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Enhanced T2NN-LogTODIM-TOPSIS Framework for Assessing Vocational College Students' Employment Quality Using Type-2 Neutrosophic Numbers

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Abstract: With the ongoing development of vocational education in our country, the employment quality of vocational college graduates has emerged as a crucial metric for assessing the overall strength and effectiveness of these institutions. Establishing a robust employment quality evaluation system for vocational colleges not only complements and enhances their employment-related efforts, but also represents a critical step toward improving the broader educational and teaching practices within these institutions. Currently, the construction of such evaluation systems tends to focus primarily on professional education and teaching. While this approach has undoubtedly contributed to improving the quality of vocational education, it often overlooks the dimensions of development, innovation, and entrepreneurship education, thereby limiting its potential to produce optimal educational outcomes. In light of this, vocational colleges must proactively design and implement an employment quality evaluation system that incorporates the principles of entrepreneurship and innovation, fostering the healthy and sustainable growth of vocational education. The employment quality assessment of vocational college students, within the framework of innovation and entrepreneurship (often referred to as "double innovation"), constitutes a multiple-attribute decision-making (MADM) problem. To address such complex issues, methods like Logarithmic TODIM (LogTODIM) and TOPSIS have been proposed for MADM scenarios. In this context, Type-2 neutrosophic numbers (T2NNs) are utilized to represent and manage the inherent uncertainty and vagueness in the employment quality evaluation process for vocational college students under the double innovation framework. This study introduces a novel method—the Type-2 neutrosophic number Logarithmic TODIM-TOPSIS (T2NN-LogTODIM-TOPSIS) approaches a solution for multi-attribute group decision-making (MAGDM) under T2NN conditions. Finally, a numerical case study is conducted to illustrate the application and effectiveness of the T2NN-LogTODIM-TOPSIS approach in evaluating the employment quality of vocational college students within the context of innovation and entrepreneurship.

Keywords: MADM problem; T2NNs; LogTODIM model; TOPSIS model; employment quality evaluation

1. Introduction

The so-called employment quality belongs to a relatively complex concept. Employment enables people to enhance their quality of life while meeting material needs, thereby better satisfying their own value and social value[1-3]. It can be said that employment is an important process of meeting individual material needs, and it is also a key form of ensuring that individuals receive social recognition, thereby providing them with spiritual satisfaction[4, 5]. The quality of employment refers to the process in which individuals, through the integration of labor and means of production, engage in work and ensure the effective distribution of means of production, while ultimately satisfying their own value and the mutual unity of social value[6, 7]. The key purpose of establishing a comprehensive evaluation system for the employment quality of vocational college students is to quantify the various indicators mentioned in the evaluation system, transform them into detectable indicators, and better meet the current employment requirements of vocational college students. This can provide more favorable basis for the improvement of the employment quality of vocational college students and the construction of economy and culture. However, in the current environment, there is no specialized system for evaluating the employment quality of vocational college students, and main employment quality evaluation system only focuses on college students, including the definition of subjective and objective indicators for college student employment. Generally, it includes relevant quality indicators for college students' job positions and their employment satisfaction, but no corresponding algorithm is provided; In addition, the algorithm provided is the classification form of the employment quality evaluation system. Some scholars will focus on indicators such as employment rate, structure and distribution, and salary benefits, while others will establish first and second level evaluation standards from a fuzzy perspective for quality evaluation. For the actual employment rate of graduates in current vocational colleges, it is a more intuitive method for analyzing the quality of social employment and a fundamental indicator for evaluating the employment quality of vocational college students[8, 9]. The problem of employment difficulties for vocational college students has been preliminarily solved, which is a key achievement in promoting vocational education and the level of vocational education. However, the employment rate of students is difficult to intuitively and comprehensively demonstrate the employment problems of vocational college students[10-12]. We cannot explore the employment quality of vocational college students solely from the perspective of employment rate. In the current context of entrepreneurship and entrepreneurship, vocational colleges can evaluate employment rates from two perspectives: first, the evaluation of innovation ability, which means that after vocational college students are employed, the campus should integrate innovation evaluation forms based on previous evaluation models, such as incorporating project indicators for graduates to participate in innovation into the original evaluation system, to evaluate whether the overall innovation ability of graduates has improved. Secondly, the evaluation of entrepreneurship indicators, that is, in vocational colleges, the evaluation of employment quality for students should incorporate indicators of graduate entrepreneurship projects[13, 14]. After analyzing the indicators of entrepreneurship projects and the proportion of employment and innovation entrepreneurship, it can better evaluate the specific entrepreneurial ability of students. Through this form, going to vocational colleges can better measure students' ability to innovate and start businesses, thereby achieving a reasonable evaluation of employment rates[15, 16]. The current industry structure is relatively complex and diverse, which leads to diverse employment structures. Due to the employment structure, it can not only display the specific career trends and regional differences of vocational college graduates, but also more accurately reflect the actual nature of their employment, as well as their innovation ability and entrepreneurial choices[17, 18]. By analyzing the employment structure of vocational college students, the specific employment quality can be maximized, and the competitiveness of graduates in employment can be effectively judged based on their career choices. The current overall economic development in our country is showing signs of imbalance. Exploring the employment structure based on regional economic levels can effectively demonstrate the employment orientation of vocational college students and highlight the competition and employment pressure between regions. If the employment rate in economically developed regions is relatively high, then the employment prospects for graduates are better. From this, it can be understood that the employment structure can continuously demonstrate the need for graduates to improve their own qualities, as well as the contribution of various professional talents to local development. The evaluation of the employment quality of vocational college students in the current context of entrepreneurship and entrepreneurship is an analysis of the employment situation of vocational college students[19, 20]. Through the construction of a clear evaluation system, it can better understand the employment situation of vocational college students, and finally provide favorable improvement strategies for vocational education. Only by formulating comprehensive educational strategies for students can we provide guarantees for the stable development of vocational college students in the future.

The evaluation of employment quality for vocational college students within the context of innovation and entrepreneurship ("double innovation") can be framed as a MADM problem. To address this, techniques such as LogTODIM [21] and TOPSIS [22, 23] have been proposed as effective MADM methods. However, the existing approaches have yet to fully integrate the handling of fuzzy and uncertain information, which is essential for accurately evaluating employment quality in this dynamic context. To address this gap, T2NNs [24] have been introduced as a means to represent and manage the inherent fuzziness of the data involved in the employment quality evaluation process for vocational college students under the double innovation framework. Despite the advancements in the LogTODIM and TOPSIS techniques, few or no studies have yet explored their application in combination with an entropy-based weighting model and T2NNs. Therefore, this study proposes a novel T2NN-LogTODIM-TOPSIS model, which integrates T2NNs to enhance the MADM process. A numerical example illustrating the employment quality evaluation of vocational college students in the double innovation context, along with a comparative analysis, is provided to validate the effectiveness and applicability of this approach.

1.2 Importance of Neutrosophic Theory

The neutrosophic theory is vital for addressing uncertainties, improving decision-making, and fostering innovation across various domains. Its flexibility and comprehensive approach make it an essential tool for researchers and practitioners.

- Neutrosophic theory effectively handles uncertainty and imprecision in data, allowing for more accurate modeling of real-world situations.
- It provides a robust framework for decision-making processes that involve multiple criteria, accommodating various perspectives and preferences.
- Applicable across various fields, including economics, engineering, medicine, and social sciences, enhancing analysis in diverse contexts.
- Allows for a more nuanced interpretation of data by incorporating degrees of truth, indeterminacy, and falsehood, leading to better conclusions.
- Promotes the development of new methodologies and approaches to complex problems, fostering innovative solutions in research and practice.
- Clarifies ambiguous concepts and improves communication among stakeholders, facilitating collaboration in multidisciplinary teams.
- Compatible with AI and machine learning, enhancing their ability to process and analyze complex, uncertain data.

The structure of this study is organized as follows:

Section 2 introduces the formulation of T2NNs, providing the foundational framework for handling uncertainty and imprecision in decision-making processes.

Section 3 presents the development of the T2NN-Logarithmic TODIM-TOPSIS model, specifically designed for MADM under the T2NN environment.

Section 4 offers a detailed numerical case study that evaluates the employment quality of vocational college students in the context of innovation and entrepreneurship ("double innovation"). This section also includes various comparative analyses to validate and demonstrate the effectiveness of the proposed model.

Finally, Section 5 concludes the study, summarizing key findings and offering insights into the future application of the T2NN-LogTODIM-TOPSIS approach.

2. Preliminaries

Wang et al. [25] built the SVNSs

Definition 1 [25]. The SVNSs is raised:

$$HA=\left\{\left(\theta, HT_{HA}(\theta), HI_{HA}(\theta), HF_{HA}(\theta)\right)\middle|\theta\in\Theta\right\} \tag{1}$$

where the $HT_{HA}(\theta), HI_{HA}(\theta), HF_{HA}(\theta)$ is truth-membership (TM), indeterminacy-membership (IM) and falsity-membership (FM), $HT_{HA}(\theta), HI_{HA}(\theta), HF_{HA}(\theta)\in[0,1]$, $0\le HT_{HA}(\theta)+HI_{HA}(\theta)+HF_{HA}(\theta)\le 3$. The SVNN is implemented as $HA=(HT_A, HI_A, HF_A)$, where $HT_A, HI_A, HF_A\in[0,1]$, and $0\le HT_A+HI_A+HF_A\le 3$.

Abdel-Basset et al. [24] raised the T2NNs.

Definition 1[24]. The T2NN is raised:

$$HH = \left\{ \left(\theta, HA(\theta), HB(\theta), HC(\theta) \right) \middle| \theta \in \Theta \right\} \quad (2)$$

where $HA(\theta), HB(\theta), HC(\theta) \in [0,1]$ be TM, IM and FM with triangular fuzzy numbers (TFNs).

$$HA(\theta) = \left(HA^L(\theta), HA^M(\theta), HA^U(\theta) \right), 0 \le HA^L(\theta) \le HA^M(\theta) \le HA^U(\theta) \le 1 \quad (3)$$

$$HB(\theta) = \left(HB^L(\theta), HB^M(\theta), HB^U(\theta) \right), 0 \le HB^L(\theta) \le HB^M(\theta) \le HB^U(\theta) \le 1 \quad (4)$$

$$HC(\theta) = \left(HC^L(\theta), HC^M(\theta), HC^U(\theta) \right), 0 \le HC^L(\theta) \le HC^M(\theta) \le HC^U(\theta) \le 1 \quad (5)$$

We let $HH = \left\{ \begin{array}{l} \left(HA^L, HA^M, HA^U \right), \\ \left(HB^L, HB^M, HB^U \right), \left(HC^L, HC^M, HC^U \right) \end{array} \right\}$ be a T2NN, $0 \le HA^U + HB^U + HC^U \le 3$.

Definition 2[24]. Let $HH_1 = \left\{ \begin{array}{l} \left(HA_1^L, HA_1^M, HA_1^U \right), \\ \left(HB_1^L, HB_1^M, HB_1^U \right), \left(HC_1^L, HC_1^M, HC_1^U \right) \end{array} \right\}$, $HH_2 = \left\{ \begin{array}{l} \left(HA_2^L, HA_2^M, HA_2^U \right), \\ \left(HB_2^L, HB_2^M, HB_2^U \right), \left(HC_2^L, HC_2^M, HC_2^U \right) \end{array} \right\}$ and $HH = \left\{ \begin{array}{l} \left(HA^L, HA^M, HA^U \right), \\ \left(HB^L, HB^M, HB^U \right), \left(HC^L, HC^M, HC^U \right) \end{array} \right\}$ be TFNNs, the operation laws are raised:

$$(1)\ HH_1 \oplus HH_2 = \left\{ \begin{array}{l} \left(\begin{array}{l} HA_1^L + HA_2^L - HA_1^L HA_2^L, HA_1^M + HA_2^M - HA_1^M HA_2^M, \\ HA_1^U + HA_2^U - HA_1^U HA_2^U \end{array} \right), \\ \left(HB_1^L HB_2^L, HB_1^M HB_2^M, HB_1^U HB_2^U \right), \\ \left(HC_1^L HC_2^L, HC_1^M HC_2^M, HC_1^U HC_2^U \right) \end{array} \right\};$$

$$(2)\ HH_1 \otimes HH_2 = \left\{ \begin{array}{l} \left(HA_1^L HA_2^L, HA_1^M HA_2^M, HA_1^U HA_2^U \right), \\ \left(\begin{array}{l} HB_1^L + HB_2^L - HB_1^L HB_2^L, HB_1^M + HB_2^M - HB_1^M HB_2^M, \\ HB_1^U + HB_2^U - HB_1^U HB_2^U \end{array} \right), \\ \left(\begin{array}{l} HC_1^L + HC_2^L - HC_1^L HC_2^L, HC_1^M + HC_2^M - HC_1^M HC_2^M, \\ HC_1^U + HC_2^U - HC_1^U HC_2^U \end{array} \right) \end{array} \right\};$$

(3) $\lambda HH = \left\{ \begin{array}{l} \left(1-\left(1-HA^L\right)^\lambda, 1-\left(1-HA^M\right)^\lambda, 1-\left(1-HA^U\right)^\lambda\right), \\ \left(\left(HB^L\right)^\lambda, \left(HB^M\right)^\lambda, \left(HB^U\right)^\lambda\right), \\ \left(\left(HC^L\right)^\lambda, \left(HC^M\right)^\lambda, \left(HC^U\right)^\lambda\right) \end{array} \right\}, \lambda > 0;$

(4) $HH^\lambda = \left\{ \begin{array}{l} \left(\left(HA^L\right)^\lambda, \left(HA^M\right)^\lambda, \left(HA^U\right)^\lambda\right), \\ \left(1-\left(1-HB^L\right)^\lambda, 1-\left(1-HB^M\right)^\lambda, 1-\left(1-HB^U\right)^\lambda\right), \\ \left(1-\left(1-HC^L\right)^\lambda, 1-\left(1-HC^M\right)^\lambda, 1-\left(1-HC^U\right)^\lambda\right) \end{array} \right\}, \lambda > 0.$

The operational laws raised following properties.

(1) $HH_1 \oplus HH_2 = HH_2 \oplus HH_1, HH_1 \otimes HH_2 = HH_2 \otimes HH_1, \left(\left(HH_1\right)^{\lambda_1}\right)^{\lambda_2} = \left(HH_1\right)^{\lambda_1 \lambda_2}$; (6)

(2) $\lambda\left(HH_1 \oplus HH_2\right) = \lambda HH_1 \oplus \lambda HH_2, \left(HH_1 \otimes HH_2\right)^\lambda = \left(HH_1\right)^\lambda \otimes \left(HH_2\right)^\lambda$; (7)

(3) $\lambda_1 HH_1 \oplus \lambda_2 HH_1 = \left(\lambda_1 + \lambda_2\right) HH_1, \left(HH_1\right)^{\lambda_1} \otimes \left(HH_1\right)^{\lambda_2} = \left(HH_1\right)^{\left(\lambda_1 + \lambda_2\right)}$. (8)

Definition 3[24]**.** Let $HH = \left\{ \begin{array}{l} \left(HA^L, HA^M, HA^U\right), \\ \left(HB^L, HB^M, HB^U\right), \left(HC^L, HC^M, HC^U\right) \end{array} \right\}$ be TFNN, the score function and accuracy function are raised:

$$HSF\left(HH\right) = \frac{1}{12}\left[\begin{array}{l} 8 + \left(HA^L + 2HA^M + HA^U\right) \\ -\left(HB^L + HVB^M + HB^U\right) \\ -\left(HC^L + 2HC^M + HC^U\right) \end{array} \right], HSF\left(HH\right) \in \left[0,1\right] \tag{9}$$

$$HAF\left(HH\right) = \frac{1}{4}\left[\begin{array}{l} \left(HA^L + 2HA^M + HA^U\right) \\ -\left(HB^L + 2HB^M + HB^U\right) \end{array} \right], HAF\left(HH\right) \in \left[-1,1\right] \tag{10}$$

For the TFNNs HH_1 and HH_2, in light with Definition 3, the following results are raised:

(1) $if\ HSF\left(HH_1\right) \prec HSF\left(HH_2\right),\ HH_1 \prec HH_2;$

(2) $if\ HSF\left(HH_1\right) = HSF\left(HH_2\right), HAF\left(HH_1\right) \prec HAF\left(HH_2\right),\ HH_1 \prec HH_2;$

(3) $if\ HSF\left(HH_1\right) = HSF\left(HH_2\right), HAF\left(HH_1\right) = HAF\left(HH_2\right),\ HH_1 = HH_2.$

Definition 4[24]. Let $HH_1=\left\{\begin{matrix}\left(HA_1^L,HA_1^M,HA_1^U\right),\\ \left(HB_1^L,HB_1^M,HB_1^U\right),\left(HC_1^L,HC_1^M,HC_1^U\right)\end{matrix}\right\}$, $HH_2=\left\{\begin{matrix}\left(HA_2^L,HA_2^M,HA_2^U\right),\\ \left(HB_2^L,HB_2^M,HB_2^U\right),\left(HC_2^L,HC_2^M,HC_2^U\right)\end{matrix}\right\}$ be T2NNs, the T2NNs Hamming distance (T2NNHD) is raised:

$$T2NNHD\left(HH_1,HH_2\right)=\frac{1}{9}\left(\begin{array}{l}\left|HA_1^L-HA_2^L\right|+\left|HA_1^M-HA_2^M\right|+\left|HA_1^U-HA_2^U\right|\\+\left|HB_1^L-HB_2^L\right|+\left|HB_1^M-HB_2^M\right|+\left|HB_1^U-HB_2^U\right|\\+\left|HC_1^L-HC_2^L\right|+\left|HC_1^M-HC_2^M\right|+\left|HC_1^U-HC_2^U\right|\end{array}\right) \quad (11)$$

3. T2NN-LogTODIM-TOPSIS approach for MADM with entropy

The T2NN-LogTODIM-TOPSIS is raised for MAGDM. Let $HA=\left\{HA_1,HA_2,\cdots,HA_m\right\}$ be alternative and $HG=\left\{HG_1,HG_2,\cdots,HG_n\right\}$ be attributes with weight hw, $hw_j\in\left[0,1\right]$, $\sum_{j=1}^{n}hw_j=1$.Then, T2NN-LogTODIM-TOPSIS is raised for MADM.

Step 1. Cultivate the T2NN-matrix $HM=\left[HM_{ij}\right]_{m\times n}$:

$$HM=\left[HM_{ij}\right]_{m\times n}=\begin{array}{c}\\ HA_1\\ HA_2\\ \vdots\\ HA_m\end{array}\begin{array}{c}\begin{array}{cccc}HG_1 & HG_2 & \cdots & HG_n\end{array}\\ \begin{bmatrix}HM_{11} & HM_{12} & \cdots & HM_{1n}\\ HM_{21} & HM_{22} & \cdots & HM_{2n}\\ \vdots & \vdots & \vdots & \vdots\\ HM_{m1} & HM_{m2} & \cdots & HM_{mn}\end{bmatrix}\end{array} \quad (12\text{-a})$$

$$HM_{ij}=\left\{\begin{array}{l}\left(\left(HA_{ij}^L\right),\left(HA_{ij}^M\right),\left(HA_{ij}^U\right)\right),\\ \left(\left(HB_{ij}^L\right),\left(HB_{ij}^M\right),\left(HB_{ij}^U\right)\right),\\ \left(\left(HC_{ij}^L\right),\left(HC_{ij}^M\right),\left(HC_{ij}^U\right)\right)\end{array}\right\} \quad (12\text{-b})$$

Step 2. Normalize $HM=\left[HM_{ij}\right]_{m\times n}$ into $NHM=\left[NHM_{ij}\right]_{m\times n}$.

Aiming at benefit attributes:

$$NHM_{ij}=\left\{\begin{array}{l}\left(\left(NHA_{ij}^L\right),\left(NHA_{ij}^M\right),\left(NHA_{ij}^U\right)\right),\\ \left(\left(NHB_{ij}^L\right),\left(NHB_{ij}^M\right),\left(NHB_{ij}^U\right)\right),\\ \left(\left(NHC_{ij}^L\right),\left(NHC_{ij}^M\right),\left(NHC_{ij}^U\right)\right)\end{array}\right\}=\left\{\begin{array}{l}\left(\left(HA_{ij}^L\right),\left(HA_{ij}^M\right),\left(HA_{ij}^U\right)\right),\\ \left(\left(HB_{ij}^L\right),\left(HB_{ij}^M\right),\left(HB_{ij}^U\right)\right),\\ \left(\left(HC_{ij}^L\right),\left(HC_{ij}^M\right),\left(HC_{ij}^U\right)\right)\end{array}\right\} \quad (13)$$

Aiming at cost attributes:

$$NHM_{ij} = \begin{Bmatrix} \left(\left(NHA_{ij}^{L}\right),\left(NHA_{ij}^{M}\right),\left(NHA_{ij}^{U}\right)\right), \\ \left(\left(NHB_{ij}^{L}\right),\left(NHB_{ij}^{M}\right),\left(NHB_{ij}^{U}\right)\right), \\ \left(\left(NHC_{ij}^{L}\right),\left(NHC_{ij}^{M}\right),\left(NHC_{ij}^{U}\right)\right) \end{Bmatrix} = \begin{Bmatrix} \left(\left(HC_{ij}^{L}\right),\left(HC_{ij}^{M}\right),\left(HC_{ij}^{U}\right)\right), \\ \left(\left(HB_{ij}^{L}\right),\left(HB_{ij}^{M}\right),\left(HB_{ij}^{U}\right)\right), \\ \left(\left(HA_{ij}^{L}\right),\left(HA_{ij}^{M}\right),\left(HA_{ij}^{U}\right)\right) \end{Bmatrix} \tag{14}$$

Step 3. Cultivate the weight numbers with entropy.

Entropy [26] is raised for weight numbers. The T2NN-matrix is raised:

$$T2NNNHM_{ij} = \frac{\left(HSF\begin{Bmatrix} \left(\left(NHA_{ij}^{L}\right),\left(NHA_{ij}^{M}\right),\left(NHA_{ij}^{U}\right)\right), \\ \left(\left(NHB_{ij}^{L}\right),\left(NHB_{ij}^{M}\right),\left(NHB_{ij}^{U}\right)\right), \\ \left(\left(NHC_{ij}^{L}\right),\left(NHC_{ij}^{M}\right),\left(NHC_{ij}^{U}\right)\right) \end{Bmatrix} + HAF\begin{Bmatrix} \left(\left(NHA_{ij}^{L}\right),\left(NHA_{ij}^{M}\right),\left(NHA_{ij}^{U}\right)\right), \\ \left(\left(NHB_{ij}^{L}\right),\left(NHB_{ij}^{M}\right),\left(NHB_{ij}^{U}\right)\right), \\ \left(\left(NHC_{ij}^{L}\right),\left(NHC_{ij}^{M}\right),\left(NHC_{ij}^{U}\right)\right) \end{Bmatrix} + 1 \right)}{\sum_{i=1}^{m}\left(HSF\begin{Bmatrix} \left(\left(NHA_{ij}^{L}\right),\left(NHA_{ij}^{M}\right),\left(NHA_{ij}^{U}\right)\right), \\ \left(\left(NHB_{ij}^{L}\right),\left(NHB_{ij}^{M}\right),\left(NHB_{ij}^{U}\right)\right), \\ \left(\left(NHC_{ij}^{L}\right),\left(NHC_{ij}^{M}\right),\left(NHC_{ij}^{U}\right)\right) \end{Bmatrix} + HAF\begin{Bmatrix} \left(\left(NHA_{ij}^{L}\right),\left(NHA_{ij}^{M}\right),\left(NHA_{ij}^{U}\right)\right), \\ \left(\left(NHB_{ij}^{L}\right),\left(NHB_{ij}^{M}\right),\left(NHB_{ij}^{U}\right)\right), \\ \left(\left(NHC_{ij}^{L}\right),\left(NHC_{ij}^{M}\right),\left(NHC_{ij}^{U}\right)\right) \end{Bmatrix} + 1 \right)}, \tag{15}$$

The T2NN Shannon decision entropy (T2NNSDE) is raised:

$$T2NNSDE_j = -\frac{1}{\ln m}\sum_{i=1}^{m} T2NNM_{ij} \ln T2NNM_{ij} \tag{16}$$

and $T2NNM_{ij} \ln T2NNM_{ij} = 0$ if $T2NNM_{ij} = 0$.

Then, the weight numbers $hw = \left(hw_1, hw_2, \cdots, hw_n\right)$ is raised:

$$hw_j = \frac{1 - T2NNSDE_j}{\sum_{j=1}^{n}\left(1 - T2NNSDE_j\right)} \tag{17}$$

Step 4. Raise relative weight:

$$rhw_j = hw_j \big/ \max_j hw_j, \tag{18}$$

Step 5. Raise the T2NN dominance decision degree (T2NNDDD).

(1) The T2NNDDD of HA_i over HA_t for HG_j is raised:

$$T2NNDDD_j\left(HA_i, HA_t\right) = \begin{cases} \dfrac{rhw_j \times \log\left(1 + 10\rho T2NNHD\left(NHM_{ij}, NHM_{tj}\right)\right)}{\sum_{j=1}^{n} rhw_j} & \text{if } HSF\left(NHM_{ij}\right) > HSF\left(NHM_{tj}\right) \\ 0 & \text{if } HSF\left(NHM_{ij}\right) = HSF\left(NHM_{tj}\right) \\ -\dfrac{rhw_j \times \lambda \log\left(1 + 10\rho T2NNHD\left(NHM_{ij}, NHM_{tj}\right)\right)}{\sum_{j=1}^{n} rhw_j} & \text{if } HSF\left(NHM_{ij}\right) < HSF\left(NHM_{tj}\right) \end{cases} \tag{19}$$

where $\lambda \in [1,5]$ and $\rho \in N^{+}$ is raised from Ref.[27].

(2) The $T2NNDDD_j(HA_i)(j=1,2,\cdots,n)$ under HG_j is raised:

$$T2NNDDD_j(HA_i)=\left[T2NNDDD_j(HA_i,HA_t)\right]_{m\times m}$$

$$=\begin{array}{c} \\ HA_1 \\ HA_2 \\ \vdots \\ HA_m \end{array}\begin{array}{c} \begin{array}{cccc} HA_1 & HA_2 & \cdots & HA_m \end{array} \\ \begin{bmatrix} 0 & T2NNDDD_j(HA_1,HA_2) & \cdots & T2NNDDD_j(HA_1,HA_m) \\ T2NNDDD_j(HA_2,HA_1) & 0 & \cdots & T2NNDDD_j(HA_2,HA_m) \\ \vdots & \vdots & \cdots & \vdots \\ T2NNDDD_j(HA_m,HA_1) & T2NNDDD_j(HA_m,HA_2) & \cdots & 0 \end{bmatrix}\end{array}$$

(3) Raise the overall T2NNDDD of HA_i over others under HG_j:

$$T2NNDDD_j(HA_i)=\sum_{t=1}^{m}T2NNDDD_j(HA_i,HA_t) \tag{20}$$

(4) The T2NNDDD matrix is raised:

$$T2NNDDD=\left(T2NNDDD_{ij}\right)_{m\times n}$$

$$=\begin{bmatrix} & HG_1 & HG_2 & \cdots & HG_n \\ HA_1 & \sum_{t=1}^{m}T2NNDDD_1(HA_1,HA_t) & \sum_{t=1}^{m}T2NNDDD_2(HA_1,HA_t) & \cdots & \sum_{t=1}^{m}T2NNDDD_n(HA_1,HA_t) \\ HA_2 & \sum_{t=1}^{m}T2NNDDD_1(HA_2,HA_t) & \sum_{t=1}^{m}T2NNDDD_2(HA_2,HA_t) & \cdots & \sum_{t=1}^{m}T2NNDDD_n(HA_2,HA_t) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ HA_m & \sum_{t=1}^{m}T2NNDDD_1(HA_m,HA_t) & \sum_{t=1}^{m}T2NNDDD_2(HA_m,HA_t) & \cdots & \sum_{t=1}^{m}T2NNDDD_n(HA_m,HA_t) \end{bmatrix}$$

Step 6. Raise the T2NNPIDS (T2NN positive ideal decision solution) and T2NNNIDS (T2NN negative ideal decision solution):

$$T2NNPIDS=\left(T2NNPIDS_1,T2NNPIDS_1,\cdots,T2NNPIDS_n\right) \tag{21}$$

$$T2NNNIDS=\left(T2NNNIDS_1,T2NNNIDS_1,\cdots,T2NNNIDS_n\right) \tag{22}$$

$$T2NNPIDS_j=\max_{j=1}^{n}T2NNDDD_{ij}, \tag{23}$$

$$T2NNNIDS_j=\min_{j=1}^{n}T2NNDDD_{ij} \tag{24}$$

Step 7. Raise the T2NNEDV (T2NN Euclidean distance values) for T2NNPIDS and T2NNNIDS.

$$T2NNEDV(HA_i,T2NNPIDS)=\sqrt{\sum_{j=1}^{n}\left(T2NNDDD_{ij}-T2NNPIDS_j\right)^2} \tag{25}$$

$$T2NNEDV(HA_i,T2NNNIDS)=\sqrt{\sum_{j=1}^{n}\left(T2NNDDD_{ij}-T2NNNIDS_j\right)^2} \tag{26}$$

Step 8. Raise the T2NNCCV (T2NN closeness coefficient values) from T2NNPIDS.

$$T2NNCCV\left(HA_i, T2NNPIDS\right)$$
$$= \frac{T2NNEDV\left(HA_i, T2NNNIDS\right)}{\left(T2NNEDV\left(HA_i, T2NNPIDS\right) + T2NNEDV\left(HA_i, T2NNPIDS\right)\right)}$$
$$= \frac{\sqrt{\sum_{j=1}^{n}\left(T2NNDDD_{ij} - T2NNNIDS_j\right)^2}}{\left(\sqrt{\sum_{j=1}^{n}\left(T2NNDDD_{ij} - T2NNNIDS_j\right)^2} + \sqrt{\sum_{j=1}^{n}\left(T2NNDDD_{ij} - T2NNPIDS_j\right)^2}\right)} \quad (27)$$

Step 9. Choose the best scheme with maximum T2NNCCV.

4. Analytical Comparison with Numerical Examples

In this section, we will compare different methods using numerical examples. This approach will help us clearly see the advantages and disadvantages of each method, making it easier to understand their practical applications.

4.1. Numerical example

The concept of employment quality is inherently complex and can be examined through two main dimensions: employment and quality [28]. Employment refers to an individual's participation in social and economic activities, where labor is performed under certain conditions of material production in exchange for remuneration, resulting in a specific level of economic income. It is the product of the interaction between labor and the means of production. Employment not only satisfies material needs but also enhances quality of life, enabling individuals to realize their self-worth and contribute to society [29]. Beyond the material benefits, employment offers individuals social recognition and spiritual fulfillment. Quality, on the other hand, refers to the degree to which a set of inherent characteristics meets certain requirements [30, 31]. The quality of employment thus pertains to how individuals engage in work by combining labor with the means of production, ensuring the effective and rational distribution of resources, and ultimately achieving a balance between personal value and societal contribution. In summary, the standard of employment quality is a multifaceted concept. It encompasses not only tangible factors such as employment rates, job trend analysis, professional alignment, and job satisfaction, but also considers longer-term aspects like opportunities for advancement, career development prospects, and levels of social security. In essence, employment quality is a broad concept with extensive implications, capable of forming a comprehensive evaluation system [32, 33]. Such a system addresses both the immediate employment needs of vocational college students and their potential for future development. This dual focus is essential for fostering the growth of vocational students and advancing the sustainable development of the national economy. While many developed Western countries have not explicitly proposed an evaluation system specifically for the employment quality of vocational college students, they have introduced the concept of a "decent work" evaluation framework. This provides a valuable reference point for China's efforts to establish an employment quality evaluation system for vocational students. The "decent work" evaluation framework includes 11 indicators related to social welfare, and in 1999, the European Union introduced work quality indicators. The European Foundation further developed a set of indicators for "Work and Employment Quality," which are organized into four main dimensions: occupational and employment security, health and welfare, technical quality, and work-life balance. These frameworks offer useful insights for developing a comprehensive employment quality evaluation system for vocational college graduates. The primary goal of constructing an employment quality evaluation system for vocational college students is to quantify various indicators, transforming them into measurable metrics that can meet students' employment needs. Such a system would provide a reference for understanding employment quality and contribute to the broader economic and cultural development of vocational students. However, at present, there is no specific, well-defined evaluation system for the employment quality of vocational college students in China [34, 35]. Existing frameworks, which are largely aimed at general college students, focus on subjective and objective indicators such as job quality, employment satisfaction, the proportion of entrepreneurial students, and rates of postgraduate study and overseas education. However, these frameworks do not include specific algorithms to guide evaluation. Both domestic and international employment quality evaluation systems tend to cater to the needs of general workers and are insufficient for addressing the unique employment needs of vocational college students, especially those who have received education in innovation and entrepreneurship [36, 37]. Graduates from vocational colleges who have undergone such training typically exhibit greater creativity, more dynamic thinking, and a heightened desire for self-fulfillment, along with a stronger sense of social responsibility. This highlights a clear shortcoming in the current evaluation systems, which fail to take a developmental perspective in evaluating employment quality [38, 39]. To address these gaps, it is crucial to adopt a dynamic approach that continuously improves the employment quality evaluation system for vocational college students. By refining the system and defining specific indicators, we can ensure that the evaluation process is aligned with the evolving needs of vocational students, ultimately leading to more effective and meaningful results.

The employment quality evaluation of vocational college students is MADM. Five vocational colleges $HA_i\left(i=1,2,3,4,5\right)$ are assessed with different attributes: ①HG_1 is employment rate of graduates from vocational colleges; ②HG_2 is evaluation of salary status; ③HG_3 is management cost of employment quality; ④HG_4 is evaluation of social recognition level. The T2NN-LogTODIM-TOPSIS is raised for employment quality evaluation of vocational college students.

Step 1. Cultivate the T2NN-matrix $HM = \left[HM_{ij}\right]_{5\times 4}$ (Table 1).

Table 1. T2NN information

	HG1	HG2
HA1	$\begin{Bmatrix}(0.48,0.65,0.71),\\(0.56,0.68,0.74),\\(0.29,0.36,0.65)\end{Bmatrix}$	$\begin{Bmatrix}(0.48,0.52,0.57),\\(0.42,0.49,0.58),\\(0.29,0.41,0.43)\end{Bmatrix}$
HA2	$\begin{Bmatrix}(0.38,0.49,0.56),\\(0.40,0.67,0.75),\\(0.45,0.48,0.62)\end{Bmatrix}$	$\begin{Bmatrix}(0.49,0.54,0.69),\\(0.42,0.52,0.63),\\(0.50,0.65,0.78)\end{Bmatrix}$
HA3	$\begin{Bmatrix}(0.24,0.37,0.48),\\(0.28,0.51,0.62),\\(0.56,0.61,0.65)\end{Bmatrix}$	$\begin{Bmatrix}(0.21,0.35,0.49),\\(0.48,0.56,0.67),\\(0.69,0.75,0.78)\end{Bmatrix}$
HA4	$\begin{Bmatrix}(0.32,0.56,0.67),\\(0.49,0.54,0.59),\\(0.38,0.45,0.51)\end{Bmatrix}$	$\begin{Bmatrix}(0.46,0.49,0.54),\\(0.28,0.37,0.48),\\(0.45,0.48,0.51)\end{Bmatrix}$
HA5	$\begin{Bmatrix}(0.67,0.74,0.78),\\(0.72,0.79,0.87),\\(0.68,0.69,0.76)\end{Bmatrix}$	$\begin{Bmatrix}(0.62,0.65,0.74),\\(0.35,0.43,0.54),\\(0.19,0.25,0.36)\end{Bmatrix}$

	HG3	HG4
HA1	$\begin{Bmatrix}(0.48,0.65,0.69),\\(0.31,0.43,0.65),\\(0.24,0.37,0.54)\end{Bmatrix}$	$\begin{Bmatrix}(0.59,0.76,0.85),\\(0.38,0.49,0.61),\\(0.34,0.38,0.52)\end{Bmatrix}$
HA2	$\begin{Bmatrix}(0.45,0.49,0.57),\\(0.26,0.34,0.45),\\(0.41,0.43,0.47)\end{Bmatrix}$	$\begin{Bmatrix}(0.67,0.78,0.86),\\(0.54,0.56,0.67),\\(0.58,0.65,0.74)\end{Bmatrix}$

HA3	$\left\{\begin{matrix}(0.39,0.58,0.86),\\(0.46,0.62,0.73),\\(0.42,0.48,0.56)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.43,0.56,0.64),\\(0.26,0.45,0.57),\\(0.46,0.52,0.56)\end{matrix}\right\}$
HA4	$\left\{\begin{matrix}(0.29,0.39,0.68),\\(0.26,0.37,0.64),\\(0.23,0.34,0.45)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.47,0.56,0.67),\\(0.57,0.68,0.76),\\(0.46,0.54,0.62)\end{matrix}\right\}$
HA5	$\left\{\begin{matrix}(0.49,0.56,0.75),\\(0.53,0.54,0.65),\\(0.32,0.36,0.53)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.38,0.56,0.64),\\(0.49,0.65,0.78),\\(0.53,0.57,0.72)\end{matrix}\right\}$

Step 2. Normalize the $HM=\left[HM_{ij}\right]_{5\times4}$ into $NHM=\left[NHM_{ij}\right]_{5\times4}$ (See Table 2).

Table 2. The normalized T2NN

	HG1	**HG2**
HA1	$\left\{\begin{matrix}(0.48,0.65,0.71),\\(0.56,0.68,0.74),\\(0.29,0.36,0.65)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.48,0.52,0.57),\\(0.42,0.49,0.58),\\(0.29,0.41,0.43)\end{matrix}\right\}$
HA2	$\left\{\begin{matrix}(0.38,0.49,0.56),\\(0.40,0.67,0.75),\\(0.45,0.48,0.62)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.49,0.54,0.69),\\(0.42,0.52,0.63),\\(0.50,0.65,0.78)\end{matrix}\right\}$
HA3	$\left\{\begin{matrix}(0.24,0.37,0.48),\\(0.28,0.51,0.62),\\(0.56,0.61,0.65)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.21,0.35,0.49),\\(0.48,0.56,0.67),\\(0.69,0.75,0.78)\end{matrix}\right\}$
HA4	$\left\{\begin{matrix}(0.32,0.56,0.67),\\(0.49,0.54,0.59),\\(0.38,0.45,0.51)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.46,0.49,0.54),\\(0.28,0.37,0.48),\\(0.45,0.48,0.51)\end{matrix}\right\}$
HA5	$\left\{\begin{matrix}(0.67,0.74,0.78),\\(0.72,0.79,0.87),\\(0.68,0.69,0.76)\end{matrix}\right\}$	$\left\{\begin{matrix}(0.62,0.65,0.74),\\(0.35,0.43,0.54),\\(0.19,0.25,0.36)\end{matrix}\right\}$

	HG3	**HG4**

HA1	$\begin{Bmatrix}(0.24,0.37,0.54),\\(0.31,0.43,0.65),\\(0.48,0.65,0.69)\end{Bmatrix}$	$\begin{Bmatrix}(0.59,0.76,0.85),\\(0.38,0.49,0.61),\\(0.34,0.38,0.52)\end{Bmatrix}$
HA2	$\begin{Bmatrix}(0.41,0.43,0.47),\\(0.26,0.34,0.45),\\(0.45,0.49,0.57)\end{Bmatrix}$	$\begin{Bmatrix}(0.67,0.78,0.86),\\(0.54,0.56,0.67),\\(0.58,0.65,0.74)\end{Bmatrix}$
HA3	$\begin{Bmatrix}(0.42,0.48,0.56),\\(0.46,0.62,0.73),\\(0.39,0.58,0.86)\end{Bmatrix}$	$\begin{Bmatrix}(0.43,0.56,0.64),\\(0.26,0.45,0.57),\\(0.46,0.52,0.56)\end{Bmatrix}$
HA4	$\begin{Bmatrix}(0.23,0.34,0.45),\\(0.26,0.37,0.64),\\(0.29,0.39,0.68)\end{Bmatrix}$	$\begin{Bmatrix}(0.47,0.56,0.67),\\(0.57,0.68,0.76),\\(0.46,0.54,0.62)\end{Bmatrix}$
HA5	$\begin{Bmatrix}(0.32,0.36,0.53),\\(0.53,0.54,0.65),\\(0.49,0.56,0.75)\end{Bmatrix}$	$\begin{Bmatrix}(0.38,0.56,0.64),\\(0.49,0.65,0.78),\\(0.53,0.57,0.72)\end{Bmatrix}$

Step 3. Raise the weight:

$$hw_1 = 0.2505, hw_2 = 0.3326$$
$$hw_3 = 0.2206, hw_4 = 0.1963.$$

Step 4. Raise the relative weight numbers: $rhw = (0.7532, 1.0000, 0.6633, 0.5902)$

Step 5. Raise the $T2NNDDD = \left(T2NNDDD_{ij}\right)_{5\times4}$ (Table 3):

Table 3. The $T2NNDDD = \left(T2NNDDD_{ij}\right)_{5\times4}$

	HG1	HG2	HG3	HG4
HA1	-0.5885	-1.6068	-0.0164	-0.9392
HA2	0.4094	1.3050	-0.5645	-0.2002
HA3	0.5366	0.3569	-1.8893	0.3606
HA4	1.1354	1.0133	-0.4681	-0.4072
HA5	-1.3186	-1.3611	0.9138	-0.7574

Step 6. Raise the T2NNPIDS & T2NNNIDS (Table 4).

Table 4. T2NNPIDS & T2NNNIDS

	HG_1	HG_2	HG_3	HG_4
T2NNPIDS	1.1354	1.3050	0.9138	0.3606
T2NNNIDS	-1.3186	-1.6068	-1.8893	-0.9392

Step 7. Raise the $T2NNEDV\left(HA_i, T2NNPIDS\right)$ and $T2NNEDV\left(HA_i, T2NNNIDS\right)$ (Table 5).

Table 5. $T2NNEDV\left(HA_i, T2NNPIDS\right)$ and $T2NNEDV\left(HA_i, T2NNNIDS\right)$

	$T2NNEDV\left(HA_i, T2NNPIDS\right)$	$T2NNEDV\left(HA_i, T2NNNIDS\right)$
HA_1	3.7423	2.0102
HA_2	1.7398	3.7102
HA_3	3.0190	2.9980
HA_4	1.6075	3.8974
HA_5	3.7922	2.8196

Step 8. Raise the $T2NNCCV\left(HA_i, T2NNPIDS\right)$ (See Table 6).

Table 6. $T2NNCCV\left(HA_i, T2NNPIDS\right)$

	$T2NNCCV\left(HA_i, T2NNPIDS\right)$	**Order**
HA_1	0.3494	5
HA_2	0.6808	2
HA_3	0.4983	3
HA_4	0.7080	1
HA_5	0.4265	4

Step 9. In light with $T2NNCCV\left(HA_i, T2NNPIDS\right)$, the order is: $HA_4 > HA_2 > HA_3 > HA_5 > HA_1$ and the optimal vocational college is HA_4.

4.2. Comparative analysis

The T2NN-LogTODIM-TOPSIS strategy is compared with theT2NNWA strategy [24], T2NNWG strategy [24], T2NN-CE strategy [40], T2NN-TOPSIS strategy [24], T2NN-EDAS strategy [41], T2NN-MABAC strategy [42], T2NN-TODIM strategy [43] and T2NN-TODIM-VIKOR strategy [44]. The comparative results are raised in Table 7.

Table 7. Order for different strategies

Strategies	Order
T2NNWA strategy [24]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NNWG strategy [24]	$HA_4 > HA_2 > HA_5 > HA_3 > HA_1$
T2NN-CE strategy [40]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NN-TOPSIS strategy [24]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NN-EDAS strategy [41]	$HA_4 > HA_2 > HA_5 > HA_3 > HA_1$
T2NN-MABAC strategy [42]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NN-TODIM strategy [43]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NN-TODIM-VIKOR strategy [44]	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$
T2NN-LogTODIM-TOPSIS strategy	$HA_4 > HA_2 > HA_3 > HA_5 > HA_1$

Based on the detailed analysis above, it can be concluded that while the rankings produced by the different approaches vary slightly, they consistently identify the same vocational college as the best and the worst performer. This consistency confirms the effectiveness of the T2NN-LogTODIM-TOPSIS approach for evaluating the employment quality of vocational college students within the context of innovation and entrepreneurship ("double innovation").

5. Conclusion

The forms and structures of various industries are inherently complex and multifaceted, leading to a similarly diversified employment landscape. The employment structure not only comprehensively reflects the career trajectories and regional disparities among vocational college graduates, but also captures the characteristics of their employers, as well as their capacities for innovation and entrepreneurial endeavors. Analyzing this employment structure provides a comprehensive view of employment quality, while the competitiveness of vocational graduates can be inferred from the professional paths they pursue. At present, the economic development across different regions in China remains uneven. By examining employment structures through the lens of regional economic levels, we can gain deeper insights into the employment preferences of vocational college students and the varying levels of competition and job market pressures between different areas. Currently, there is a noticeable trend where vocational graduates gravitate toward regions with higher economic development for employment opportunities. In these economically advanced areas, higher employment rates correlate with more favorable job prospects and career growth for graduates. This suggests that the employment structure not only serves as an indicator of the improvement in graduate quality but also highlights the contributions of various professional talents to regional economic growth. When evaluating the employment quality of vocational college students in the context of innovation and entrepreneurship ("double innovation"), it becomes a MADM problem. To address this, the LogTODIM and TOPSIS techniques have been proposed for such MADM scenarios. To better handle the fuzzy and uncertain information that arises during the employment quality evaluation, T2NNs have been introduced. In this study, a T2NN-LogTODIM-TOPSIS model is presented as a solution for MADM, integrating the capabilities of T2NNs to manage uncertainty. A numerical example is provided to illustrate the employment quality evaluation of vocational college students under the double innovation framework, and a comparative analysis is conducted to verify the effectiveness of the T2NN-LogTODIM-TOPSIS approach.

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