Combined TOPSIS Technique for MAGDM Based on the Distance Measures and CRITIC under Single-Valued Neutrosophic Sets and Applications to Quality Evaluation of Whole Process Engineering Consulting Service Modes

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Abstract: According to survey data released by the National Bureau of Statistics, from 2011 to 2022, the total output value of China's construction industry showed an increasing trend year by year. From 2018 to 2021, infrastructure investment has always maintained a positive growth, indicating that the current construction industry is in a rapid development stage. In order to improve the development quality of the construction industry as much as possible, it is of great significance to develop the whole Process engineering consulting service model. The quality evaluation of whole process engineering consulting service modes is MAGDM. The single-valued neutrosophic sets (SVNSs) is useful tool to cope with uncertain information during the quality evaluation of whole process engineering consulting service modes. In this paper, the single-valued neutrosophic number combined TOPSIS (SVNN-CTOPSIS) model based on single-valued neutrosophic number Hamming distances (SVNNHD) and single-valued neutrosophic number Euclidean distance (SVNNED) is formed to cope with the MAGDM. The CRITIC model is utilized to obtain the weight numbers in light with the SVNNHD and SVNNED under SVNSs. Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is utilized to verify SVNN-CTOPSIS model. The main contributions of this study are formed: (1) the CRITIC model is formed to obtain the weight numbers in light with SVNNHD and SVNNED;

(2) the SVNN-CTOPSIS model is formed in light with SVNNHD and SVNNED under SVNNs; (3) Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is employed to verify SVNN-CTOPSIS model.

Keywords: MAGDM; SVNSs; TOPSIS; CRITIC model; performance evaluation

1. Introduction

Against the backdrop of rapid development in the construction industry, the investment entities of engineering projects are developing in a diversified direction[1, 2]. Traditional "fragmented" consulting services are no longer able to effectively meet the investment needs of investors. In the face of such situations, the Opinions on Promoting the Sustainable and Healthy Development of the Construction Industry (Guo Ban Fa [2017] No. 19) put forward for the first time the idea of cultivating the whole process engineering consulting, which has promoted the transformation of China's engineering consulting work from the past professional division of labor model to the whole process, cross stage integration model[3-5]. In the practical application of the consortium consulting service model[6, 7], a project will be handed over to two or more consulting units to jointly carry out the whole process engineering consulting services of engineering projects, and the lead party will be responsible for the coordination of the consulting business during the service development process. In the current process engineering consulting service development process, there are relatively many factors to apply the consortium consulting service model. Common factors include large project scale, complex work content, and lack of professional service qualifications of some consulting units. Considering that the consortium consulting service model needs to unite multiple consulting units in the application process, in order to improve the reliability of consulting services and the quality of the division of responsibilities, the management relationship and responsibilities of each consulting unit need to be noted in the contract before the application of the consortium consulting service model, so as to lay a good foundation for the orderly development of the whole process engineering consulting services. The integrated whole process consulting service model is a work mode in which a consulting unit is responsible for coordinating the entire process consulting work of engineering projects[8-10]. Due to the comprehensive range of consulting services covered by the service model, only a few consulting units in the current consulting service industry have the qualifications and experience to apply the consulting service model. Therefore, compared to other consulting service techniques, The application experience of the integrated whole process consulting service model is relatively limited. However, due to the fact that the consulting service model is mainly managed by one unit, the difficulty of consulting service management is relatively low, which can effectively improve the integration level of consulting services[11-13]. The "1+N" part of the combined consulting service mode in the whole Process engineering consulting service work is mainly composed of one consulting unit, which distributes a number of consulting businesses to different consulting units in the form of contracting or combination to complete the consulting services. In this process, the consulting unit is responsible for coordinating the whole Process engineering consulting business. In the current work process of consulting companies, the

"1+N" combined consulting service model is mainly applied to project research and decision-making, bidding agency, survey and design, engineering supervision, cost decision-making, and other work[14-16]. The business combination techniques mainly include the combination of design units and cost analysis units, design units and supervision units, supervision units and bidding agency units Combining design units with survey and supervision units, etc. For the current construction activities of engineering projects, the "1+N" part combination consulting service model is highly similar to the traditional single consulting contract business[14-18]. Therefore, this work model has been widely used in the early stage of the whole process engineering consulting service. In a word, in the process of gradually advancing the supply side structural reform, the construction industry is carrying out the organizational model reform represented by the whole Process engineering consulting. In order to make the whole Process engineering consulting service model better meet the needs of the current development of the construction industry, based on clarifying the shortcomings of the traditional professional engineering consulting service model, the actual situation of the project is analyzed, the development of a more complete and reliable process engineering consulting service model can provide strong support for the smooth implementation of project management[19-21].

With rapid development of GDM issues, MAGDM techniques have greatly attracted academic attention [22-30]. In order to put forward the objective things through employing precise numbers. Zadeh [31] creatively put forward the fuzzy sets (FSs) theory. Atanassov [32] creatively put forward intuitionistic fuzzy sets (IFSs). However, IFSs didn't put forward uncertain membership. In order to manage a more efficient technique, Smarandache [33] creatively put forward the neutrosophic sets(NSs). Zenat, Mahmoud and Amal [34] put forward the TOPSIS model for green supply chain practices under SVNSs. Ahmed, Nehal and Ibrahim [35] put forward the CRITIC model for coping with the product design in virtual reality under SVNSs. Abduallah et al. [36] put forward the AHP-VIKOR model for coping with the Supply chain (SC) networks with neutrosophic theory. Karam et al. [37] put forward the TOPSIS for assessment quality of suppliers under SVNSs. M. Sabry [38] put forward the CRITIC-EDAS model for urban energy internet assessment by type 2 neutrosophic numbers (T2NNs). Abduallah et al. [39] put forward the MEREC-CoCoSo for coping with the autonomous vehicles and distributed resources using type-2 neutrosophic numbers (T2NN). The quality evaluation of whole process engineering consulting service modes is the real-life MAGDM [40-44]. The SVNSs [45] is useful technique to cope with uncertain information during the quality evaluation of whole process engineering consulting service modes. Furthermore, many techniques employed the TOPSIS model [46-49] and CRITIC model [50-54] separately to solve the MAGDM. Unfortunately, few valuable existing works were managed the combined TOPSIS based on SVNNHD and SVNNED under SVNSs. The main objective of this study is to cope with MAGDM through employing the SVNN-CTOPSIS model with SVNNHD and SVNNED model. Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is utilized to verify SVNN-CTOPSIS model. The main research goals and motivation of this study are formed: (1) the CRITIC model is formed to obtain the weight numbers in light with SVNNHD and SVNNED; (2) the SVNN-CTOPSIS model is formed in light with SVNNHD and SVNNED under SVNNs; (3) Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is employed to verify SVNN-CTOPSIS model.

The remaining sections is formed. The SVNSs is formed in Sect 2. The SVNN-CTOPSIS model is formed for MAGDM in Sect. 3. The quality evaluation of whole process engineering consulting service modes and some comparative analyses is formed to verify the SVNN-CTOPSIS model in Sect. 4. The conclusion is formed in Sect. 5.

2. Preliminaries

Wang et al. [45] formed the SVNSs.

Definition 1 [45]. The SVNSs is formed:

$$DA = \left\{ \left(\vartheta, DT_A(\vartheta), DI_A(\vartheta), DF_A(\vartheta) \right) \middle| \vartheta \in \Theta \right\} \quad (1)$$

where $DT_A(\vartheta), DI_A(\vartheta), DF_A(\vartheta)$ depicts truth membership, indeterminacy membership and falsity membership, $DT_A(\vartheta), DI_A(\vartheta), DF_A(\vartheta) \in [0,1]$, $0 \le DT_A(\vartheta) + DI_A(\vartheta) + DF_A(\vartheta) \le 3$.

Definition 2 [55]. The score value information (SVI) of $DA = (DT_A, DI_A, DF_A)$ and $DB = (DT_B, DI_B, DF_B)$ is formed:

$$SVI(DA) = \frac{(2 + DT_A - DI_A - DF_A)}{3}, SVI(DA) \in [0,1]. \quad (2)$$

$$SVI(DB) = \frac{(2 + DT_B - DI_B - DF_B)}{3}, SVI(DB) \in [0,1]. \quad (3)$$

Definition 3 [55]. The accuracy value information (AVI) of $DA = (DT_A, DI_A, DF_A)$ and $DB = (DT_B, DI_B, DF_B)$ is formed:

$$AVI(DA) = \frac{1 + DT_A - DF_A}{2},\ AVI(DA) \in [0,1]\ . \quad (4)$$

$$AVI(DB) = \frac{1 + DT_B - DF_B}{2},\ AVI(DB) \in [0,1]\ . \quad (5)$$

Peng et al. [55] formed the order between two SVNNs.

Definition 4[55]. Let $DA=\left(DT_A,DI_A,DF_A\right)$ and $DB=\left(DT_B,DI_B,DF_B\right)$, let $SVI\left(DA\right)=\frac{\left(2+DT_A-DI_A-DF_A\right)}{3}$ and $SVI\left(DB\right)=\frac{\left(2+DT_B-DI_B-DF_B\right)}{3}$, and let $AVI\left(DA\right)=\frac{1+DT_A-DF_A}{2}$ and $AVI\left(DB\right)=\frac{1+DT_B-DF_B}{2}$, if $SVI\left(DA\right)<SVI\left(DB\right)$, then: $DA<DB$; if $SVI\left(DA\right)=SVI\left(DB\right)$, then: (1)if $AVI\left(DA\right)=AVI\left(DB\right)$, then $DA=DB$; (2) if $AVI\left(DA\right)>AVI\left(DB\right)$, then: $DA<DB$.

Definition 5[45]. Let $DA=\left(DT_A,DI_A,DF_A\right)$ and $DB=\left(DT_B,DI_B,DF_B\right)$ be SVNNs, the following operations are formed:

(1) $DA\oplus DB=\left(DT_A+DT_B-DT_ADT_B,DI_ADI_B,DF_ADF_B\right)$;

(2) $DA\otimes DB=\left(DT_ADT_B,DI_A+DI_B-DI_ADI_B,DF_A+DF_B-DF_ADF_B\right)$;

(3) $\pi DA=\left(1-\left(1-DT_A\right)^{\pi},\left(DI_A\right)^{\pi},\left(DF_A\right)^{\pi}\right),\pi>0$;

(4) $\left(DA\right)^{\pi}=\left(\left(DT_A\right)^{\pi},\left(DI_A\right)^{\pi},1-\left(1-DF_A\right)^{\pi}\right),\pi>0$.

Definition 6 [56]. Let $DA=\left(DT_A,DI_A,DF_A\right)$ and $DB=\left(DT_B,DI_B,DF_B\right)$, then SVNN Hamming distance (SVNNHD) and SVNN Euclidean distance (SVNNED) between $DA=\left(DT_A,DI_A,DF_A\right)$ and $DB=\left(DT_B,DI_B,DF_B\right)$ is formed:

$$SVNNHD\left(DA,DB\right)=\frac{1}{3}\left(\left|DT_A-DT_B\right|+\left|DI_A-DI_B\right|+\left|DF_A-DF_B\right|\right) \tag{6}$$

$$SVNNED\left(DA,DB\right)=\sqrt{\frac{1}{3}\left(\left|DT_A-DT_B\right|^2+\left|DI_A-DI_B\right|^2+\left|DF_A-DF_B\right|^2\right)} \tag{7}$$

The SVNNWA & SVNNWG model are formed.

Definition 8 [55]. If $DA_j=\left(DT_j,DI_j,DF_j\right)$, the SVNNWA operator is formed:

$$\begin{aligned}&\text{SVNNWA}_{dw}\left(DA_1,DA_2,\cdots,DA_n\right)=\overset{n}{\underset{j=1}{\oplus}}\left(dw_jDA_j\right)\\&=\left(1-\prod_{j=1}^{n}\left(1-DT_j\right)^{dw_j},\prod_{j=1}^{n}\left(DI_j\right)^{dw_j},\prod_{j=1}^{n}\left(DF_j\right)^{dw_j}\right)\end{aligned} \tag{8}$$

with weight $dw=\left(dw_1,dw_2,...,dw_n\right)^T$, $\sum_{j=1}^{n} dw_j=1.$

Definition 9 [55]. If $DA_j=\left(DT_j,DI_j,DF_j\right)$, the SVNNWG model is formed::

$$\begin{aligned}&\text{SVNNWG}_{dw}\left(DA_1,DA_2,\cdots,DA_n\right)=\underset{j=1}{\overset{n}{\otimes}}\left(DA_j\right)^{dw_j}\\&=\left(\prod_{j=1}^{n}\left(DT_j\right)^{dw_j},1-\prod_{j=1}^{n}\left(1-DI_j\right)^{dw_j},1-\prod_{j=1}^{n}\left(1-DF_j\right)^{dw_j}\right)\end{aligned} \tag{9}$$

with weight $dw=\left(dw_1,dw_2,...,dw_n\right)^T$, $\sum_{j=1}^{n} dw_j=1.$

3.

4. SVNN-CTOPSIS FOR MAGDM IN LIGHT WITH SVNNHD AND SVNNED

Then, the SVNN-CTOPSIS model is formed for MAGDM. Let $DY=\left(DY_1,DY_2,\ldots,DY_m\right)$ be alternatives. Let $DZ=\left(DZ_1,DZ_2,\ldots,DZ_n\right)$ be attributes, $dw=\left\{dw_1,dw_2,\ldots,dw_n\right\}$ be weight for $DZ=\left(DZ_1,DZ_2,\ldots,DZ_n\right)$, where $dw_j\in[0,1],\sum_{j=1}^{n}dw_j=1$. Assume DMs $DX=\left\{DX_1,DX_2,\ldots,DX_l\right\}$ with weight $d\omega=\left\{d\omega_1,d\omega_2,\ldots,d\omega_l\right\}$, $d\omega_k\in[0,1]$, $\sum_{k=1}^{l}d\omega_k=1$. And $DR^{(k)}=\left(DR_{ij}^{(k)}\right)_{m\times n}=\left(DT_{ij}^{(k)},DI_{ij}^{(k)},DF_{ij}^{(k)}\right)_{m\times n}$ is called as group SVNN-matrix. The calculating procedures are formed (See Figure 1).

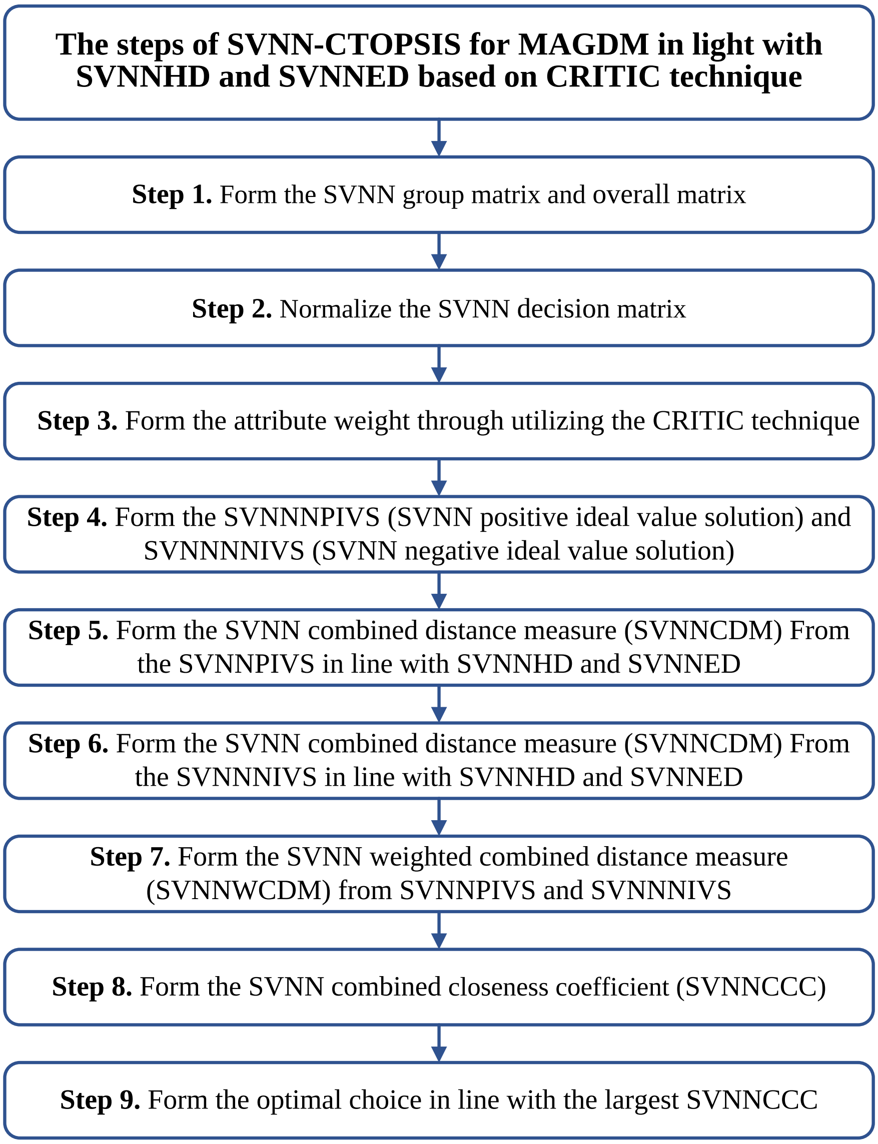

Figure 1. SVNN-CTOPSIS for MAGDM in light with SVNNHD and SVNNED based on CRITIC technique

Step 1. Form group SVNN-matrix $DR^{(k)} = \left(DR_{ij}^{(k)}\right)_{m\times n} = \left(DT_{ij}^{(k)}, DI_{ij}^{(k)}, DF_{ij}^{(k)}\right)_{m\times n}$ and single SVNN-matrix $DR = \left(DR_{ij}\right)_{m\times n}$ through SVNNWG technique.

$$DR^{(k)} = \left[DR_{ij}^{(k)}\right]_{m\times n} = \begin{bmatrix} DR_{11}^{(k)} & DR_{12}^{(k)} & \dots & DR_{1n}^{(k)} \\ DR_{21}^{(k)} & DR_{22}^{(k)} & \dots & DR_{2n}^{(k)} \\ \vdots & \vdots & \vdots & \vdots \\ DR_{m1}^{(k)} & DR_{m2}^{(k)} & \dots & DR_{mn}^{(k)} \end{bmatrix} \tag{10}$$

$$DR = \left[DR_{ij} \right]_{m\times n} = \begin{bmatrix} DR_{11} & DR_{12} & \dots & DR_{1n} \\ DR_{21} & DR_{22} & \dots & DR_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ DR_{m1} & DR_{m2} & \dots & DR_{mn} \end{bmatrix} \tag{11}$$

$$\begin{aligned} DR_{ij} &= \left(DT_{ij}, DI_{ij}, DF_{ij} \right) \\ &= \left(1-\prod_{k=1}^{l}\left(1-DT_{ij}^{(k)}\right)^{d\omega_k}, \prod_{k=1}^{l}\left(DI_{ij}^{(k)}\right)^{d\omega_k}, \prod_{k=1}^{l}\left(DF_{ij}^{(k)}\right)^{d\omega_k} \right) \end{aligned} \tag{12}$$

Step 2. Form normalized $DR^N = \left[DR_{ij}^N \right]_{m\times n}$ in line with $DR = \left[DR_{ij} \right]_{m\times n}$

$$\begin{aligned} DR_{ij}^N &= \left(DT_{ij}^N, DI_{ij}^N, DF_{ij}^N \right) \\ &= \begin{cases} \left(DT_{ij}, DI_{ij}, DF_{ij} \right), & DZ_j \textit{ is the benefit attribute} \\ \left(DF_{ij}, DI_{ij}, DT_{ij} \right), & DZ_j \textit{ is the cost attribute} \end{cases} \end{aligned} \tag{13}$$

Step 3. Form the weight information through utilizing the CRITIC technique.

The CRITIC [57] is utilized to put forward the weights information.

(1) The SVNN correlation decision coefficient (SVNNCDC) is formed.

$$SVNNCDC_{jt} = \frac{\sum_{i=1}^{m}\left(\varphi\left(DSVNN_{ij}\right)-\varphi\left(DSVNN_{j}\right)\right)\left(\varphi\left(DSVNN_{it}\right)-\varphi\left(DSVNN_{t}\right)\right)}{\sqrt{\sum_{i=1}^{m}\left(\varphi\left(DSVNN_{ij}\right)-\varphi\left(DSVNN_{j}\right)\right)^2}\sqrt{\sum_{i=1}^{m}\left(\varphi\left(DSVNN_{it}\right)-\varphi\left(DSVNN_{t}\right)\right)^2}},$$

$$j,t = 1,2,\dots,n, \tag{14}$$

where

$$\varphi\left(DSVNN_j\right) = \frac{1}{2m}\sum_{i=1}^{m}\left(SVI\left(DR_{ij}^N\right)+AVI\left(DR_{ij}^N\right)\right),$$

$$\varphi\left(DSVNN_t\right) = \frac{1}{2m}\sum_{i=1}^{m}\left(SVI\left(DR_{it}^N\right)+AVI\left(DR_{it}^N\right)\right),$$

$$\varphi\left(DSVNN_{ij}\right) = \frac{1}{2}\left(SVI\left(DR_{ij}^N\right)+AVI\left(DR_{ij}^N\right)\right),$$

$$\varphi\left(DSVNN_{it}\right) = \frac{1}{2}\left(SVI\left(DR_{it}^N\right)+AVI\left(DR_{it}^N\right)\right).$$

(2) Form the SVNN standard deviation numbers (SVNNSDN).

$$SVNNSDN_j = \sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(\varphi\left(DSVNN_{ij}\right)-\varphi\left(DSVNN_j\right)\right)^2} \tag{15}$$

(3) Form the attribute weight information.

$$dw_j = \frac{SVNNSDN_j \sum_{t=1}^{n}\left(1-SVNNCDC_{jt}\right)}{\sum_{j=1}^{n}\left(SVNNSDN_j \sum_{t=1}^{n}\left(1-SVNNCDC_{jt}\right)\right)} \tag{16}$$

Step 4. Form the SVNNNPIVS (SVNN positive ideal value solution) and SVNNNNIVS (SVNN negative ideal value solution):

$$SVNNPIVS = \left(SVNNPIVS_1, SVNNPIVS_2, \cdots, SVNNPIVS_n\right) \tag{17}$$

$$SVNNNIVS = \left(SVNNNIVS_1, SVNNNIVS_2, \cdots, SVNNNIVS_n\right) \tag{18}$$

$$SVNNPIVS_j = \left(DT_j^{N+}, DI_j^{N+}, DF_j^{N+}\right) \tag{19}$$

$$SVNNNIVS_j = \left(DT_j^{N-}, DI_j^{N-}, DF_j^{N-}\right) \tag{20}$$

$$SVI\left(SVNNPIVS_j\right) = \max_i SVI\left(DR_{ij}^N\right) = \max_i SVI\left(DT_{ij}^N, DI_{ij}^N, DF_{ij}^N\right) \tag{21}$$

$$SVI\left(SVNNNIVS_j\right) = \min_i SVI\left(DR_{ij}^N\right) = \min_i SVI\left(DT_{ij}^N, DI_{ij}^N, DF_{ij}^N\right) \tag{22}$$

Step 5. Construct the SVNN combined distance measure (SVNNCDM) between $DR_{ij}^N = \left(DT_{ij}^N, DI_{ij}^N, DF_{ij}^N\right)$ and $SVNNPIVS_j = \left(DT_j^{N+}, DI_j^{N+}, DF_j^{N+}\right)$ in line with SVNNHD and SVNNED.

$$\begin{aligned} &SVNNCDM\left(DR_{ij}^N, SVNNPIVS_j\right) \\ &= \frac{1}{2}\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right| + \left|DI_{ij}^N - DI_j^{N+}\right| + \left|DF_{ij}^N - DF_j^{N+}\right|\right) \\ + \sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right|^2 + \left|DI_{ij}^N - DI_j^{N+}\right|^2 + \left|DF_{ij}^N - DF_j^{N+}\right|^2\right)} \end{array}\right) \end{aligned} \tag{23}$$

Step 6. Construct the SVNN combined distance measure (SVNNCDM) between $DR_{ij}^N = \left(DT_{ij}^N, DI_{ij}^N, DF_{ij}^N\right)$ and $SVNNNIVS_j = \left(DT_j^{N-}, DI_j^{N-}, DF_j^{N-}\right)$ in line with SVNNHD and SVNNED.

$$SVNNCDM\left(DR_{ij}^{N}, SVNNNIVS_{j}\right) = \frac{1}{2}\left(\begin{array}{l}\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N-}\right| + \left|DI_{ij}^{N} - DI_{j}^{N-}\right| + \left|DF_{ij}^{N} - DF_{j}^{N-}\right|\right) \\ + \sqrt{\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N-}\right|^{2} + \left|DI_{ij}^{N} - DI_{j}^{N-}\right|^{2} + \left|DF_{ij}^{N} - DF_{j}^{N-}\right|^{2}\right)}\end{array}\right) \tag{24}$$

Step 7. Construct the SVNN weighted combined distance measure (SVNNWCDM) between $DR_{ij}^{N} = \left(DT_{ij}^{N}, DI_{ij}^{N}, DF_{ij}^{N}\right)$ and $SVNNPIVS_{j} = \left(DT_{j}^{N+}, DI_{j}^{N+}, DF_{j}^{N+}\right)$ in line with SVNNHD and SVNNED and SVNN weighted combined distance measure (SVNNWCDM) between $DR_{ij}^{N} = \left(DT_{ij}^{N}, DI_{ij}^{N}, DF_{ij}^{N}\right)$ and $SVNNNIVS_{j} = \left(DT_{j}^{N-}, DI_{j}^{N-}, DF_{j}^{N-}\right)$ in line with SVNNHD and SVNNED.

$$\begin{aligned} & SVNNWCDM\left(DR_{i}^{N}, SVNNPIVS\right) \\ & = \sum_{j=1}^{n}\left(dw_{j} SVNNCDM\left(DR_{ij}^{N}, SVNNPIVS_{j}\right)\right) \\ & = \frac{1}{2}\sum_{j=1}^{n}\left(dw_{j}\left(\begin{array}{l}\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N+}\right| + \left|DI_{ij}^{N} - DI_{j}^{N+}\right| + \left|DF_{ij}^{N} - DF_{j}^{N+}\right|\right) \\ + \sqrt{\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N+}\right|^{2} + \left|DI_{ij}^{N} - DI_{j}^{N+}\right|^{2} + \left|DF_{ij}^{N} - DF_{j}^{N+}\right|^{2}\right)}\end{array}\right)\right) \end{aligned} \tag{25}$$

$$\begin{aligned} & SVNNWCDM\left(DR_{i}^{N}, SVNNNIVS\right) \\ & = \sum_{j=1}^{n}\left(dw_{j} SVNNCDM\left(DR_{ij}^{N}, SVNNNIVS_{j}\right)\right) \\ & = \frac{1}{2}\sum_{j=1}^{n}\left(dw_{j}\left(\begin{array}{l}\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N-}\right| + \left|DI_{ij}^{N} - DI_{j}^{N-}\right| + \left|DF_{ij}^{N} - DF_{j}^{N-}\right|\right) \\ + \sqrt{\frac{1}{3}\left(\left|DT_{ij}^{N} - DT_{j}^{N-}\right|^{2} + \left|DI_{ij}^{N} - DI_{j}^{N-}\right|^{2} + \left|DF_{ij}^{N} - DF_{j}^{N-}\right|^{2}\right)}\end{array}\right)\right) \end{aligned} \tag{26}$$

Step 8. Form the SVNN combined closeness coefficient (SVNNCCC):

$$SVNNCCC_i = \frac{SVNNWCDM\left(DR_i^N, SVNNNIVS\right)}{\left(\begin{array}{l} SVNNWCDM\left(DR_i^N, SVNNNIVS\right) \\ +SVNNWCDM\left(DR_i^N, SVNNPIVS\right) \end{array}\right)}$$

$$= \frac{\sum_{j=1}^{n}\left(dw_j SVNNCDM\left(DR_{ij}^N, SVNNNIVS_j\right)\right)}{\left(\begin{array}{l} \sum_{j=1}^{n}\left(dw_j SVNNCDM\left(DR_{ij}^N, SVNNNIVS_j\right)\right) \\ +\sum_{j=1}^{n}\left(dw_j SVNNCDM\left(DR_{ij}^N, SVNNPIVS_j\right)\right) \end{array}\right)}$$

$$= \frac{\frac{1}{2}\sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right| + \left|DI_{ij}^N - DI_j^{N-}\right| + \left|DF_{ij}^N - DF_j^{N-}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right|^2 + \left|DI_{ij}^N - DI_j^{N-}\right|^2 + \left|DF_{ij}^N - DF_j^{N-}\right|^2\right)} \end{array}\right)\right)}{\left(\begin{array}{l} \frac{1}{2}\sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right| + \left|DI_{ij}^N - DI_j^{N-}\right| + \left|DF_{ij}^N - DF_j^{N-}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right|^2 + \left|DI_{ij}^N - DI_j^{N-}\right|^2 + \left|DF_{ij}^N - DF_j^{N-}\right|^2\right)} \end{array}\right)\right) \\ +\frac{1}{2}\sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right| + \left|DI_{ij}^N - DI_j^{N+}\right| + \left|DF_{ij}^N - DF_j^{N+}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right|^2 + \left|DI_{ij}^N - DI_j^{N+}\right|^2 + \left|DF_{ij}^N - DF_j^{N+}\right|^2\right)} \end{array}\right)\right) \end{array}\right)}$$

$$= \frac{\sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right| + \left|DI_{ij}^N - DI_j^{N-}\right| + \left|DF_{ij}^N - DF_j^{N-}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right|^2 + \left|DI_{ij}^N - DI_j^{N-}\right|^2 + \left|DF_{ij}^N - DF_j^{N-}\right|^2\right)} \end{array}\right)\right)}{\left(\begin{array}{l} \sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right| + \left|DI_{ij}^N - DI_j^{N-}\right| + \left|DF_{ij}^N - DF_j^{N-}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N-}\right|^2 + \left|DI_{ij}^N - DI_j^{N-}\right|^2 + \left|DF_{ij}^N - DF_j^{N-}\right|^2\right)} \end{array}\right)\right) \\ +\sum_{j=1}^{n}\left(dw_j\left(\begin{array}{l} \frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right| + \left|DI_{ij}^N - DI_j^{N+}\right| + \left|DF_{ij}^N - DF_j^{N+}\right|\right) \\ +\sqrt{\frac{1}{3}\left(\left|DT_{ij}^N - DT_j^{N+}\right|^2 + \left|DI_{ij}^N - DI_j^{N+}\right|^2 + \left|DF_{ij}^N - DF_j^{N+}\right|^2\right)} \end{array}\right)\right) \end{array}\right)} \quad (27)$$

Step 9. Form the optimal choice in line with the largest SVNNCCC.

4. Illustrative example and comparative analysis

4.1 Illustrative example

Considering that the promotion time of the whole process consulting service model in the consulting service industry in China is relatively short, some consulting service units have insufficient understanding of this work model. In actual work, the whole process consulting service model cannot achieve satisfactory work results for owners. In order to improve the application effect of the whole Process engineering consulting service model, in the current development process of the consulting service industry, consulting service units can improve their own working ability by optimizing their own ideas, implementing corresponding rules and policies, building talent teams, carrying out resource integration work, etc., and provide impetus for the implementation of the whole process consulting service projects. Although the National Development and Reform Commission and the Ministry of Housing and Urban Rural Development jointly issued the Guiding Opinions on Promoting the Development of Process engineering consulting Services, the housing construction management departments in most regions have insufficient awareness of the policies and the degree of implementation is not deep enough, so that some government public resource service platforms have not opened businesses related to bidding transactions, In the process of engineering project promotion, only the segmented engineering consulting service transaction module has been established, which has hindered the development of the whole process engineering consulting service. At this stage, in order to effectively solve the above problems and achieve the smooth implementation of relevant policies, the competent construction departments, construction owners and consulting service enterprises in various regions need to fully recognize the advantages of the whole Process engineering consulting service model in the application process for engineering project survey, design, supervision, management and cost services, and the way to open the whole Process engineering consulting service module by the local government's public resource service platform, Ensure the smooth implementation of the whole process engineering consulting project. Then, in the process of carrying out subsequent consulting services, the coherence of engineering consulting services is improved by constructing the entire industry chain, providing support for the improvement of the quality of subsequent engineering construction activities. Although the consulting service enterprises, owners and regulators can carry out their work based on the Guiding Opinions on Promoting the Development of process engineering consulting Services in the actual work process, due to the relatively short application time of the whole process engineering consulting service model in China, each entity may lack a mature contract model in the process of carrying out the whole process engineering consulting services, and disputes arise. In order to effectively solve the above problems, in the current process of engineering consulting services, consulting service units can strengthen communication and negotiation between various entities based on the actual needs of the engineering project and traditional engineering consulting contracts, and clarify the rights and responsibilities of different participating units. Specifically, in order to minimize the probability of conflicts and disputes, during the contract signing process, each participating entity needs to refine the issues of defining the rights and responsibilities of each entity, the requirements for clause performance, and dispute resolution clauses, in order to achieve effective division of the rights and responsibilities of each participating entity. At the same time, when negotiating related business, consulting service units can, on the basis of clarifying relevant systems and policies, complete consulting fee negotiation activities that can meet the requirements of the owner based on factors such as the scale and complexity of the project and the scope of the engineering consultation. Then, by recording the negotiation results in the contract, economic disputes can be avoided. The quality evaluation of whole process engineering consulting service modes is MAGDM. In this work, the quality evaluation of whole process engineering consulting service modes is formed through SVNN-CTOPSIS technique. There are five whole process engineering consulting service modes $DY_i\left(i=1,2,3,4,5\right)$ which are evaluated through three experts $DX=\left\{DX_1,DX_2,DX_3\right\}$ with equal weight values in light with four attributes: ① DZ_1 is the resource integration for whole process engineering consulting service; ② DZ_2 is the talent team construction for whole process engineering consulting service; ③ DZ_3 is the work ability for whole process engineering consulting service; ④ DZ_4 is the management cost for whole process engineering consulting service. The DZ_4 is cost type. Then, the SVNN-CTOPSIS model is formed to achieve the optimal whole process engineering consulting service mode.

Step 1. Form group SVNN-matrix $DR^{(k)}=\left(DR_{ij}^{(k)}\right)_{5\times 4}\left(k=1,2,3\right)$ in light with linguistic scales (See Table 1) as in Table 2-4. The single SVNN-matrix is achieved in Table 5.

Table 1. Linguistic scale and SVNNs

Linguistic scales	SVNNs
Exceedingly Terrible-DET	(0.0000, 1.0000, 1.0000)
Very Terrible-DVT	(0.1000, 0.9000, 0.9000)
Terrible-DT	(0.3000, 0.7000, 0.7000)
Medium-DM	(0.5000, 0.5000, 0.5000)
Well-DW	(0.7000, 0.3000, 0.3000)
Very Well-DVW	(0.9000, 0.1000, 0.1000)
Exceedingly Well-DEW	(1.0000, 0.0000, 0.0000)

Table 2. SVNN-matrix from DX_1

	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	DT	DVW	DVT	DM
DY_2	DVW	DW	DM	DVT
DY_3	DW	DM	DT	DVW
DY_4	DM	DW	DVW	DVT
DY_5	DVT	DVT	DVW	DM

Table 3. SVNN-matrix from DX_2

	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	DVW	DW	DVT	DM
DY_2	DM	DW	DVT	DVW
DY_3	DM	DT	DVW	DW
DY_4	DVT	DM	DVW	DT
DY_5	DT	DW	DM	DVW

Table 4. SVNN-matrix from DX_3

	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	DVW	DVT	DT	DW
DY_2	DW	DT	DM	DM
DY_3	DVW	DT	DM	DW
DY_4	DVT	DM	DW	DVT
DY_5	DT	DVW	DW	DM

Table 5. $DR = \left[DR_{ij} \right]_{5\times 4}$

	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	(0.45, 0.49, 0.41)	(0.47, 0.36, 0.48)	(0.43, 0.28, 0.32)	(0.48, 0.36, 0.39)
DY_2	(0.40, 0.28, 0.34)	(0.69, 0.31, 0.38)	(0.39, 0.34, 0.46)	(0.56, 0.48, 0.45)
DY_3	(0.58, 0.46, 0.37)	(0.56, 0.39, 0.46)	(0.48, 0.35, 0.39)	(0.25, 0.34, 0.43)

DY_4	(0.43, 0.19, 0.31)	(0.49, 0.43, 0.52)	(0.56, 0.49, 0.47)	(0.53, 0.37, 0.49)
DY_5	(0.51, 0.28, 0.16)	(0.54, 0.29, 0.34)	(0.63, 0.26, 0.35)	(0.67, 0.43, 0.36)

Step 2. Form the $DR = \left[DR_{ij}\right]_{5\times 4}$ into standardized $DR^N = \left[DR_{ij}^N\right]_{5\times 4}$ (See Table 6).

Table 6. The $DR^N = \left[DR_{ij}^N\right]_{5\times 4}$

	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	(0.45, 0.49, 0.41)	(0.47, 0.36, 0.48)	(0.43, 0.28, 0.32)	(0.39, 0.36, 0.48)
DY_2	(0.40, 0.28, 0.34)	(0.69, 0.31, 0.38)	(0.39, 0.34, 0.46)	(0.45, 0.48, 0.56)
DY_3	(0.58, 0.46, 0.37)	(0.56, 0.39, 0.46)	(0.48, 0.35, 0.39)	(0.43, 0.34, 0.25)
DY_4	(0.43, 0.19, 0.31)	(0.49, 0.43, 0.52)	(0.56, 0.49, 0.47)	(0.49, 0.37, 0.53)
DY_5	(0.51, 0.28, 0.16)	(0.54, 0.29, 0.34)	(0.63, 0.26, 0.35)	(0.36, 0.43, 0.67)

Step 3. Form the weight numbers in light with CRITIC (Table 7).

Table 7. The achieved weight

Attributes	DZ_1	DZ_2	DZ_3	DZ_4
weight numbers	0.2803	0.3002	0.2573	0.1622

Step 4. Form the SVNNNPIVS and SVNNNNIVS (Table 8):

Table 8. The SVNNNPIVS and SVNNNNIVS

	DZ_1	DZ_2
SVNNNPIVS	(0.58, 0.46, 0.37)	(0.69, 0.31, 0.38)
SVNNNNIVS	(0.40, 0.28, 0.34)	(0.47, 0.36, 0.48)
	DZ_3	DZ_4
SVNNNPIVS	(0.63, 0.26, 0.35)	(0.49, 0.37, 0.53)
SVNNNNIVS	(0.39, 0.34, 0.46)	(0.36, 0.43, 0.67)

Step 5. Calculate the $SVNNCDM\left(DR_{ij}^{N}, SVNNPIVS_{j}\right)$ between $DR_{ij}^{N}=\left(DT_{ij}^{N}, DI_{ij}^{N}, DF_{ij}^{N}\right)$ and $SVNNPIVS_{j}=\left(DT_{j}^{N+}, DI_{j}^{N+}, DF_{j}^{N+}\right)$ in line with SVNNHD and SVNNED (Table 9).

Table 9. $SVNNCDM\left(DR_{ij}^{N}, SVNNPIVS_{j}\right)$.

Alternatives	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	0.4601	0.2837	0.3718	0.5046
DY_2	0.5183	0.0000	0.4138	0.3371
DY_3	0.0000	0.3168	0.4446	0.3653
DY_4	0.4857	0.3760	0.6098	0.0000
DY_5	0.4208	0.4284	0.0000	0.4551

Step 6. Calculate the $SVNNCDM\left(DR_{ij}^{N}, SVNNNIVS_{j}\right)$ between $DR_{ij}^{N}=\left(DT_{ij}^{N}, DI_{ij}^{N}, DF_{ij}^{N}\right)$ and $SVNNPIVS_{j}=\left(DT_{j}^{N-}, DI_{j}^{N-}, DF_{j}^{N-}\right)$ in line with SVNNHD and SVNNED (Table 10).

Table 10. $SVNNCDM\left(DR_{ij}^{N}, SVNNNIVS_{j}\right)$.

Alternatives	DZ_1	DZ_2	DZ_3	DZ_4
DY_1	0.4514	0.0000	0.3647	0.4950
DY_2	0.0000	0.3689	0.0000	0.3307
DY_3	0.4128	0.3108	0.4059	0.4465
DY_4	0.4765	0.2783	0.5982	0.3583
DY_5	0.5085	0.4202	0.4361	0.0000

Step 7. Construct the SVNNWCDM from the SVNNPIVS and SVNNNIVS (Table 11).

Table 11. The SVNNWCDM from the SVNNPIVS and SVNNNIVS

	$SVNNWCDM\left(DR_{i}^{N}, SVNNPIVS\right)$	$SVNNWCDM\left(DR_{i}^{N}, SVNNNIVS\right)$

DY_1	0.3916	0.3006
DY_2	0.3064	0.1644
DY_3	0.2687	0.3858
DY_4	0.4059	0.4291
DY_5	0.3204	0.3809

Step 8. Form the SVNNCCC (Table 12).

Table 12. The SVNNCCC

	SVNNCCC	Order
DY_1	0.4343	4
DY_2	0.3491	5
DY_3	0.5895	1
DY_4	0.5139	3
DY_5	0.5432	2

Step 9. In light with SVNNCCC, the obtained order is: $DY_3 > DY_5 > DY_4 > DY_1 > DY_2$ and DY_3 is the optimal whole process engineering consulting service mode.

4.2. Comparative analysis

The formed SVNN-CTOPSIS model is compared with SVNNWA model [55], SVNNWG model [55], SVNWBPM operator [58], SVNWGBPM operator[58], SVNN-WASPAS technique [59] and SVNN-TODIM technique [60], SVNN-GRA method[61], SVNN-VIKOR technique[62] and SVNN-CODAS technique [63]. The sufficient comparative results are verified in Table 17 and Figure 2.

Table 17. Order for different models

	Order
SVNNWA model [55]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$
SVNNWG model [55]	$DY_3 > DY_5 > DY_1 > DY_4 > DY_2$
SVNWBPM operator [58]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$
SVNWGBPM operator[58]	$DY_3 > DY_5 > DY_1 > DY_4 > DY_2$
SVNN-WASPAS technique [59]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$
SVNN-TODIM technique [60]	$DY_3 > DY_5 > DY_1 > DY_4 > DY_2$
SVNN-GRA method [61]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$

SVNN-VIKOR technique [62]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$
SVNN-CODAS technique [63]	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$
SVNN-CTOPSIS model	$DY_3 > DY_5 > DY_4 > DY_1 > DY_2$

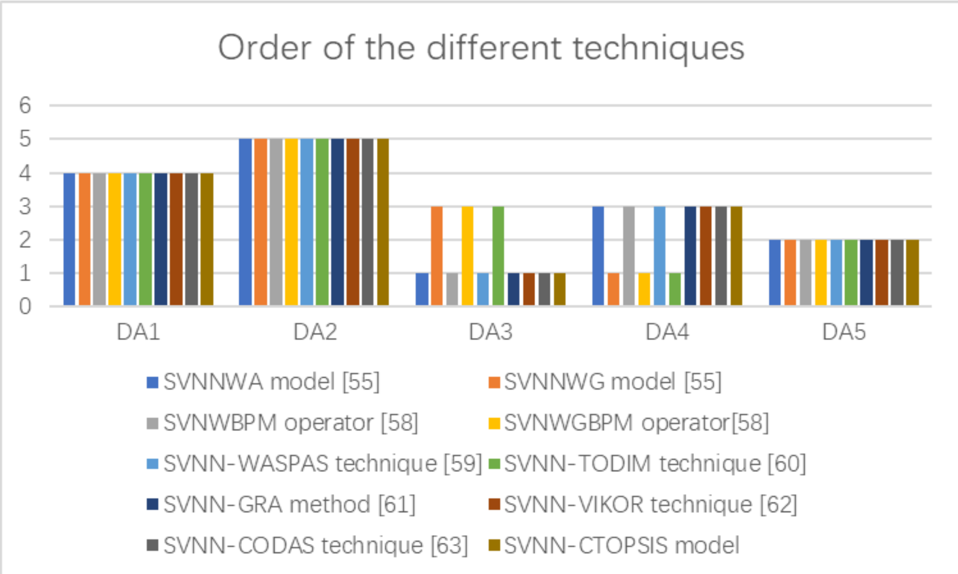

Figure 2. Order for different models

Through the above analysis, it could be seen that the order of these models is slightly different, however, these models have the same optimal whole process engineering consulting service mode and worst whole process engineering consulting service mode. This verifies the SVNN-CTOPSIS model is effective. Thus, the main advantages of the conducted SVNN-CTOPSIS model are formed: (1) the formed SVNN-CTOPSIS not only formed the uncertainty in MAGDM, but also portrays the combined distance measures from the SVNNNPIVS and SVNNNNIVS during the quality evaluation of whole process engineering consulting service modes. (2) the formed SVNN-CTOPSIS conducted the different behavior of the SVNNHD and SVNNED model as MAGDM techniques when they are combined.

5. Conclusion

The whole Process engineering consulting is a mode of providing all-round and full life cycle engineering consulting services for engineering construction projects from the perspective of the overall value appreciation of the project in order to effectively achieve the value objectives of engineering construction projects, which is also an international practice. With the rapid development of China's engineering construction industry, the scale of engineering projects continues to expand, and the complexity of engineering continues to increase. This poses serious challenges to China's engineering consulting industry. The previous fragmented engineering consulting model is no longer suitable for the new national conditions, nor can it cope with the international development of China's engineering consulting industry both domestically and internationally. Seamless integration with the international engineering consulting industry, large-scale implementation of the whole Process engineering consulting model is imperative. The quality evaluation of whole process engineering consulting service modes is MAGDM. In this paper, the SVNN-CTOPSIS model based on SVNNHD and SVNNED is formed to cope with the MAGDM. The CRITIC model is utilized to obtain the weight numbers in light with the SVNNHD and SVNNED under SVNSs. Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is employed to verify SVNN-CTOPSIS model. The main contributions of this study are formed: (1) the CRITIC model is formed to obtain the weight numbers in light with SVNNHD and SVNNED; (2) the SVNN-CTOPSIS model is formed in light with SVNNHD and SVNNED under SVNNs; (3) Finally, numerical example and comparative analysis for quality evaluation of whole process engineering consulting service modes is utilized to verify SVNN-CTOPSIS model.

There may be some possible research limitations for quality evaluation of whole process engineering consulting service modes, which could be further conducted in our future research contents: (1) It is a worthwhile research contents to conduct prospect theory[64-70] for quality evaluation of whole process engineering consulting service modes under SVNSs; (2) It is also worthwhile research contents to conduct regret theory[71-77] for quality evaluation of whole process engineering consulting service modes under SVNSs environment; (3) In subsequent research contents, the application of SVNSs needs to be formed with consensus issues [78-83] for quality evaluation of whole process engineering consulting service modes.

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References

[1] M. Jaafar, A.R.A. Aziz, A.L.S. Wai, Marketing practices of professional engineering consulting firms: Implement or not to implement?, Journal of Civil Engineering and Management, 14 (2008) 199-206.

[2] J. Ploennigs, M. Neugebauer, K. Kabitzsch, Diagnosis and consulting for control network performance engineering of csma-based networks, Ieee Transactions on Industrial Informatics, 4 (2008) 71-79.

[3] Q.E. Wang, M.M. Ding, A study on the impact of digital management on willingness to transfer knowledge in whole-process engineering consulting projects, Buildings, 13 (2023) 19.

[4] S.H. Wang, Effective assignment of work items for an engineering consulting project based on consulting engineer selection matrix, Journal of the Chinese Institute of Engineers, 46 (2023) 229-241.

[5] S.H. Wang, Engineering consulting project budget allocation and cost control model based on baseline productivity, Ksce Journal of Civil Engineering, 27 (2023) 2339-2355.

[6] M. Van Name, G. Klingensmith, B. Nelson, K. Wintergerst, J. Mitchell, K. Norris, W.V. Tamborlane, C. Pediat

Diabet, Transforming performance of clinical trials in pediatric type 2 diabetes: A consortium model, Diabetes Technology & Therapeutics, 22 (2020) 330-336.

[7] L. Carter-Edwards, J.L. Cook, M.A. McDonald, S.M. Weaver, K. Chukwuka, M. Eder, Report on ctsa consortium use of the community engagement consulting service, Cts-Clinical and Translational Science, 6 (2013) 34-39.

[8] J. Zhu, Z. Tian, T. Li, W. Sun, S. Ye, W. Ding, C.C. Wang, G. Wu, L. Weng, S. Huang, B. Liu, D. Chou, Mode-driven business process integration and management: A case study with the bank sinopac regional service platform, Ibm Journal of Research and Development, 48 (2004) 649-669.

[9] C.M. Blom, P.M. Guthrie, Infrastructure outcomes: What new project operational expenditure reveals as missing, Proceedings of the Institution of Civil Engineers-Municipal Engineer, 171 (2018) 216-233.

[10] Z.Z. Shen, J.Y. Zhao, M. Guo, Evaluating the engineering-procurement-construction approach and whole process engineering consulting mode in construction projects, Iranian Journal of Science and Technology-Transactions of Civil Engineering, 47 (2023) 2533-2547.

[11] W. Piyadasa, B.H.W. Hadikusumo, Risk assessment in non-standard forms of civil engineering consulting services, Journal of Civil Engineering and Management, 20 (2014) 746-759.

[12] J. Rogers, H.Y. Chong, C. Preece, Adoption of building information modelling technology (bim) perspectives from malaysian engineering consulting services firms, Engineering Construction and Architectural Management, 22 (2015) 424-445.

[13] Y.F. Chen, J. Yan, Z.F. Yang, J. Bian, H. Chi, Measuring service quality using a hierarchical model: An application of engineering consulting services in china, in: International Conference on Construction and Real Estate Management (ICCREM), Amer Soc Civil Engineers, Guangzhou, PEOPLES R CHINA, 2017, pp. 270-278.

[14] G.S. Stroe, On the strategic role of suppliers in the case of engineering consulting and design services firms, in: 6th International Conference on Management and Industrial Engineering - ICMIE 2013, Editura Niculescu, Bucharest, ROMANIA, 2013, pp. 273-280.

[15] A. Alvaro-Moya, The globalization of knowledge-based services: Engineering consulting in spain, 1953-1975, Business History Review, 88 (2014) 681-707.

[16] L.P. Feng, Z.H. Dong, Application of hall for workshop of meta-synthetic engineering in the knowledge consulting services, in: 4th International Conference on Mechatronics, Control and Electronic Engineering (MCE), Atlantis Press, Shenyang, PEOPLES R CHINA, 2014, pp. 481-484.

[17] J. Becker, M. Eggert, J. Saat, P. Dirding, S. Assoc Informat, The influence of regulation on data warehouse engineering - investigating an it consulting case in the financial service industry completed research paper, in: 19th Americas Conference on Information Systems (AMCIS) - Hyperconnected World - Anything, Anywhere, Anytime, Assoc Information Systems, Chicago, IL, 2013.

[18] M.R.A. Moreira, M.A.S. Maia, P.S.A. Sousa, R.F.C. Meneses, Factors influencing the internationalization of services firms: The case of design, engineering and architecture consulting firms, in: 4th International

Conferences on Exploring Service Science, Springer-Verlag Berlin, Univ Porto, Fac Engn, Porto, PORTUGAL, 2013, pp. 246-262.

[19] Y. Ding, H.W. Zhou, S.Y. Deng, E.B.M.O. Comm, Professional service firm's business development: A case study on chinese engineering consulting firms, in: 2nd International Conference on Engineering and Business Management, Sci Res Publ, Inc-Srp, Wuhan, PEOPLES R CHINA, 2011, pp. 155-158.

[20] S.O. Shrake, A.E. Landis, M.M. Bilec, Ieee, Greening the service industries: A case study of a united states engineering consulting firm, in: IEEE International Symposium on Sustainable Systems and Technology (ISSST), Ieee, Chicago, IL, 2011.

[21] Y.X. Zhao, S.Y. Hao, The innovation of knowledge service for network-based engineering consulting industry in china, in: International Conference on Green Building, Materials and Civil Engineering (GBMCE 2011), Trans Tech Publications Ltd, Shangri La, PEOPLES R CHINA, 2011, pp. 4035-4038.

[22] C. Jana, G. Muhiuddin, M. Pal, Multiple-attribute decision making problems based on svtnh methods, Journal of Ambient Intelligence and Humanized Computing, 11 (2020) 3717-3733.

[23] M. Qiyas, S. Abdullah, S. Ashraf, M. Aslam, Utilizing linguistic picture fuzzy aggregation operators for multiple-attribute decision-making problems, International Journal of Fuzzy Systems, 22 (2020) 310-320.

[24] N. Zarbakhshnia, Y. Wu, K. Govindan, H. Soleimani, A novel hybrid multiple attribute decision-making approach for outsourcing sustainable reverse logistics, Journal of Cleaner Production, 242 (2020) 16.

[25] M. Al-Gharabally, A.F. Almutairi, A.A. Salman, Particle swarm optimization application for multiple attribute decision making in vertical handover in heterogenous wireless networks, Journal of Engineering Research, 9 (2021) 12.

[26] I. Alshammari, P. Mani, C. Ozel, H. Garg, Multiple attribute decision making algorithm via picture fuzzy nano topological spaces, Symmetry-Basel, 13 (2021) 12.

[27] X.P. Lu, J. Ye, Similarity measures of linguistic cubic hesitant variables for multiple attribute group decision-making, Information, 10 (2019).

[28] M. Olgun, E. Turkarslan, M. Unver, J. Ye, A cosine similarity measure based on the choquet integral for intuitionistic fuzzy sets and its applications to pattern recognition, Informatica, 32 (2021) 849-864.

[29] J. Ye, Similarity measures based on the generalized distance of neutrosophic z-number sets and their multi-attribute decision making method, Soft Computing, 25 (2021) 13975-13985.

[30] J. Ye, S.G. Du, R. Yong, Similarity measures between intuitionistic fuzzy credibility sets and their multicriteria decision-making method for the performance evaluation of industrial robots, Mathematical Problems in Engineering, 2021 (2021) 10.

[31] L.A. Zadeh, Fuzzy sets, Information and Control, 8 (1965) 338-353.

[32] K.T. Atanassov, More on intuitionistic fuzzy-sets, Fuzzy Sets and Systems, 33 (1989) 37-45.

[33] F. Smarandache, Neutrosophic probability, set, and logic, proquest information & learning, Ann Arbor, Michigan, USA, 105 (1998) 118-123.

[34] M. Zenat, M.I. Mahmoud, F.A.E.-G. Amal, Neutrosophic model to examine the challenges faced by

manufacturing businesses in adopting green supply chain practices and to provide potential solutions, Neutrosophic Systems with Applications, 3 (2023) 45-52.

[35] S. Ahmed, M. Nehal, E. Ibrahim, Neutrosophic critic mcdm methodology for ranking factors and needs of customers in product's target demographic in virtual reality metaverse, Neutrosophic Systems with Applications, 2 (2023) 55-65.

[36] A. Gamal, R. Mohamed, M. Abdel-Basset, I.M. Hezam, F. Smarandache, Consideration of disruptive technologies and supply chain sustainability through α-discounting ahp–vikor: Calibration, validation, analysis, and methods, Soft Computing, (2023).

[37] K. M. Sallam, A.W. Mohamed, Single valued neutrosophic sets for assessment quality of suppliers under uncertainty environment, Multicriteria Algorithms with Applications, 1 (2023) 1-10.

[38] W. M. Sabry, An integrated neutrosophic approach for the urban energy internet assessment under sustainability dimensions, Neutrosophic Systems with Applications, 12 (2023) 22-35.

[39] A. Gamal, M. Abdel-Basset, I.M. Hezam, K.M. Sallam, I.A. Hameed, An interactive multi-criteria decision-making approach for autonomous vehicles and distributed resources based on logistic systems: Challenges for a sustainable future, 15 (2023) 12844.

[40] G. Hu, Modified edas method for spherical fuzzy multiple attribute group decision making and applications to english classroom teaching quality evaluation, Journal of Intelligent & Fuzzy Systems, 45 (2023) 2799-2811.

[41] P. Gao, Vikor method for intuitionistic fuzzy multi-attribute group decision-making and its application to teaching quality evaluation of college english, Journal of Intelligent & Fuzzy Systems, 42 (2022) 5189-5197.

[42] W. Dou, Madm framework based on the triangular pythagorean fuzzy sets and applications to college public english teaching quality evaluation, Journal of Intelligent & Fuzzy Systems, 45 (2023) 4395-4414.

[43] X. Rong, Triangular pythagorean fuzzy bonferroni mean operators in multiple attribute decision making and applications to college english smart classroom teaching quality evaluation, Journal of Intelligent & Fuzzy Systems, 45 (2023) 2871-2886.

[44] L. Wei, An integrated decision-making framework for blended teaching quality evaluation in college english courses based on the double-valued neutrosophic sets, Journal of Intelligent & Fuzzy Systems, 45 (2023) 3259-3266.

[45] H. Wang, F. Smarandache, Y.Q. Zhang, R. Sunderraman, Single valued neutrosophic sets, Multispace Multistruct, (2010) 410-413.

[46] Y.-J. Lai, T.-Y. Liu, C.-L. Hwang, Topsis for modm, European Journal of Operational Research, 76 (1994) 486-500.

[47] C.T. Chen, Extensions of the topsis for group decision-making under fuzzy environment, Fuzzy Sets and Systems, 114 (2000) 1-9.

[48] S. Giove, Interval topsis for multicriteria decision making, in: M. Marinaro, R. Tagliaferri (Eds.) Neural nets, Springer-Verlag Berlin, Berlin, 2002, pp. 56-63.

[49] M. Braglia, M. Frosolini, R. Montanari, Fuzzy topsis approach for failure mode, effects and criticality analysis, Quality and Reliability Engineering International, 19 (2003) 425-443.

[50] D. Diakoulaki, G. Mavrotas, L. Papayannakis, Determining objective weight in multple criteria problems:The critic method, Computers & Operations Research, 22 (1995) 763-770.

[51] I. Hassan, I. Alhamrouni, N.H. Azhan, A critic-topsis multi-criteria decision-making approach for optimum site selection for solar pv farm, Energies, 16 (2023) 26.

[52] T. Mahmood, Z. Ali, M. Naeem, Aggregation operators and critic-vikor method for confidence complex q-rung orthopair normal fuzzy information and their applications, Caai Transactions on Intelligence Technology, 8 (2023) 40-63.

[53] J.L. Xiao, Z.S. Xu, X.X. Wang, An improved multimoora with critic weights based on new equivalent transformation functions of nested probabilistic linguistic term sets, Soft Computing, 27 (2023) 11629-11646.

[54] J.Y. Yin, J.Q. Wang, C.Y. Wang, L.X. Wang, Z.Y. Chang, Critic-topsis based evaluation of smart community governance: A case study in china, Sustainability, 15 (2023) 18.

[55] J.J. Peng, J.Q. Wang, J. Wang, H.Y. Zhang, X.H. Chen, Simplified neutrosophic sets and their applications in multi-criteria group decision-making problems, International Journal of Systems Science, 47 (2016) 2342-2358.

[56] P. Majumdar, S.K. Samanta, On similarity and entropy of neutrosophic sets, Journal of Intelligent & Fuzzy Systems, 26 (2014) 1245-1252.

[57] D. Diakoulaki, G. Mavrotas, L. Papayannakis, Determining objective weights in multiple criteria problems: The critic method, Computers & Operations Research, 22 (1995) 763-770.

[58] G.W. Wei, Z.P. Zhang, Some single-valued neutrosophic bonferroni power aggregation operators in multiple attribute decision making, Journal of Ambient Intelligence and Humanized Computing, 10 (2019) 863-882.

[59] E.K. Zavadskas, R. Bausys, D. Stanujkic, M. Magdalinovic-Kalinovic, Selection of lead-zinc flotation circuit design by applying waspas method with single-valued neutrosophic set, Acta Montanistica Slovaca, 21 (2016) 85-92.

[60] D.S. Xu, C. Wei, G.W. Wei, Todim method for single-valued neutrosophic multiple attribute decision making, Information, 8 (2017) 125.

[61] Y.H. Sun, Y.L. Cai, A flexible decision-making method for green supplier selection integrating topsis and gra under the single-valued neutrosophic environment, Ieee Access, 9 (2021) 83025-83040.

[62] H. Eroglu, R. Sahin, A neutrosophic vikor method-based decision-making with an improved distance measure and score function: Case study of selection for renewable energy alternatives, Cognitive Computation, 12 (2020) 1338-1355.

[63] E. Bolturk, A. Karasan, Prioritization of investment alternatives for a hospital by using neutrosophic codas method, Journal of Multiple-Valued Logic and Soft Computing, 33 (2019) 381-396.

[64] A. Tversky, D. Kahneman, Prospect theory: An analysis of decision under risk, Econometrica, 47 (1979) 263-291.

[65] X.F. Huang, J.M. Zhan, Z.S. Xu, H. Fujita, A prospect-regret theory-based three-way decision model with intuitionistic fuzzy numbers under incomplete multi-scale decision information systems, Expert Systems with Applications, 214 (2023) 17.

[66] X. Jin, Gra method based on cumulative prospect theory for mcgdm with ivnss and applications to college english translation teaching quality evaluation, Journal of Intelligent & Fuzzy Systems, 45 (2023) 1303-1312.

[67] G.L. Tang, X.Y. Zhang, B.Y. Zhu, H. Seiti, F. Chiclana, P.D. Liu, A mathematical programming method based on prospect theory for online physician selection under an r-set environment, Information Fusion, 93 (2023) 441-468.

[68] Z.Y. Wang, Q. Cai, G.W. Wei, Modified todim method based on cumulative prospect theory with type-2 neutrosophic number for green supplier selection, Engineering Applications of Artificial Intelligence, 126 (2023) 18.

[69] H.Y. Zhang, H.J. Wang, G.W. Wei, Spherical fuzzy todim method for magdm integrating cumulative prospect theory and critic method and its application to commercial insurance selection, Artificial Intelligence Review, 56 (2023) 10275-10296.

[70] Y.J.Y. Zhang, Q. Cai, G.W. Wei, H.J. Wang, C. Wei, A modified edas method based on cumulative prospect theory for magdm with 2-tuple linguistic pythagorean fuzzy information, International Journal of Fuzzy Systems, 25 (2023) 2109-2122.

[71] H. Bleichrodt, A. Cillo, E. Diecidue, A quantitative measurement of regret theory, Management Science, 56 (2010) 161-175.

[72] J.J. Wang, X.L. Ma, Z.S. Xu, J.M. Zhan, Regret theory-based three-way decision model in hesitant fuzzy environments and its application to medical decision, Ieee Transactions on Fuzzy Systems, 30 (2022) 5361-5375.

[73] N. Zhang, Y.F. Zhou, Q. Pan, G.W. Wei, Multi-attribute decision-making method with triangular fuzzy numbers based on regret theory and the catastrophe progression method, Mathematical Biosciences and Engineering, 19 (2022) 12013-12030.

[74] X. Jia, Y.M. Wang, A multi-criterion group decision-making method based on regret theory under 2-tuple linguistic environment, Kybernetes, 52 (2023) 1400-1424.

[75] L.J. Peng, D.S. Xu, A multi-criteria decision-making with regret theory-based multimoora method under interval neutrosophic environment, Journal of Intelligent & Fuzzy Systems, 44 (2023) 4059-4077.

[76] N. Zhang, X. Yuan, J. Liu, G.W. Wei, Stochastic multiple attribute decision making with pythagorean hesitant fuzzy set based on regret theory, Mathematical Biosciences and Engineering, 20 (2023) 12562-12578.

[77] N. Zhang, Y.F. Zhou, J. Liu, G.W. Wei, Vikor method for pythagorean hesitant fuzzy multi-attribute

decision-making based on regret theory, Engineering Applications of Artificial Intelligence, 126 (2023) 8.

[78] P. Wu, F.G. Li, J. Zhao, L.G. Zhou, L. Martfnez, Consensus reaching process with multiobjective optimization for large-scale group decision making with cooperative game, Ieee Transactions on Fuzzy Systems, 31 (2023) 293-306.

[79] K. Xiong, Y. Dong, Q. Zha, A large-scale consensus model to manage non-cooperative behaviors in group decision making: A perspective based on historical data, Expert Systems with Applications, 214 (2023).

[80] X.X. Xu, Z.W. Gong, E. Herrera-Viedma, G. Kou, F.J. Cabrerizo, Consensus reaching in group decision making with linear uncertain preferences and asymmetric costs, Ieee Transactions on Systems Man Cybernetics-Systems, 53 (2023) 2887-2899.

[81] R.N. Zhang, J. Huang, Y.J. Xu, E. Herrera-Viedma, Consensus models with aggregation operators for minimum quadratic cost in group decision making, Applied Intelligence, 53 (2023) 1370-1390.

[82] Y.Z. Zhao, Z.W. Gong, G. Wei, R. Slowinski, Consensus modeling with interactive utility and partial preorder of decision-makers, involving fairness and tolerant behavior, Information Sciences, 638 (2023) 21.

[83] W.C. Zou, S.P. Wan, J.Y. Dong, L. Martinez, A new social network driven consensus reaching process for multi-criteria group decision making with probabilistic linguistic information, Information Sciences, 632 (2023) 467-502.

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