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Combined Group Decision-Making Framework for Employment Quality Evaluation in Higher Education Institutions under Single-Valued Neutrosophic Sets

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Abstract: The evaluation of employment quality in higher education institutions refers to assessing graduates' performance and employment status through multiple dimensions. It mainly includes employment rate, job satisfaction, salary levels, industry distribution, and career development prospects. This evaluation not only reflects the educational quality and social recognition of the institution but also provides valuable insights for optimizing teaching and training programs, helping graduates better meet the demands of the labor market. The employment quality evaluation in higher education institutions is a multi-attribute group decision-making (MAGDM) problem. Recently, the Exponential TODIM (ExpTODIM) and VIKOR methods have been applied to address MAGDM challenges. Single-valued neutrosophic sets (SVNSs) are employed as a tool to represent uncertain data in the employment quality evaluation in higher education institutions. In this paper, we propose the single-valued neutrosophic number Exponential TODIM-VIKOR (SVNN-ExpTODIM-VIKOR) method to solve MAGDM problems under SVNSs. Finally, a numerical case study is presented to validate the effectiveness of the proposed method in evaluating the employment quality in higher education institutions.

Keywords: MAGDM; SVNSs; information entropy; ExpTODIM approach; VIKOR approach; employment quality evaluation

1. Introduction

The evaluation of employment quality in higher education institutions holds significant importance and has far-reaching impacts on various stakeholders. Firstly, it objectively reflects the actual effectiveness of talent cultivation in universities. By assessing indicators such as employment rate, salary levels, and job satisfaction, universities can better understand the competitiveness of their graduates in the labor market, identify shortcomings in teaching and talent development, optimize curriculum design, and improve the overall quality of education. Secondly, the evaluation provides crucial reference information for students and parents when choosing schools. By understanding the employment quality data of different institutions, students can make more informed decisions that align with their career development plans, selecting more competitive programs and schools. Additionally, this evaluation offers valuable insights for employers. The results help companies assess the overall quality of graduates from different institutions, allowing them to better match talent to job requirements and improve recruitment efficiency. Finally, from a macro perspective, the evaluation of employment quality serves as an important metric for measuring the alignment between higher education and market demand. It helps drive higher education reform, promotes a deeper connection between talent cultivation and societal needs, and enhances the contribution of universities to social and economic development. Employment quality evaluation in higher education institutions represents a classical MAGDM problem. Decision-makers (DMs) often utilize SVNSs [1] in the employment quality evaluation in higher education institutions. The SVNSs [1] offer significant advantages in handling uncertainty and fuzzy information. First, SVNSs can simultaneously represent truth, falsity, and indeterminacy, providing a more flexible modeling approach compared to traditional fuzzy sets. This allows for a precise description of uncertainty in complex systems. Second, SVNSs effectively address common issues of uncertainty and incomplete information in decision-making, especially in cases where information is ambiguous or contradictory. Third, SVNSs offer greater flexibility by independently representing truth, falsity, and indeterminacy in a three-dimensional space, thereby improving the accuracy and rationality of decisions. Finally, SVNSs are widely applied in areas such as MADM, risk assessment, and medical diagnosis, making them particularly suitable for dealing with fuzzy and uncertain information in complex decision environments. Thus, SVNSs provide a powerful and flexible solution for uncertainty-related problems. However, due to limited knowledge about the decision domain and time constraints, the attribute weights are frequently unknown. This challenge motivated us to develop a novel decision-making approach to determine weight values based on entropy under SVNSs. Gomes and Lima [2] and Gomes and Lima [3] initially introduced the TODIM method for MADM under risk, and later, Leoneti and Gomes [4] proposed the Exponential

TODIM (ExpTODIM). While many decision algorithms use ExpTODIM[4-6] and VIKOR[7, 8] methods independently to identify optimal decisions, few have explored the combination of information entropy with ExpTODIM-VIKOR under SVNSs. To address this gap, we propose an integrated SVNN-ExpTODIM-VIKOR method to solve the MAGDM problem. An illustrative example of employment quality evaluation in higher education institutions, accompanied by a comparative analysis, is provided to validate the effectiveness and reliability of the SVNN-ExpTODIM-VIKOR approach.

The main contributions of this paper are outlined: (1) To design an information entropy method using SVNSs to derive weight information; (2) To establish an integrated SVNN-ExpTODIM-VIKOR method to solve the MAGDM problem; and (3) To present an illustrative example of employment quality evaluation in higher education institutions to demonstrate the effectiveness of SVNN-ExpTODIM-VIKOR method.

The structure of this paper is outlined: Section 2 introduces the literature review. Section 3 introduces the concept of SVNSs. In Section 4, the SVNN-ExpTODIM-VIKOR method, incorporating entropy, is developed under the SVNS framework. Section 5 presents an illustrative case study on the employment quality evaluation in higher education institutions, along with a comparative analysis. Finally, concluding remarks are provided in Section 6.

2. Literature review

In recent years, research on the employment quality evaluation systems for university graduates has become a significant topic in the field of education. As economic and social development progresses and the job market becomes increasingly complex, traditional evaluation methods have struggled to fully capture the actual employment status of graduates. As a result, researchers have begun exploring more diversified evaluation indicators and methods in order to scientifically and comprehensively assess how well university talent aligns with society's needs. Early research primarily focused on objective indicators such as employment rates and salary levels. However, these singular quantitative metrics often fail to reflect the multidimensional nature of employment quality. As research has advanced, scholars have increasingly recognized the importance of incorporating subjective indicators, such as graduate satisfaction, career development potential, and social recognition. Additionally, the construction of an evaluation system should not only consider the short-term employment situation of graduates but also their long-term career development and alignment with changes in industrial structures. With the rise of big data technologies, more studies have begun to incorporate data mining and machine learning to improve the accuracy and dynamism of evaluations. A multidimensional, multi-level evaluation system is gradually becoming the norm, with the focus shifting to how to comprehensively account for the diverse needs of universities, employers, governments, and individual graduates. The literature review for employment quality evaluation in higher education institutions is constructed in Table 1.

Table 1. Literature review for employment quality evaluation in higher education institutions

Author Information	*Method Information*	*Research Content*
Li and Huang [9]	Proposed objective indicators such as employment rate, supply-demand ratio, and employment structure, along with subjective indicators like graduate satisfaction and social recognition. Attempted to adjust the weighting of objective and subjective metrics.	Explored the construction of an employment quality evaluation index system for university graduates, proposing five primary indicators and seventeen secondary indicators.
Wu and Wang [10]	Analyzed employment quality annual reports and proposed suggestions for constructing a more scientific and reasonable evaluation index system.	Studied the employment quality evaluation system for Ministry of Education-affiliated universities, identifying issues such as differing evaluation standards and inconsistent data sources.
Song [11]	Proposed an evaluation index framework based on MBO (Management by Objectives) theory for constructing a China-specific university graduate employment quality evaluation system.	Reflected on the construction of an employment quality evaluation system that fits China's national conditions, emphasizing comprehensiveness, scientific rigor, and operability.
Wu and Dong [12]	Proposed employment quality influencing factors and constructed an evaluation system.	Constructed an employment quality evaluation system for university graduates, identifying diverse and complex evaluation factors to adapt to new requirements.
Hu [13]	Literature review suggested introducing new indicators and establishing a scientific evaluation model.	Reviewed research on employment quality evaluation index systems for university graduates, identifying limitations in existing studies and proposing improvements.
Huang [14]	Conducted empirical surveys to analyze provincial university graduate employment structures and proposed measures to improve employment quality.	Investigated the employment structure of 2015 graduates from 47 universities within a province, analyzing industry, regional distribution, and employment satisfaction.
Gao, Wang, Wang, Ma and Tang [15]	Designed 14 indicators from the employer's perspective and conducted an empirical evaluation.	Analyzed university graduate employment quality from an employer's viewpoint, providing suggestions for improving employment quality based on employer satisfaction.
Wang [16]	Researched the application of big data technology in employment quality evaluation and proposed methods to enhance its use.	Explored the application of big data technology in the employment quality evaluation system for university graduates, introducing data processing techniques and suggesting methods for improvement.
Yan [17]	Analyzed domestic and international research findings and proposed constructing an employment quality evaluation system from four dimensions.	Suggested constructing an employment quality evaluation index system from the perspectives of government, employers, universities, and graduates, recommending large-scale sample studies.
Gu and Lin [18]	Proposed constructing a diversified evaluation mechanism led by universities and optimizing evaluation paths and methods.	Discussed the employment quality evaluation system for university graduates, arguing that it should reflect not only employment rates but also discipline construction and talent cultivation quality.
Guo [19]	Proposed an evaluation model based on AHP (Analytic Hierarchy Process) and RBM (deep learning).	Developed a university student employment quality evaluation method using AHP and deep learning to increase evaluation accuracy.
Liang, Zhang and Liang [20]	Applied the Analytic Hierarchy Process and expert scoring methods to build a fuzzy comprehensive evaluation model.	Studied the employment quality evaluation system for industry-specific universities in the context of the new era, constructing evaluation indices from four dimensions: graduates, universities, employers, and society.
Yan, Pei and Li [21]	Constructed a focused and quantifiable evaluation system, conducted empirical testing, and proposed improvement suggestions.	Built a graduate employment quality evaluation system from the perspective of universities' capacity to serve local economic development, proposing suggestions to promote a virtuous cycle of "admissions-training-employment-feedback."

MAGDM is a decision-making method where multiple decision-makers evaluate and select from multiple alternatives based on several attributes or criteria [22-24]. This method is widely used in complex decision-making scenarios, especially when multiple stakeholders are involved, and a variety of factors need to be considered, such as project evaluation, policy making, and supplier selection [25]. The core of MAGDM lies in balancing the weights of different attributes and forming a rational decision outcome from the information provided by different DMs [26, 27]. In practice, there are two main challenges: first, how to handle the trade-offs between different attributes, and second, how to integrate the preferences and opinions of multiple DMs [28, 29]. To address these issues, common methods include weighted averaging, Analytic Hierarchy Process (AHP), fuzzy set theory, and entropy weighting methods. These approaches aim to assign appropriate weights to each attribute to comprehensively evaluate the advantages and disadvantages of each option. In situations with high uncertainty (such as incomplete or fuzzy information), methods like SVNS and grey system theory are widely used to better handle uncertain data. In recent years, hybrid decision-making models that combine various methods, such as ExpTODIM [4] and VIKOR [7, 8], have become a research focus in MAGDM. These methods integrate different decision tools to provide more flexible and accurate decision support. The ultimate goal of MAGDM is to synthesize various pieces of information and the opinions of decision-makers to arrive at an optimal or near-optimal decision, ensuring fairness and rationality in the decision-making process[30, 31].

2. Preliminaries

Wang et al. [1] designed the SVNSs based on neutrosophic sets (NSs)[32].

Definition 1 [1]. The SVNSs is designed:

$$YA=\left\{\left(\phi,YT_A\left(\phi\right),YI_A\left(\phi\right),YF_A\left(\phi\right)\right)\middle|\phi\in\Phi\right\} \tag{1}$$

where $YT_A\left(\phi\right),YI_A\left(\phi\right),YF_A\left(\phi\right)$ designed the truth-membership, indeterminacy-membership and falsity-membership, $YT_A\left(\phi\right),YI_A\left(\phi\right),YF_A\left(\phi\right)\in\left[0,1\right]$ and satisfies $0\le YT_A\left(\phi\right)+YI_A\left(\phi\right)+YF_A\left(\phi\right)\le 3$.

The single-valued neutrosophic number (SVNN) is designed as $YA=\left(YT_A,YI_A,YF_A\right)$, where $YT_A,YI_A,YF_A\in\left[0,1\right]$, and $0\le YT_A+YI_A+YF_A\le 3$.

Definition 2 [33]. Let $YA=\left(YT_A,YI_A,YF_A\right)$ and $YB=\left(YT_B,YI_B,YF_B\right)$ be SVNN, score values are designed:

$$SV\left(YA\right)=\frac{\left(2+YT_A-YI_A-YF_A\right)}{3},\ S\left(YA\right)\in\left[0,1\right]. \tag{2-a}$$

$$SV\left(YB\right)=\frac{\left(2+YT_B-YI_B-YF_B\right)}{3},\ S\left(YB\right)\in\left[0,1\right]. \tag{2-a}$$

Definition 3[33]. Let $YA=\left(YT_A,YI_A,YF_A\right)$ and $YB=\left(YT_B,YI_B,YF_B\right)$ be SVNN, an accuracy value is designed:

$$HV\left(YA\right)=YT_A-YF_A,\ AV\left(YA\right)\in\left[-1,1\right]. \tag{3}$$

$$HV(YB)=YT_B-YF_B,\ AV(YB)\in[-1,1]\ . \tag{3}$$

Peng, Wang, Wang, Zhang and Chen [33] designed the order for SVNNs.

Definition 4[33]. Let $YA=(YT_A,YI_A,YF_A)$ and $YB=(YT_B,YI_B,YF_B)$ be two given SVNNs, $SV(YA)=\frac{(2+YT_A-YI_A-YF_A)}{3}$ and $SV(YB)=\frac{(2+YT_B-YI_B-YF_B)}{3}$, and $HV(YA)=YT_A-YF_A$ and $HV(YB)=YT_B-YF_B$, then if $SV(YA)<SV(YB)$, then $YA<YB$; if $SV(YA)=SV(YB)$, then (1)if $AV(YA)=AV(YB)$, then $YA=YB$; (2) if $AV(YA)<AV(YB)$, then $YA<YB$.

Definition 5[1]. Let $YA=(YT_A,YI_A,YF_A)$ and $YB=(YT_B,YI_B,YF_B)$ be SVNNs, basic operations are designed:

(1) $YA\oplus YB=(YT_A+YT_B-YT_AYT_B,YI_AYI_B,YF_AYF_B)$;
(2) $YA\otimes YB=(YT_AYT_B,YI_A+YI_B-YI_AYI_B,YF_A+YF_B-YF_AYF_B)$;
(3) $\lambda YA=\left(1-(1-YYT_A)^{\lambda},(YI_A)^{\lambda},(YF_A)^{\lambda}\right),\lambda>0;$
(4) $(YA)^{\lambda}=\left((YT_A)^{\lambda},(YI_A)^{\lambda},1-(1-YF_A)^{\lambda}\right),\lambda>0.$

Definition 6[34]. Let $YA=(YT_A,YI_A,YF_A)$ and $YB=(YT_B,YI_B,YF_B)$, the SVNN Hamming distance (SVNNHD) is designed:

$$SVNNHD(XA,XB)=\frac{|YT_A-YT_B|+|YI_A-YI_B|+|YF_A-YF_B|}{3} \tag{4}$$

The SVNNWA and SVNNWG approach is designed:

Definition 7[33]. Let $YA_j=(YT_j,YI_j,YF_j)$ be SVNNs, the SVNNWA is designed:

$$\begin{aligned}&\mathrm{SVNNWA}(YA_1,YA_2,\ldots,YA_n)\\&=yw_1YA_1\oplus yw_2YA_2\ldots\oplus yw_nYA_n=\mathop{\oplus}_{j=1}^{n}yw_jYA_j\\&=\left(1-\prod_{j=1}^{n}(1-YT_{ij})^{yw_j},\prod_{k=1}^{l}(YF_{ij})^{yw_j},\prod_{k=1}^{l}(YT_{ij})^{yw_j}\right)\end{aligned} \tag{5}$$

where $yw=(yw_1,yw_2,...,yw_n)^T$ be weight of YA_j, $yw_j>0,\sum_{j=1}^{n}yw_j=1.$

Definition 8[33]. Let $YA_j = \left(YT_j, YI_j, YF_j\right)$ be SVNNs, the SVNNWG approach is designed:

$$\begin{aligned} & \text{SVNNWG}\left(YA_1, YA_2, \ldots, YA_n\right) \\ & = \left(YA_1\right)^{yw_1} \otimes \left(YA_2\right)^{yw_2}, \ldots \otimes \left(YA_n\right)^{yw_n} = \mathop{\otimes}_{j=1}^{n} \left(YA_j\right)^{yw_j} \\ & = \left(\prod_{j=1}^{n} \left(YT_{ij}\right)^{yw_j}, 1 - \prod_{j=1}^{n} \left(1 - YF_{ij}\right)^{yw_j}, 1 - \prod_{j=1}^{n} \left(1 - YT_{ij}\right)^{yw_j} \right) \end{aligned} \tag{6}$$

where $yw = \left(yw_1, yw_2, ..., yw_n\right)^T$ be weight of YA_j, $yw_j > 0, \sum_{j=1}^{n} yw_j = 1.$

3. Approach for MAGDM

3.1. SVNN-MAGDM description

The SVNN-ExpTODIM-VIKOR approach is designed for MAGDM. Let $YA = \left\{YA_1, YA_2, \cdots, YA_m\right\}$ be alternatives, and the attributes set $YG = \left\{YG_1, YG_2, \cdots, YG_n\right\}$ with weight $y\omega$, where $y\omega_j \in [0,1]$, $\sum_{j=1}^{n} y\omega_j = 1$ and invited experts $YE = \left\{YE_1, YE_2, \cdots, YE_q\right\}$ with weight $yw = \left\{yw_1, yw_2, \cdots, yw_t\right\}$.

Then, SVNN-ExpTODIM-VIKOR approach is designed for MAGDM (**Figure 1**).

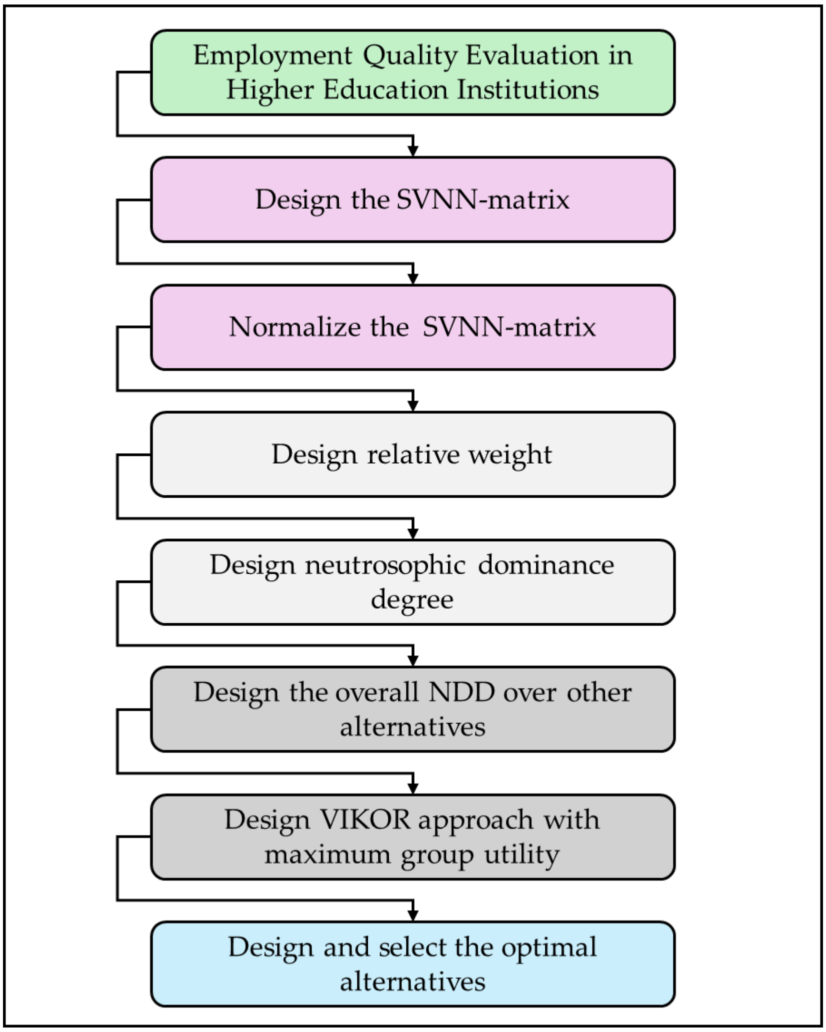

Figure 1. The framework of SVNNTODIM-VIKOR for MAGDM

Step 1. Design the SVNN-matrix $YR^t = \left[YR_{ij}^t\right]_{m\times n} = \left(YT_{ij}^t, YI_{ij}^t, YF_{ij}^t\right)_{m\times n}$ and average matrix $YR = \left[YR_{ij}\right]_{m\times n}$:

$$YR = \left[YR_{ij}^t\right]_{m\times n} = \begin{array}{c} \\ YA_1 \\ YA_2 \\ \vdots \\ YA_m \end{array}\begin{array}{c} \begin{array}{cccc} YG_1 & YG_2 & \dots & YG_n \end{array} \\ \begin{bmatrix} YR_{11}^t & YR_{12}^t & \dots & YR_{1n}^t \\ YR_{21}^t & YR_{22}^t & \dots & YR_{2n}^t \\ \vdots & \vdots & \vdots & \vdots \\ YR_{m1}^t & YR_{m2}^t & \dots & YR_{mn}^t \end{bmatrix} \end{array} \quad (7)$$

$$YR = \left[YR_{ij}\right]_{m\times n} = \begin{array}{c} \\ YA_1 \\ YA_2 \\ \vdots \\ YA_m \end{array}\begin{array}{c} \begin{array}{cccc} YG_1 & YG_2 & \dots & YG_n \end{array} \\ \begin{bmatrix} YR_{11} & YR_{12} & \dots & YR_{1n} \\ YR_{21} & YR_{22} & \dots & YR_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ YR_{m1} & YR_{m2} & \dots & YR_{mn} \end{bmatrix} \end{array} \quad (8)$$

Based on SVNNWA, the $YR = \left[YR_{ij} \right]_{m \times n} = \left(YT_{ij}, YI_{ij}, YF_{ij} \right)_{m \times n}$ is designed:

$$\begin{aligned} YR_{ij} &= yw_1 YR_{ij}^1 \oplus yw_2 YR_{ij}^2 \oplus \cdots \oplus yw_t YR_{ij}^t \\ &= \left(1 - \prod_{k=1}^{t} \left(YT_{ij}^t \right)^{yw_k}, \prod_{k=1}^{t} \left(YF_{ij}^t \right)^{yw_k}, \prod_{k=1}^{t} \left(1 - YT_{ij}^t \right)^{yw_k} \right) \end{aligned} \tag{9}$$

Step 2. Normalize the $YR = \left[YR_{ij} \right]_{m \times n} = \left(YT_{ij}, YI_{ij}, YF_{ij} \right)_{m \times n}$ into $NYR = \left[NYR_{ij} \right]_{m \times n} = \left(YT_{ij}^N, YI_{ij}^N, YF_{ij}^N \right)_{m \times n}$.

For benefit attributes:

$$NYR_{ij} = \left(YT_{ij}^N, YI_{ij}^N, YF_{ij}^N \right) = YR_{ij} = \left(YT_{ij}, YI_{ij}, YF_{ij} \right) \tag{10}$$

For cost attributes:

$$NYR_{ij} = \left(YT_{ij}^N, YI_{ij}^N, YF_{ij}^N \right) = \left(YF_{ij}, YI_{ij}, YT_{ij} \right) \tag{11}$$

3.2. Design the attributes weight.

Entropy [35] is utilized to derive weight. The normalized SVNN-matrix YY_{ij} is designed:

$$YY_{ij} = \frac{SV\left(YT_{ij}^N, YI_{ij}^N, YF_{ij}^N \right) + 1}{\sum_{i=1}^{m} \left(SV\left(YT_{ij}^N, YI_{ij}^N, YF_{ij}^N \right) + 1 \right)}, \tag{12}$$

The neutrosophic Shannon entropy $NSE = \left(NSE_1, NSE_2, \cdots, NSE_n \right)$ is designed:

$$NSE_j = -\frac{1}{\ln m} \sum_{i=1}^{m} YY_{ij} \ln YY_{ij} \tag{13}$$

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

Then, the weights $y\omega = \left(y\omega_1, y\omega_2, \cdots, y\omega_n \right)$ is designed:

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

3.3. SVNN-ExpTODIM-VIKOR method for MAGDM

The SVNN-ExpTODIM-VIKOR method is designed for MAGDM.

(1) Design relative weight:

$$ry\omega_j = y\omega_j \Big/ \max_j y\omega_j \,, \tag{15}$$

(2) Design neutrosophic dominance degree (NDD) $NDD_j\left(YA_i, YA_t\right)$ of YA_i over YA_t for YG_j in light with ExpTODIM approach:

$$NDD_j\left(YA_i, YA_t\right) = \begin{cases} \dfrac{ry\omega_j \times \left(1 - 10^{-\rho SVNNHD\left(NYR_{ij}, NYR_{tj}\right)}\right)}{\sum_{j=1}^{n} ry\omega_j} & \text{if } SV\left(NYR_{ij}\right) > SV\left(NYR_{tj}\right) \\ 0 & \text{if } SV\left(NYR_{ij}\right) = SV\left(NYR_{tj}\right) \\ -\dfrac{1}{\theta}\dfrac{\sum_{j=1}^{n} ry\omega_j \times \left(1 - 10^{-\rho SVNNHD\left(NYR_{ij}, NYR_{tj}\right)}\right)}{ry\omega_j} & \text{if } SV\left(NYR_{ij}\right) < SV\left(NYR_{tj}\right) \end{cases} \tag{16}$$

where θ is from Ref. [36] and $\rho \in [1,5]$ [4].

The dominance degree matrix $NYR_j\left(YA_i\right)\left(j = 1, 2, \cdots, n\right)$ under YG_j is designed:

$$NDD_j\left(YA_i\right) = \left[NDD_j\left(YA_i, YA_t\right)\right]_{m \times m}$$

$$= \begin{array}{c} \\ YA_1 \\ YA_2 \\ \vdots \\ YA_m \end{array} \begin{array}{c} \begin{array}{cccc} YA_1 & YA_2 & \cdots & YA_m \end{array} \\ \begin{bmatrix} 0 & NDD_j\left(YA_1, YA_2\right) & \cdots & NDD_j\left(YA_1, YA_m\right) \\ NDD_j\left(YA_2, YA_1\right) & 0 & \cdots & NDD_j\left(YA_2, YA_m\right) \\ \vdots & \vdots & \cdots & \vdots \\ NDD_j\left(YA_m, YA_1\right) & NDD_j\left(YA_m, YA_2\right) & \cdots & 0 \end{bmatrix} \end{array}$$

where the θ means the risk factor.

(3) Design the overall NDD of YA_i over other alternatives under YG_j :

$$NDD_j\left(YA_i\right) = \sum_{t=1}^{m} NDD_j\left(YA_i, YA_t\right) \tag{12}$$

with all NDD of YG_j calculated, the overall NDD is designed:

$$NDD = \left(NDD_{ij}\right)_{m \times n} = \begin{bmatrix} & YG_1 & YG_2 & \dots & YG_n \\ YA_1 & \sum_{t=1}^{m} NDD_1\left(YA_1, YA_t\right) & \sum_{t=1}^{m} NDD_2\left(YA_1, YA_t\right) & \dots & \sum_{t=1}^{m} NDD_n\left(YA_1, YA_t\right) \\ YA_2 & \sum_{t=1}^{m} NDD_1\left(YA_2, YA_t\right) & \sum_{t=1}^{m} NDD_2\left(YA_2, YA_t\right) & \dots & \sum_{t=1}^{m} NDD_n\left(YA_2, YA_t\right) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ YA_m & \sum_{t=1}^{m} NDD_1\left(YA_m, YA_t\right) & \sum_{t=1}^{m} NDD_2\left(YA_m, YA_t\right) & \dots & \sum_{t=1}^{m} NDD_n\left(YA_m, YA_t\right) \end{bmatrix}$$

(4) Design VIKOR approach with maximum group utility $SVNNYS_i$, minimum individual regret value $SVNNYR_i$ and relationship degree $SVNNYQ_i$ between $SVNNYS_i$ and $SVNNYR_i$.

$$SVNNYS_i = \sum_{j=1}^{n} y\omega_j \frac{\left|NDD_j^+ - NDD_{ij}\right|}{\left|NDD_j^+ - NDD_j^-\right|} \tag{13}$$

$$SVNNYR_i = \max_{j=1}^{n} y\omega_j \frac{\left|NDD_j^+ - NDD_{ij}\right|}{\left|NDD_j^+ - NDD_j^-\right|} \tag{14}$$

$$SVNNYQ_i = v \times \frac{SVNNYS_i - SVNNYS_i^-}{SVNNYS_i^+ - SVNNYS_i^-} + (1-v) \times \frac{SVNNYR_i - SVNNYR_i^-}{SVNNYR_i^+ - SVNNYR_i^-} \tag{15}$$

where $SVNNYS_i^+ = \max_{i=1}^{m} SVNNYS_i$, $SVNNYS_i^- = \min_{i=1}^{m} SVNNYS_i$, $SVNNYR_i^+ = \max_{i=1}^{m} SVNNYR_i$ and $SVNNYR_i^- = \min_{i=1}^{m} SVNNYR_i$. v is strategic weight and $v = 0.5$, $NDD_j^+ = \max_{i=1}^{m} NDD_{ij}$ and $NDD_j^- = \min_{i=1}^{m} NDD_{ij}$.

(5) Design and select the optimal alternatives through $SVNNYS_i$, $SVNNYR_i$ and $SVNNYQ_i$.

4. Numerical example and comparative analysis

4.1. Numerical Example for employment quality evaluation in higher education institutions

The evaluation of employment quality in higher education institutions is an important tool for assessing the performance and career development potential of graduates after entering the workforce. It covers several key indicators that comprehensively reflect the effectiveness of talent cultivation in universities. The main dimensions of evaluation include employment rate, contract signing rate, salary levels, industry distribution, job satisfaction, employment stability, and career development prospects. These indicators not only reflect whether graduates can smoothly find jobs after entering the labor market but also assess the alignment between their jobs and their fields of study, as well as their potential for growth and long-term career development. The employment rate and contract signing rate are the most basic metrics, indicating graduates' ability to enter the workforce promptly after graduation. Salary levels can indirectly reflect the market value of graduates and the university's ability to cultivate high-quality talent. Industry distribution helps analyze whether graduates are employed across diverse sectors or are concentrated in specific industries or regions. Job satisfaction evaluates, from a subjective perspective, the graduates' recognition of their jobs and their confidence in their career development. Moreover, the evaluation of employment quality is significant not only for universities but also provides reference information for various sectors of society. For universities, the results of this evaluation help identify shortcomings in talent cultivation, thereby allowing them to optimize their curriculum and teaching models to enhance graduates' core competitiveness. For students and parents, the evaluation results offer important reference information for choosing schools and majors. For employers, the data helps them understand the overall quality of graduates from different institutions, enabling better recruitment and job matching. Thus, the evaluation of employment quality has become a key metric for measuring the educational level, social reputation, and alignment of talent cultivation with market demands in universities. It also plays a crucial role in driving higher education reform and improving the quality of talent cultivation. The employment quality evaluation in higher education institutions is MAGDM. Five potential local colleges $YA_i\left(i=1,2,3,4,5\right)$ are assessed with four attributes: ①XG_1 is Employment Rate: The employment rate measures the proportion of graduates who secure jobs within a certain period after graduation. This is one of the most fundamental indicators, reflecting the overall demand for the institution’s graduates in the labor market. ②XG_2 is Salary Levels: Salary levels refer to the income of graduates after entering the workforce, usually measured by average or median salaries. This indicator reflects the market value of graduates and serves as an important reference for assessing the institution's ability to cultivate high-quality talent. ③XG_3 is Job Satisfaction: Job satisfaction is assessed through surveys that gauge graduates' satisfaction with their positions, evaluating their subjective feelings about the work environment, compensation, and career development prospects. High satisfaction often indicates that graduates are positive about their career choices and the training they received from the institution. ④XG_4 is Industry and Job Distribution: This indicator analyzes the industries and types of positions graduates are employed in, assessing the alignment between their jobs and their fields of study, as well as the diversity of employment sectors. It helps to understand the institution's influence in specific industries or fields and reflects the match between graduates' career preferences and market demand.

Five possible local colleges $YA_i\left(i=1,2,3,4,5\right)$ are evaluated with Linguistic scales (Table 2) through three experts $YE_t\left(t=1,2,3\right)$ with equal weight.

Table 2. Linguistic scales and SVNNs

Linguistic Terms	SVNNs
Exceedingly Terrible-YET	(0.0000, 1.0000, 1.0000)
Very Terrible-YVT	(0.1000, 0.9000, 0.9000)
Terrible-YT	(0.3000, 0.7000, 0.7000)
Medium-YM	(0.5000, 0.5000, 0.5000)
Well-YW	(0.7000, 0.3000, 0.3000)
Very Well-YVW	(0.9000, 0.1000, 0.1000)
Exceedingly Well-YEW	(1.0000, 0.0000, 0.0000)

The SVNN-ExpTODIM-VIKOR approach is used to solve the employment quality evaluation in higher education institutions.

Step 1. Design the SVNN matrix $YR^t=\left[YR_{ij}^t\right]_{5\times4}=\left(YT_{ij}^t,YI_{ij}^t,YF_{ij}^t\right)_{5\times4}$ (See Table 3).

Table 3. Evaluation by YE_1

	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4	C_1	C_2	C_3	C_4
A_1	YM	YT	YVW	YW	YT	YVW	YW	YM	YVT	YM	YW	YVW
A_2	YVT	YM	YVW	YT	YVW	YVT	YT	YW	YM	YVT	YVT	YVW
A_3	YT	YW	YM	YVW	YW	YT	YM	YM	YM	YT	YVW	YVT
A_4	YVW	YW	YVT	YM	YVW	YT	YM	YW	YVT	YVW	YW	YM
A_5	YM	YW	YVT	YVW	YVT	YM	YW	YVT	YVW	YW	YM	YT

The $YR=\left[YR_{ij}\right]_{5\times4}$ is designed through the SVNNWA technique (See Table 4).

Table 4. The $CR=\left[c\phi_{ij}\right]_{5\times4}$

	C_1	C_2	C_3	C_4
A_1	(0.7523, 0.2032, 0.2445)	(0.6484, 0.3125, 0.2379)	(0.7237, 0.1566, 0.2198)	(0.4876, 0.3518, 0.2604)
A_2	(0.6925, 0.2434, 0.2643)	(0.6312, 0.2028, 0.2659)	(0.7128, 0.1821, 0.2057)	(0.5934, 0.3106, 0.1958)
A_3	(0.8134, 0.1905, 0.1962)	(0.6586, 0.2259, 0.2158)	(0.5717, 0.2491, 0.2783)	(0.6254, 0.2976, 0.1764)
A_4	(0.7452, 0.2348, 0.3203)	(0.5893, 0.2928, 0.2181)	(0.6315, 0.2176, 0.2514)	(0.7022, 0.2044, 0.1937)
A_5	(0.6343, 0.2205, 0.2457)	(0.7124, 0.1845, 0.2035)	(0.5921, 0.2685, 0.2396)	(0.5739, 0.3326, 0.1943)

Step 2. Normalize the $YR=\left[YR_{ij}\right]_{5\times4}$ into $NYR=\left[NYR_{ij}\right]_{5\times4}$ (See Table 5).

Table 5. The $NYR=\left[NYR_{ij}\right]_{5\times4}$

	C_1	C_2	C_3	C_4
A_1	(0.3544, 0.5467, 0.3766)	(0.3741, 0.5434, 0.3456)	(0.4734, 0.4547, 0.4536)	(0.4734, 0.415, 0.4346)
A_2	(0.3457, 0.4167, 0.3746)	(0.3736, 0.3574, 0.3141)	(0.4346, 0.4665, 0.4376)	(0.4346, 0.4017, 0.4643)
A_3	(0.3347, 0.3543, 0.5744)	(0.3567, 0.3376, 0.5436)	(0.4037, 0.4066, 0.5656)	(0.4345, 0.5454, 0.5654)
A_4	(0.3364, 0.5447, 0.5764)	(0.5737, 0.4557, 0.5134)	(0.5546, 0.4476, 0.4347)	(0.5613, 0.5434, 0.5073)
A_5	(0.5713, 0.3367, 0.3064)	(0.6565, 0.3634, 0.3556)	(0.4537, 0.4466, 0.5567)	(0.4346, 0.5657, 0.5447)

Step 3. Design the weight: $y\omega_1 = 0.2344, y\omega_2 = 0.3265, y\omega_3 = 0.1967, y\omega_4 = 0.2424$.

Step 4. Design the relative weight: $ry\omega = \{0.7179, 1.0000, 0.6025, 0.7424\}$

Step 5. Design the $NDD = \left(NDD_{ij}\right)_{5\times4}$ (See table 6):

Table 6. The $NDD = \left(NDD_{ij}\right)_{5\times4}$

	C_1	C_2	C_3	C_4
A_1	-0.2239	0.9149	0.2867	-0.4913
A_2	0.2259	0.3099	-1.5659	0.3861
A_3	-1.0225	-0.7543	0.7077	-1.0643
A_4	0.7029	-0.4211	-0.4131	0.8542
A_5	-0.9274	-1.2010	-0.4934	-0.0467

Step 6. Design the $SVNNYS_i$, $SVNNYR_i$ and $SVNNYQ_i$.

Step 7. Sort these alternatives by using the $SVNNYS_i$, $SVNNYR_i$ and $SVNNYQ_i$. Thus, the best of local college is A_4 Figure 2 shows the rank of alternatives.

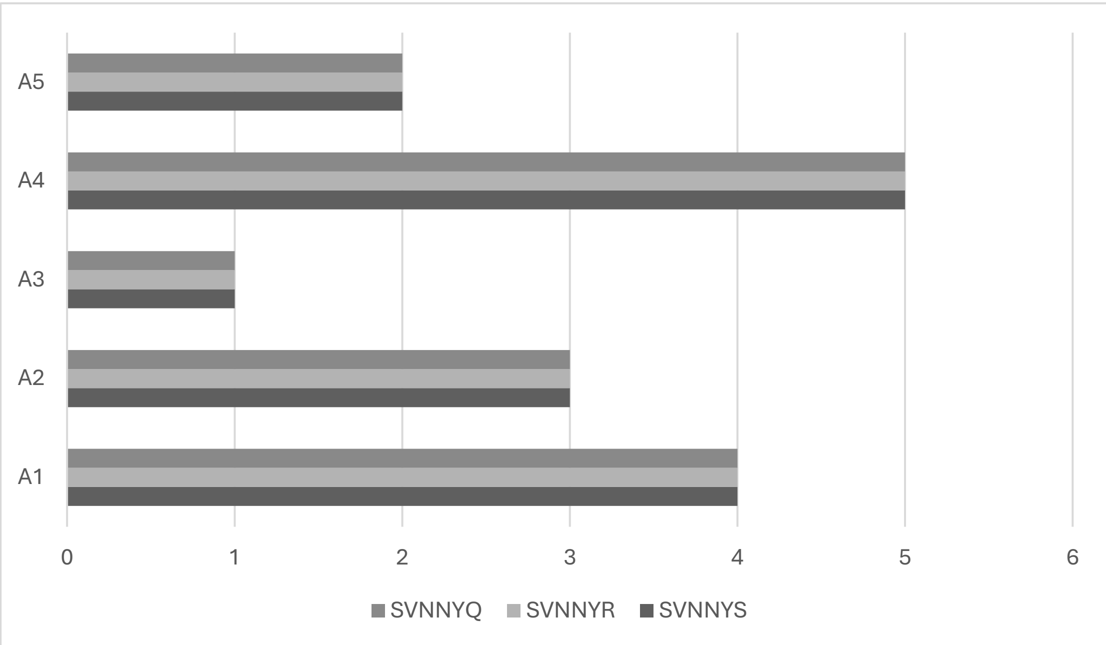

Figure 2. The rank of alternatives.

4.2. Comparative analysis and discussion analysis

The SVNN-ExpTODIM-VIKOR approach is compared with SVNNWA approach [33] and SVNNWG approach [33], SVNN-VIKOR approach [37], SVNN-GRA approach [38], SVNN-CODAS approach [39], SVNN-EDAS approach [40] and SVNN-TODIM approach [41]. The comparative results are shown in Figure 3.

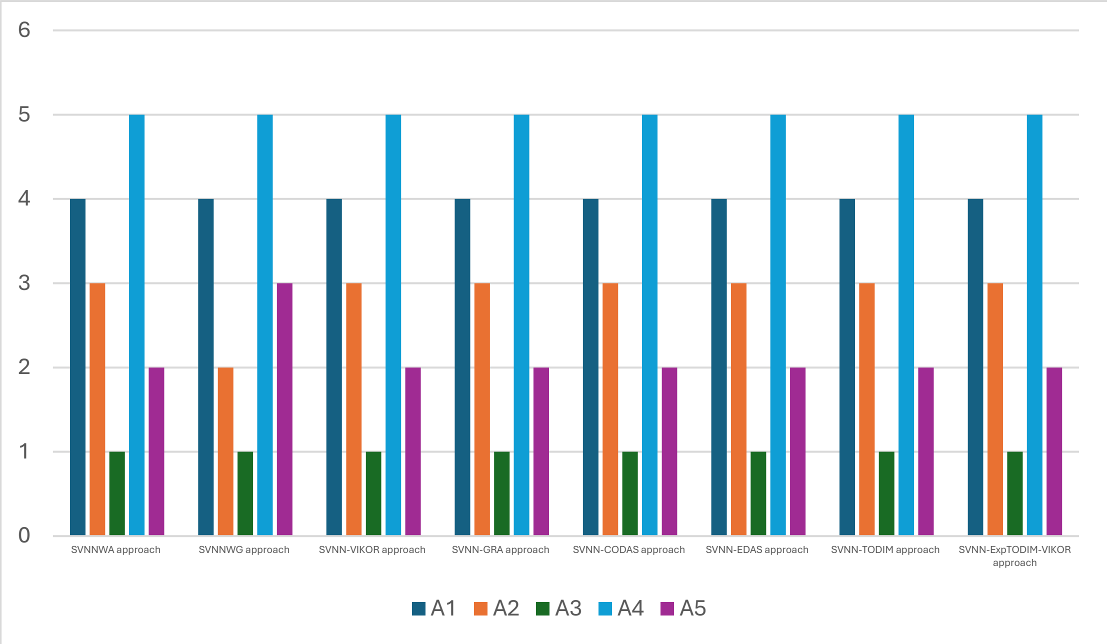

Figure 3. The rank of alternatives under comparative analysis.

From the detailed analysis above, it can be observed that all five models yield the same optimal choice and follow the same ranking order. This confirms that the SVNN-ExpTODIM-VIKOR approach is both reasonable and effective.

In the comparative analysis with existing methods such as SVNNWA, SVNNWG, SVNN-VIKOR, SVNN-GRA, SVNN-CODAS, SVNN-EDAS, and SVNN-TODIM, although these approaches demonstrate effectiveness in solving multi-attribute group decision-making (MAGDM) problems, they also have certain drawbacks. First, many of these methods lack flexibility in adapting to diverse decision-making scenarios, particularly when dealing with complex preference structures or nonlinear problems, which may result in insufficient accuracy. Second, most of the existing methods have relatively high computational complexity, especially when dealing with a large number of decision-makers or attributes, leading to an increased computational burden. Lastly, some methods struggle to handle uncertainty effectively, especially when facing vague or incomplete information, making it difficult to accurately capture the real preferences of decision-makers.

In contrast, the SVNN-ExpTODIM-VIKORapproach proposed in this paper offers the following three main advantages: (1) High Flexibility: This method effectively addresses MAGDM problems with uncertainty and fuzziness, particularly within the framework of SVNSs, providing a more accurate representation of uncertain information in decision-making. (2) Improved Computational Efficiency: Compared to some existing methods, SVNN-ExpTODIM-VIKOR exhibits relatively lower computational complexity when handling multiple decision-makers and attributes, maintaining high accuracy while reducing the computational burden. (3) Good Consistency in Decision Results: In comparison with other methods, SVNN-ExpTODIM-VIKOR demonstrates superior performance in terms of ranking consistency and the rationality of results, confirming its effectiveness and reasonableness in solving MAGDM problems.

However, despite these advantages, the proposed method also has the following two limitations: (1) High Sensitivity to Parameters: Certain parameters in the SVNN-ExpTODIM-VIKOR method significantly impact the results, which may lead to instability in different decision-making scenarios, requiring parameter tuning to ensure optimal performance. (2) Increased Complexity in Application: Compared to some more straightforward methods, the theoretical framework and computational process of this approach are relatively complex, which may demand higher levels of expertise and computational capacity from users, thus increasing the difficulty of practical application.

Overall, while the proposed method demonstrates notable advantages in flexibility, efficiency, and result consistency, there is still room for improvement in terms of parameter sensitivity and application complexity.

5. Conclusion and future research directions

The evaluation of employment quality in higher education institutions is a comprehensive assessment tool that measures graduates' performance in the job market after graduation. It uses multidimensional indicators such as employment rate, contract signing rate, salary levels, industry distribution, job satisfaction, and career development potential to reflect the quality of talent cultivation in universities and the alignment with societal needs. This evaluation not only provides feedback to universities, helping them optimize curriculum design, teaching models, and career planning services, but also serves as a valuable reference for students and parents in school selection. Additionally, it assists employers in understanding the overall quality and potential of graduates, improving job-person fit efficiency. Therefore, the evaluation of employment quality has become an important metric for assessing the educational level and societal impact of higher education institutions. The employment quality evaluation in higher education institutions is MAGDM. Recently, the ExpTODIM-VIKOR method has been utilized to address MAGDM problems, with SVNSs employed to represent uncertain information in satisfaction evaluations. In this paper, we introduce the SVNN-ExpTODIM-VIKOR model to solve MAGDM within the framework of SVNSs. Lastly, a numerical case study focused on the employment quality evaluation in higher education institutions is presented to validate the effectiveness of the proposed method.

Although the SVNN-ExpTODIM-VIKOR method proposed in this paper demonstrates significant advantages in evaluating the employment quality in higher education institutions, there are several research limitations that merit attention. First, the complexity of the model is relatively high. While the SVNN-ExpTODIM-VIKOR method effectively handles uncertain information, its computational process is complex. This complexity, especially when dealing with large datasets, results in high computational time and resource consumption, potentially making it less suitable for real-time decision-making scenarios. Second, parameter tuning issues. The SVNN-ExpTODIM-VIKOR model is highly sensitive to the selection of certain parameters, which significantly affect the final outcome. The sensitivity to these parameters means that different parameter choices can lead to varying decision results, thereby impacting the model's stability and generalizability. Lastly, a lack of extensive empirical validation. Although the effectiveness of the method is verified through a numerical case study, it is limited to a specific scenario with simulated data. The model's applicability and robustness in other fields or real-world applications have not yet been fully tested, lacking broad empirical case support.

Based on the above research limitations, future studies can explore the following three directions:(1) Optimizing the computational efficiency of the model: To improve the applicability of the SVNN-ExpTODIM-VIKOR method for large datasets, further research can focus on incorporating parallel computing, distributed computing, and other techniques to optimize the algorithm's computational efficiency. This would reduce time and resource consumption, making the method more suitable for real-time decision-making, particularly in dynamic data environments. (2) Parameter optimization and automatic tuning mechanisms: To address the limitation of parameter sensitivity, future research could explore the use of intelligent optimization algorithms (such as genetic algorithms, particle swarm optimization, etc.) to automatically tune the parameters. This would reduce the subjectivity in parameter settings and improve the model's adaptability and stability across different scenarios. (3) Empirical studies and application expansion across multiple fields: Beyond the employment quality evaluation in higher education institutions, future research could apply the SVNN-ExpTODIM-VIKOR method in other educational or non-educational fields for broader empirical validation. By testing and verifying the method in various domains, the generalizability of the approach can be further evaluated, enhancing its application value across multiple fields and scenarios.

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