n} SVNNDD_j\left(RA_2, RA_2\right) & \cdots & \sum_{j=1}^{n} SVNNDD_j\left(RA_2, RA_m\right) \\ \vdots & \vdots & \vdots & \vdots \\ \sum_{j=1}^{n} SVNNDD_j\left(RA_m, RA_1\right) & \sum_{j=1}^{n} SVNNDD_j\left(RA_m, RA_2\right) & \cdots & \sum_{j=1}^{n} SVNNDD_j\left(RA_m, RA_m\right) \end{array}\right]$$

4) The overall $SVNNDD\left(RA_i\right)$ of RA_i is presented:

$$SVNNDD\left(RA_i\right) = \frac{\sum_{t=1}^{m} SVNNDD\left(RA_i, RA_t\right) - \min_i\left\{\sum_{t=1}^{m} SVNNDD\left(RA_i, RA_t\right)\right\}}{\max_i\left\{\sum_{t=1}^{m} SVNNDD\left(RA_i, RA_t\right)\right\} - \min_i\left\{\sum_{t=1}^{m} SVNNDD\left(RA_i, RA_t\right)\right\}}. \quad (18)$$

5) Sort and select the optimal alternative with $SVNNDD\left(RA_i\right)\left(i=1,2,\cdots,m\right)$, the greater $SVNNDD\left(RA_i\right)\left(i=1,2,\cdots,m\right)$, the better alternative is.

IV. Numerical Example and Comparative Analysis

A. Numerical Example

The world is currently undergoing a major transformation from a resource-based and knowledge-based industrial economy to a networked and data-driven digital economy. The digital economy has also become important driving force for China's economy to achieve the transformation of old and new driving forces, and has provided opportunities for enterprise development to overtake others. The 14th Five Year Plan clearly proposes to "drive production methods as a whole through digital transformation... promote the deep integration of digital technology and real economy, empower the transformation and upgrading of traditional industries". The 2021 Accenture China Enterprise Digital Transformation Index shows that since 2018, the average score of China's enterprise digital transformation index has increased from 37 points to 54 points. 16% of enterprises have significant transformation effects, and the overall digital level of enterprises in various industries has steadily improved, but there are still significant differences between different industries. The management involved in the digital transformation process of retail enterprises could be mainly divided into two categories: first, digital management, which refers to use of digital technology to upgrade the informatization and automation of front-end business processes such as research and development, procurement, production, and sales, and improve the production efficiency of retail enterprises. To measure the maturity of digital management in small retail enterprises, it is necessary to analyze the production management, quality management, design management, research and development management, order management, procurement management, and other aspects of retail enterprises. For retail enterprises, digital management can connect modules such as resources, customer relationships, orders, and supply chain management, thereby reducing various costs for retail enterprises. The second is data management, which includes basic data informatization, data visualization, data decision-making ability, data automatic processing ability, and data optimization processing ability for retail enterprises. By continuously exploring the value of data and driving the development of business intelligence, retail enterprises can enhance their data analysis and processing capabilities, optimize their data management capabilities, and the future business innovation and management transformation of retail enterprises depend on their control over data and application maturity. Data is the core content of digital management, which can effectively handle the accumulated data of oneself and various platforms, thus grasping the core of digital transformation. Therefore, data management is particularly important, and data management capabilities will directly affect the speed and results of digital transformation in retail enterprises. The maturity evaluation of digital transformation in retail enterprise is MAGDM. Therefore, the maturity evaluation of digital transformation in retail enterprise is presented to demonstrate the SVNN-ExpTODIM technique. Five potential retail enterprises $RA_i\left(i=1,2,3,4,5\right)$ are assessed with different attributes: ① RG_1 is application of new technologies for digital transformation in retail enterprise;② RG_2 is organizational structure for digital transformation in retail enterprise;③ RG_3 is team for digital transformation in retail enterprise; ④ RG_4 is administration for digital transformation in retail enterprise; ⑤ RG_5 is strategy for digital transformation in retail enterprise; ⑥ RG_6 is leadership for digital transformation in retail enterprise. Five possible retail enterprises $RA_i\left(i=1,2,3,4,5\right)$ are evaluated in light with linguistic scales (see Table I) through four attributes and three experts $PE_t\left(t=1,2,3\right)$ with expert's weight $rw=\left(1/3,1/3,1/3\right)$.

TABLE. I. LINGUISTIC SCALES AND SVNNS

Linguistic scales	SVNNs
Exceedingly Terrible-RET	(0.0000, 1.0000, 1.0000)
Very Terrible-RVT	(0.1000, 0.9000, 0.9000)
Terrible-RT	(0.3000, 0.7000, 0.7000)
Medium-RM	(0.5000, 0.5000, 0.5000)
Well-RW	(0.7000, 0.3000, 0.3000)
Very Well-RVW	(0.9000, 0.1000, 0.1000)
Exceedingly Well-REW	(1.0000, 0.0000, 0.0000)

The SVNN-ExpTODIM technique is presented to solve the maturity evaluation of digital transformation in retail enterprise.

Step 1. Present the SVNN-matrix $RM^t=\left[RM_{ij}^t\right]_{5\times6}=\left(RT_{ij}^t,RI_{ij}^t,RF_{ij}^t\right)_{5\times6}$ (see Tables II to IV).

TABLE. II. EVALUATION VALUES THROUGH RE_1

	RG_1	RG_2	RG_3	RG_4	RG_5	RG_6
RA_1	RVW	RVW	RW	RVT	RM	RW
RA_2	RVT	RVT	RM	RM	RVT	RVT
RA_3	RT	RW	RVW	RM	RT	RM
RA_4	RVW	RVT	RVT	RVT	RVW	RW
RA_5	RW	RVT	RVW	RVW	RW	RM

TABLE. III. EVALUATION VALUES BY PE_2

	RG_1	RG_2	RG_3	RG_4	RG_5	RG_6
RA_1	RVW	RW	RT	RW	RVT	RM
RA_2	RM	RW	RVW	RW	RVT	RVW
RA_3	RM	RT	RM	RVW	RVW	RW
RA_4	RVT	RM	RVT	RM	RVW	RT
RA_5	RT	RW	RVT	RM	RM	RVW

TABLE. IV. EVALUATION VALUES BY PE_3

	RG_1	RG_2	RG_3	RG_4	RG_5	RG_6
RA_1	RM	RVT	RT	RM	RT	RT
RA_2	RM	RT	RM	RW	RVW	RT
RA_3	RW	RT	RM	RVT	RVW	RM
RA_4	RW	RW	RVW	RVW	RVT	RVW
RA_5	RT	RVT	RVW	RW	RM	RVT

Then according to SVNNWA technique, the $RM=\left[RM_{ij}\right]_{5\times6}$ is presented (see Table V).

TABLE. V. THE $RM = \left[RM_{ij} \right]_{5\times6}$

	RG₁	RG₂
RA_1	(0.4325, 0.3142, 0.4105)	(0.1681, 0.1536, 0.4103)
RA_2	(0.6561, 0.2323, 0.1916)	(0.7108, 0.2004, 0.2105)
RA_3	(0.2142, 0.3007, 0.4319)	(0.5265, 0.3326, 0.4506)
RA_4	(0.8617, 0.1213, 0.4062)	(0.4332, 0.2057, 0.2104)
RA_5	(0.2135, 0.1167, 0.5408)	(0.2536, 0.3032, 0.4072)
	RG_4	RG_3
RA_1	(0.4652, 0.0357, 0.2546)	(0.4658, 0.0254, 0.3327)
RA_2	(0.3124, 0.3435, 0.2872)	(0.4436, 0.4315, 0.2378)
RA_3	(0.5803, 0.2724, 0.1105)	(0.5121, 0.0546, 0.1559)
RA_4	(0.4237, 0.3548, 0.1543)	(0.4873, 0.1215, 0.3436)
RA_5	(0.5154, 0.3217, 0.3632)	(0.6436, 0.2528, 0.3217)
	RG_5	RG_6
RA_1	(0.2487,0.7189,0.6956)	(0.4612,0.5183,0.2178)
RA_2	(0.3512,0.1579,0.1154)	(0.6753,0.7426,0.6816)
RA_3	(0.4378,0.5436,0.2417)	(0.6768,0.8182,0.2354)
RA_4	(0.7546,0.4913,0.3084)	(0.4723,0.2736,0.6132)
RA_5	(0.4934,0.5149,0.4843)	(0.2814,0.2746,0.4875)

Step 2. Normalize the $RM = \left[RM_{ij} \right]_{5\times6}$ into $RM^N = \left[RM_{ij}^N \right]_{5\times6}$ (see Table VI).

TABLE. VI. THE $PN = \left[PN_{ij} \right]_{5\times6}$

	RG_1	RG_2
RA_1	(0.4325, 0.3142, 0.4105)	(0.1681, 0.1536, 0.4103)
RA_2	(0.6561, 0.2323, 0.1916)	(0.7108, 0.2004, 0.2105)
RA_3	(0.2142, 0.3007, 0.4319)	(0.5265, 0.3326, 0.4506)
RA_4	(0.8617, 0.1213, 0.4062)	(0.4332, 0.2057, 0.2104)
RA_5	(0.2135, 0.1167, 0.5408)	(0.2536, 0.3032, 0.4072)
	RG_4	RG_3
RA_1	(0.4652, 0.0357, 0.2546)	(0.4658, 0.0254, 0.3327)
RA_2	(0.3124, 0.3435, 0.2872)	(0.4436, 0.4315, 0.2378)
RA_3	(0.5803, 0.2724, 0.1105)	(0.5121, 0.0546, 0.1559)
RA_4	(0.4237, 0.3548, 0.1543)	(0.4873, 0.1215, 0.3436)
RA_5	(0.5154, 0.3217, 0.3632)	(0.6436, 0.2528, 0.3217)
	RG_5	RG_6
RA_1	(0.2487,0.7189,0.6956)	(0.4612,0.5183,0.2178)
RA_2	(0.3512,0.1579,0.1154)	(0.6753,0.7426,0.6816)
RA_3	(0.4378,0.5436,0.2417)	(0.6768,0.8182,0.2354)
RA_4	(0.7546,0.4913,0.3084)	(0.4723,0.2736,0.6132)
RA_5	(0.4934,0.5149,0.4843)	(0.2814,0.2746,0.4875)

Step 3. Present the weight values (see Table VII):

TABLE. VII. THE ATTRIBUTES WEIGHT

	RG_1	RG_2	RG_3	RG_4	RG_5	RG_6
$p\varpi$	0.2101	0.2720	0.2088	0.0567	0.1158	0.1366

Step 4. Present the relative weight (see Table VIII):

TABLE. VIII. THE RELATIVE ATTRIBUTES WEIGHT

	RG_1	RG_2	RG_3	RG_4	RG_5	RG_6
$rr\varpi$	0.7724	1.0000	0.7676	0.2085	0.4257	0.5022

Step 5. Present the $SVNNDD = SVNNDD\left(RA_i, RA_t\right)_{5\times5}$ (see Table IX):

TABLE. IX. THE $SVNNDD = SVNNDD\left(RA_i, RA_t\right)_{5\times5}$

Alternatives	RA_1	RA_2	RA_3	RA_4	RA_5
RA_1	0.0000	-1.5655	1.6493	-1.8237	0.8803
RA_2	-0.1843	0.0000	1.5971	0.1458	-1.8461
RA_3	1.3441	-2.0903	0.0000	-2.2418	1.2768
RA_4	-0.6074	-0.8641	1.9479	0.0000	-0.5955
RA_5	1.1840	-2.2138	-0.1230	-2.0459	0.0000

Step 6. Present the $SVNNDD\left(RA_i\right)\left(i=1,2,\cdots,5\right)$ (see Table X).

TABLE. X. THE $SVNNDD\left(RA_i\right)\left(i=1,2,\cdots,5\right)$

Alternatives	RA_1	RA_2	RA_3	RA_4	RA_5
SVNNDD	0.7595	0.9453	0.4830	1.0000	0.0000

Step 7. Finally, the order could be presented: $RA_4 \succ RA_2 \succ RA_1 \succ RA_3 \succ RA_5$, and thus the optimal retail enterprise is RA_4.

B. *Comparative Analysis*

Then, the SVNN-ExpTODIM technique is compared with SVNNWA technique [71] and SVNNWG technique[71], SVNN-CODAS technique [75], SVNN-EDAS technique [76] and SVNN-TODIM technique [77]. The comparative results are presented in Table XI and Fig. 1.

TABLE. XI. ORDER FOR DIFFERENT TECHNIQUES

	Order
SVNNWA technique [71]	$RA_4 \succ RA_2 \succ RA_1 \succ RA_3 \succ RA_5$
SVNNWG technique[71]	$RA_4 \succ RA_2 \succ RA_3 \succ RA_1 \succ RA_5$
SVNN-CODAS technique [75]	$RA_4 \succ RA_2 \succ RA_1 \succ RA_3 \succ RA_5$
SVNN-EDAS technique [76]	$RA_4 \succ RA_2 \succ RA_3 \succ RA_1 \succ RA_5$
SVNN-TODIM technique [77]	$RA_4 \succ RA_2 \succ RA_1 \succ RA_3 \succ RA_5$
The SVNN-ExpTODIM technique	$RA_4 \succ RA_2 \succ RA_1 \succ RA_3 \succ RA_5$

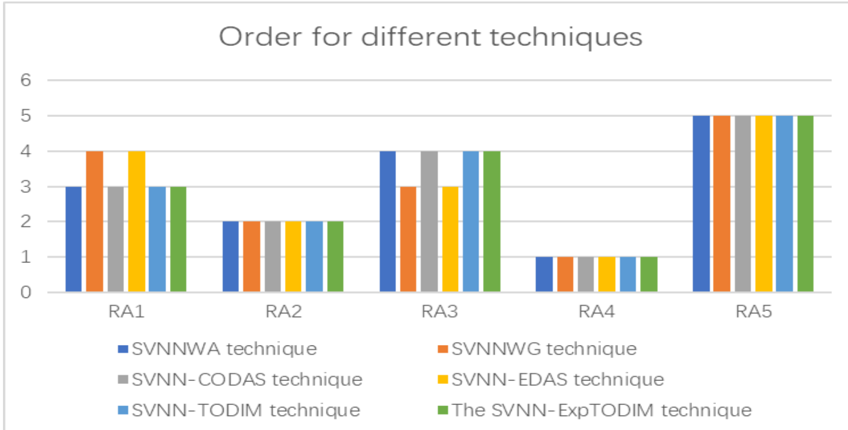

Fig. 1. Order for different techniques

From detailed analysis, it could be presented that order of these techniques is slightly different, however, these techniques have same optimal retail enterprise and worst retail enterprise. This verifies the SVNN-ExpTODIM is effective.

V. Conclusion

Against the backdrop of extensive digital transformation in various industries, China's traditional retail industry is facing very good development opportunities, but at the same time, it is also facing severe impacts. The full application of digital technologies such as big data will contribute to the long-term development of China's traditional retail industry. In this context, if China's traditional retail industry wants to achieve healthy and sustainable development, it should actively change its business model and actively use digital technologies such as big data in order to gain a certain advantage in the increasingly fierce competition. The maturity evaluation of digital transformation in retail enterprise is MAGDM. Currently, the ExpTODIM technique was presented to put forward the MAGDM. The SVNSs are presented as decision tool for characterizing fuzzy information during the maturity evaluation of digital transformation in retail enterprise. In this study, the SVNN-ExpTODIM approach is presented to solve the MAGDM under SVNSs. At last, numerical study for maturity evaluation of digital transformation in retail enterprise is presented to validate the SVNN-ExpTODIM approach through comparative analysis.

There are still several shortcomings in the research process of this article, which are worth further research in the future. Firstly, the digital transformation model proposed in this article is only based on the internal transformation evaluation model of the enterprise. In the process of digital transformation, retail enterprises not only need to transform themselves internally, but also need to consider external factors. National policies, the situation of competitors, and the development of upstream and downstream enterprises in the value chain will all become important factors affecting the digital transformation of enterprises. Secondly, although the evaluation indicators and process proposed in this article try to analyze the transformation work of enterprises from an objective perspective, the selection and evaluation of many indicators still have some subjective influences. Therefore, in future research, how to make the evaluation work as objective and specific as possible will be a key research direction.

References

[1] S. Grimes, "Networking china: The digital transformation of the chinese economy," (in English), Chinese Journal of Communication, Book Review vol. 11, no. 2, pp. 236-238, 2018.

[2] N. A. Efimova, M. O. Ruchkina, and O. Y. Tereshina, "Transformation of the energy sector in conditions of digital economy," (in English), Light & Engineering, Article vol. 26, no. 4, pp. 69-75, 2018.

[3] J. Y. Lee, "Contesting the digital economy and culture: Digital technologies and the transformation of popular music in korea," (in English), Inter-Asia Cultural Studies, Article vol. 10, no. 4, pp. 489-506, 2009, Art. no. Pii 916893212.

[4] A. Maiurova et al., "Promoting digital transformation in waste collection service and waste recycling in moscow (russia): Applying a circular economy paradigm to mitigate climate change impacts on the environment," (in English), Journal of Cleaner Production, Article vol. 354, p. 15, Jun 2022, Art. no. 131604.

[5] X. F. Chang, J. Su, and Z. H. Yang, "The effect of digital economy on urban green transformation-an empirical study based on the yangtze river delta city cluster in china," (in English), Sustainability, Article vol. 14, no. 21, p. 19, Nov 2022, Art. no. 13770.

[6] G. Dash and D. Chakraborty, "Digital transformation of marketing strategies during a pandemic: Evidence from an emerging economy during covid-19," (in English), Sustainability, Article vol. 13, no. 12, p. 19, Jun 2021, Art. no. 6735.

[7] A. Szalavetz, "Digital transformation - enabling factory economy actors' entrepreneurial integration in global value chains?," (in English), Post-Communist Economies, Article vol. 32, no. 6, pp. 771-792, Aug 2020.

[8] J. W. Sun and J. Z. Chen, "Digital economy, energy structure transformation, and regional carbon dioxide emissions," (in English), Sustainability, Article vol. 15, no. 11, p. 16, May 2023, Art. no. 8557.

[9] M. Skare, M. D. de Obesso, and S. Ribeiro-Navarrete, "Digital transformation and european small and medium enterprises (smes): A comparative study using digital economy and society index data," (in English), International Journal of Information Management, Article vol. 68, p. 16, Feb 2023, Art. no. 102594.

[10] A. Sestino, A. Kahlawi, and A. De Mauro, "Decoding the data economy: A literature review of its impact on business, society and digital transformation," (in English), European Journal of Innovation Management, Review; Early Access p. 26, 2023 Aug 2023.

[11] Okorie, J. Russell, R. Cherrington, O. Fisher, and F. Charnley, "Digital transformation and the circular economy: Creating a competitive advantage from the transition towards net zero manufacturing," (in English), Resources Conservation and Recycling, Article vol. 189, p. 14, Feb 2023, Art. no. 106756.

[12] J. Hou, M. Y. Zhang, and Y. Li, "Can digital economy truly improve agricultural ecological transformation? New insights from china," (in English), Humanities & Social Sciences Communications, Article vol. 11, no. 1, p. 13, Jan 2024, Art. no. 153.

[13] X. F. Chang, Z. H. Yang, and Abdullah, "Digital economy, innovation factor allocation and industrial structure transformation-a case study of the yangtze river delta city cluster in china," (in English), Plos One, Article vol. 19, no. 4, p. 16, Apr 2024, Art. no. e0300788.

[14] H. M. Zhai, F. Yang, F. X. Gao, S. Sindakis, and G. Showkat, "Digital transformation and over-investment: Exploring the role of rational decision-making and resource surplus in the knowledge economy," (in English), Journal of the Knowledge Economy, Article; Early Access p. 32, 2023 Dec 2023.

[15] M. Zhong, M. Umar, N. Mirza, and A. Safi, "Mineral resource optimization: The nexus of sustainability, digital transformation, and green finance in oecd economies," (in English), Resources Policy, Article vol. 90, p. 9, Mar 2024, Art. no. 104829.

[16] S. Y. Yin, M. Q. Jiang, L. J. Chen, and F. Jia, "Digital transformation and the circular economy: An institutional theory perspective," (in English), Industrial Management & Data Systems, Article vol. 124, no. 4, pp. 1627-1655, Apr 2024.

[17] D. H. Xiao, C. Zhang, and Y. J. Huang, "Digital economy policy and enterprise digital transformation: Evidence from innovation and structural effect," (in English), Managerial and Decision Economics, Article; Early Access p. 12, 2024 Feb 2024.

[18] M. Wu, Y. Ma, Y. Gao, and Z. H. Ji, "The impact of digital economy on income inequality from the perspective of technological progress-biased transformation: Evidence from china," (in English), Empirical Economics, Article; Early Access p. 41, 2024 Feb 2024.

[19] H. Wang and C. H. Kang, "Digital economy and the green transformation of manufacturing industry: Evidence from chinese cities," (in English), Frontiers in Environmental Science, Article vol. 12, p. 16, Jan 2024, Art. no. 1324117.

[20] J. Liu and Q. Y. Zhao, "Mechanism testing of the empowerment of green transformation and upgrading of industry by the digital economy in china," (in English), Frontiers in Environmental Science, Article vol. 11, p. 21, Feb 2024, Art. no. 1292795.

[21] A. Abouzahra, A. Sabraoui, and K. Afdel, "Model composition in model driven engineering: A systematic literature review," (in English), Information and Software Technology, Review vol. 125, p. 18, Sep 2020, Art. no. 106316.

[22] Z. Korachi and B. Bounabat, "Data driven maturity model for assessing smart cities," in 2nd International Conference on Smart Digital Environment (ICSDE'18), Rabat, MOROCCO, 2018, pp. 140-147, NEW YORK: Assoc Computing Machinery, 2018.

[23] C. Klötzer and A. Pflaum, "Toward the development of a maturity model for digitalization within the manufacturing industry's supply chain," in 50th Annual Hawaii International Conference on System Sciences(HICSS), Hi, 2017, pp. 4210-4219, Honolulu: Hicss, 2017.

[24] M. Kirmizi and B. Kocaoglu, "Digital transformation maturity model development framework based on design science: Case studies in manufacturing industry," (in English), Journal of Manufacturing Technology Management, Article vol. 33, no. 7, pp. 1319-1346, Sep 2022.

[25] C. Zitoun, O. Belghith, S. Ferjaoui, S. S. D. Gabouje, and Ieee, "Dmmm: Data management maturity model," in International Conference on Advanced Enterprise Information System (AEIS), Electr Network, 2021, pp. 33-39, NEW YORK: Ieee, 2021.

[26] N. Soares, P. Monteiro, F. J. Duarte, and R. J. Machado, "Extended maturity model for digital transformation," in 21st International Conference on Computational Science and Its Applications (ICCSA), Cagliari, ITALY, 2021, vol. 12952, pp. 183-200, CHAM: Springer International Publishing Ag, 2021.

[27] E. E. Nebati, B. Ayvaz, and A. O. Kusakci, "Digital transformation in the defense industry: A maturity model combining sf-ahp and sf-todim approaches," (in English), Applied Soft Computing, Article vol. 132, p. 23, Jan 2023, Art. no. 109896.

[28] F. Hein-Pensel et al., "Maturity assessment for industry 5.0: A review of existing maturity models," (in English), Journal of Manufacturing Systems, Review vol. 66, pp. 200-210, Feb 2023.

[29] E. Doctor et al., "A maturity model for assessing the digitalization of public health agencies development and evaluation," (in English), Business & Information Systems Engineering, Article vol. 65, no. 5, pp. 539-554, Oct 2023.

[30] H. X. Yang, X. W. Xu, and Ieee, "Research on computer evaluation index system of digital maturity of automotive supply chain," in IEEE International Conference on Electrical Engineering, Big Data and Algorithms (EEBDA), Changchun, PEOPLES R CHINA, 2022, pp. 442-446, NEW YORK: Ieee, 2022.

[31] V. Mishra and M. G. Sharma, "Digital transformation evaluation of telehealth using convergence, maturity, and adoption," (in English), Health Policy and Technology, Article vol. 11, no. 4, p. 12, Dec 2022, Art. no. 100684.

[32] L. Li, "Evaluation of digital transformation maturity of small and medium-sized entrepreneurial enterprises based on multicriteria framework," (in English), Mathematical Problems in Engineering, Article vol. 2022, p. 11, Jul 2022, Art. no. 7085322.

[33] T. Thordsen and M. Bick, "A decade of digital maturity models: Much ado about nothing?," (in English), Information Systems and E-Business Management, Article vol. 21, no. 4, pp. 947-976, Dec 2023.

[34] A. Borovkov, O. Rozhdestvenskiy, E. Pavlova, A. Glazunov, and K. Savichev, "Key barriers of digital transformation of the high-technology manufacturing: An evaluation method," (in English), Sustainability, Article vol. 13, no. 20, p. 13, Oct 2021, Art. no. 11153.

[35] S. Gallego-Garcia, M. Groten, and J. Halstrick, "Integration of improvement strategies and industry 4.0 technologies in a dynamic evaluation model for target-oriented optimization," (in English), Applied Sciences-Basel, Article vol. 12, no. 3, p. 21, Feb 2022, Art. no. 1530.

[36] E. Eisner et al., "Self-assessment framework for corporate environmental sustainability in the era of digitalization," (in English), Sustainability, Article vol. 14, no. 4, p. 33, Feb 2022, Art. no. 2293.

[37] Q. M. Chen, W. Zhang, N. S. Jin, X. C. Wang, and P. R. Dai, "Digital transformation evaluation for small- and medium-sized manufacturing enterprises using the fuzzy synthetic method dematel-anp," (in English), Sustainability, Article vol. 14, no. 20, p. 23, Oct 2022, Art. no. 13038.

[38] D. Manzini, R. Oosthuizen, H. K. Chikwanda, and Ieee, "A resilience framework for digital transformation in the banking sector: A systems thinking approach," in Joint Conference of the IEEE 28th International Conference on Engineering, Technology and Innovation (ICE/ITMC) / 31st Conference of the International-Association-for-Management-of-Technology (IAMOT), Nancy, FRANCE, 2022, NEW YORK: Ieee, 2022.

[39] M. Bertl, P. Ross, and D. Draheim, "Systematic ai support for decision-making in the healthcare sector: Obstacles and success factors," (in English), Health Policy and Technology, Article vol. 12, no. 3, p. 8, Sep 2023, Art. no. 100748.

[40] G. Akman and Z. Kökümer, "Evaluation of digital transformation competency in the white-goods sector in the context of industry 4.0 by macbeth and edas methods," (in English), Journal of the Faculty of Engineering and Architecture of Gazi University, Article vol. 38, no. 4, pp. 2033-2053, 2023.

[41] Z. H. Yi, L. J. Yao, and H. Garg, "Power geometric operations of trapezoidal atanassov's intuitionistic fuzzy numbers based on strict t-norms and t-conorms and its application to multiple attribute group decision making," (in English), International Journal of Fuzzy Systems, Article; Early Access p. 21, 2023 Sep 2023.

[42] R. Verma and E. Alvarez-Miranda, "Group decision-making method based on advanced aggregation operators with entropy and divergence measures under 2-tuple linguistic pythagorean fuzzy environment," (in English), Expert Systems with Applications, Article vol. 231, p. 32, Nov 2023, Art. no. 120584.

[43] S. Shabu, K. Yadav, E. Kariri, K. K. Gola, M. AnulHaq, and A. Kumar, "Trajectory clustering and query processing analysis framework for knowledge discovery in cloud environment," (in English), Expert Systems, Article vol. 40, no. 4, p. 19, May 2023, Art. no. e12968.

[44] A. U. Rahman, M. Saeed, M. A. Mohammed, A. S. Al-Waisy, S. Kadry, and J. Kim, "An innovative fuzzy parameterized madm approach to site selection for dam construction based on sv-complex neutrosophic hypersoft set," (in English), Aims Mathematics, Article vol. 8, no. 2, pp. 4907-4929, 2023.

[45] M. Palanikumar, N. Kausar, H. Garg, S. Kadry, and J. Kim, "Robotic sensor based on score and accuracy values in q-rung complex diophatine neutrosophic normal set with an aggregation operation," (in English), Alexandria Engineering Journal, Article vol. 77, pp. 149-164, Aug 2023.

[46] Y. Liang, "An exptodim-macont based multiple-attribute group decision-making technique for smart classroom teaching evaluation of basic english under interval-valued pythagorean fuzzy circumstances," IEEE Access, vol. 12, pp. 14130-14145, 2024.

[47] T. M. H. Nguyen, V. Nguyen, and D. T. Nguyen, "Model-based evaluation for online food delivery platforms with the probabilistic double hierarchy linguistic edas method," (in English), Journal of the Operational Research Society, Article; Early Access p. 18, 2023 Feb 2023.

[48] A. Mondal, S. K. Roy, and J. M. Zhan, "A reliability-based consensus model and regret theory-based selection process for linguistic hesitant-z multi-attribute group decision making," (in English), Expert Systems with Applications, Article vol. 228, p. 18, Oct 2023, Art. no. 120431.

[49] F. Lei et al., "Todim-vikor method based on hybrid weighted distance under probabilistic uncertain linguistic information and its application in medical logistics center site selection," (in English), Soft Computing, Article vol. 27, no. 13, pp. 8541-8559, Jul 2023.

[50] A. Hussain, K. Ullah, M. Mubasher, T. Senapati, and S. Moslem, "Interval-valued pythagorean fuzzy information aggregation based on aczel-alsina operations and their application in multiple attribute decision making," (in English), Ieee Access, Article vol. 11, pp. 34575-34594, 2023.

[51] F. Habibi, A. Abbasi, and R. K. Chakrabortty, "Designing an efficient vaccine supply chain network using a two-phase optimization approach: A case study of covid-19 vaccine," (in English), International Journal of Systems Science-Operations & Logistics, Article vol. 10, no. 1, p. 34, Dec 2023.

[52] S. H. Gurmani, Z. Zhang, R. M. Zulqarnain, and S. Askar, "An interaction and feedback mechanism-based group decision-making for emergency medical supplies supplier selection using t-spherical fuzzy information," (in English), Scientific Reports, Article vol. 13, no. 1, p. 20, May 2023.

[53] J. Wang, Q. Cai, G. Wei, and N. Liao, "An extended edas approach based on cumulative prospect theory for multiple attributes group decision making with interval-valued intuitionistic fuzzy information," Informatica, pp. https://doi.org/10.15388/24-INFOR547, 03/15 2024.

[54] F. Lei, Q. Cai, and G. Wei, "Novel aczel-alsina operations-based probabilistic double hierarchy linguistic aggregation operators and their applications in blockchain performance evaluation blockchain," Journal of Intelligent & Fuzzy Systems, vol. 46, no. 4, pp. 7989-8024, 2024.

[55] P. Jiang, "Logtodim framework for magdm with neutrosophic sets: Energy conservation and emission reduction case," International Journal of Knowledge-based and Intelligent Engineering Systems, vol. 28, no. 1, pp. 149-161, 2024.

[56] S. M. U. Sankar, N. J. Kumar, G. Elangovan, and R. Praveen, "An integrated z-number and dematel-based cooperation enforcement scheme for thwarting malicious nodes in manets," (in English), Wireless Personal Communications, Article vol. 130, no. 4, pp. 2531-2563, Jun 2023.

[57] A. Saghari, I. Budinská, M. Hosseinimehr, and S. Rahmani, "A robust-reliable decision-making methodology based on a combination of stakeholders' preferences simulation and kdd techniques for selecting automotive platform benchmark," (in English), Symmetry-Basel, Article vol. 15, no. 3, p. 22, Mar 2023, Art. no. 750.

[58] D. Rani and H. Garg, "Multiple attributes group decision-making based on trigonometric operators, particle swarm optimization and complex intuitionistic fuzzy values," (in English), Artificial Intelligence Review, Article vol. 56, no. 2, pp. 1787-1831, Feb 2023.

[59] B. Q. Ning, R. Lin, G. W. Wei, and X. D. Chen, "Edas method for multiple attribute group decision making with probabilistic dual hesitant fuzzy information and its application to suppliers selection," (in English), Technological and Economic Development of Economy, Article vol. 29, no. 2, pp. 326-352, 2023.

[60] A. B. Leoneti and L. Gomes, "A novel version of the todim method based on the exponential model of prospect theory: The exptodim method," (in English), European Journal of Operational Research, Article vol. 295, no. 3, pp. 1042-1055, Dec 2021.

[61] H. Sun, Z. Yang, Q. Cai, G. Wei, and Z. Mo, "An extended exp-todim method for multiple attribute decision making based on the z-wasserstein distance," Expert Systems with Applications, vol. 214, p. 119114, 2023.

[62] H. Wang, F. Smarandache, Y. Q. Zhang, and R. Sunderraman, "Single valued neutrosophic sets," Multispace Multistruct, no. 4, pp. 410-413, 2010.

[63] P. Biswas, S. Pramanik, and B. C. Giri, "Entropy based grey relational analysis method for multi-attribute decision making under single valued neutrosophic assessments," Neutrosophic Sets and Systems, vol. 2, pp. 102-110, 2014.

[64] J. Ye, "Single valued neutrosophic cross-entropy for multicriteria decision making problems," (in English), Applied Mathematical Modelling, Article vol. 38, no. 3, pp. 1170-1175, Feb 2014.

[65] A. R. Mishra, P. Rani, and A. Saha, "Single-valued neutrosophic similarity measure-based additive ratio assessment framework for optimal site selection of electric vehicle charging station," (in English), International Journal of Intelligent Systems, Article vol. 36, no. 10, pp. 5573-5604, Oct 2021.

[66] P. Rani, J. Ali, R. Krishankumar, A. R. Mishra, F. Cavallaro, and K. S. Ravichandran, "An integrated single-valued neutrosophic combined compromise solution methodology for renewable energy resource selection problem," (in English), Energies, Article vol. 14, no. 15, p. 23, Aug 2021, Art. no. 4594.

[67] S. Ridvan, A. Fuat, and K. G. Dilek, "A single-valued neutrosophic multicriteria group decision approach with dpl-topsis method based on optimization," (in English), International Journal of Intelligent Systems, Article vol. 36, no. 7, pp. 3339-3366, Jul 2021.

[68] H. Garg, "Svnmpr: A new single-valued neutrosophic multiplicative preference relation and their application to decision-making process," (in English), International Journal of Intelligent Systems, Article; Early Access vol. 37, no. 3, pp. 2089-2130, 2022.

[69] X. Yang and Y. Liu, "An integrated taxonomy method using single-valued neutrosophic number magdm for evaluating the physical education teaching quality in colleges and universities," Mathematical Problems in Engineering, vol. 2022, p. 2795788, 2022/08/25 2022.

[70] Y. Liu and X. Yang, "Edas method for single-valued neutrosophic number multiattribute group decision-making and applications to physical education teaching quality evaluation in colleges and universities," Mathematical Problems in Engineering, vol. 2023, p. 5576217, 2023/02/03 2023.

[71] J. J. Peng, J. Q. Wang, J. Wang, H. Y. Zhang, and X. H. Chen, "Simplified neutrosophic sets and their applications in multi-criteria group decision-making problems," (in English), International Journal of Systems Science, Article vol. 47, no. 10, pp. 2342-2358, Jul 2016.

[72] P. Majumdar and S. K. Samanta, "On similarity and entropy of neutrosophic sets," Journal of Intelligent & Fuzzy Systems, vol. 26, no. 3, pp. 1245-1252, 2014.

[73] C. E. Shannon, "A mathematical theory of communication," Bell System Technical Journal, vol. 27, no. 4, pp. 379-423, 1948.

[74] A. Tversky and D. Kahneman, "Prospect theory: An analysis of decision under risk," Econometrica, vol. 47, no. 2, pp. 263-291, 1979.

[75] E. Bolturk and A. Karasan, "Prioritization of investment alternatives for a hospital by using neutrosophic codas method," (in English), Journal of Multiple-Valued Logic and Soft Computing, Article vol. 33, no. 4-5, pp. 381-396, 2019.

[76] D. Stanujkic et al., "A single-valued neutrosophic extension of the edas method," (in English), Axioms, Article vol. 10, no. 4, p. 13, Dec 2021, Art. no. 245.

[77] D. S. Xu, C. Wei, and G. W. Wei, "Todim method for single-valued neutrosophic multiple attribute decision making," Information, vol. 8, no. 4, p. 125, Dec 2017, Art. no. 125.