University of New Mexico

Comprehensive Framework for Collaborative Decision-Making in Evaluating Computer Network Security Using Interval Neutrosophic Information

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Abstract: Computer network security (CNS) evaluation is crucial for protecting information assets and maintaining the stable operation of network systems. Through this evaluation, potential threats and vulnerabilities within the network can be systematically identified, effectively preventing possible cyber-attacks and data breaches. Additionally, network security evaluation helps enterprises and organizations allocate security resources appropriately, enhancing their ability to respond to emergencies and ensuring business continuity and data integrity. In summary, network security evaluation is one of the foundational tasks for achieving continuous, secure, and stable network operations. The CNS evaluation is multiple-attribute group decision making (MAGDM). Then, the generalized TODIM(GTODIM) approach has been developed to deal with MAGDM. The interval neutrosophic sets (INSs) are defined as an effective tool for representing uncertain data during the CNS evaluation. In this manuscript, the interval neutrosophic number generalized TODIM (INN-GTODIM) approach is proposed to put forward the MAGDM under INSs. Finally, numerical example study for CNS evaluation is introduced to validate the INN-GTODIM approach. The primary contributions of this study are outlined: (1) Deriving weight information through the application of average method, enhancing the robustness of the decision-making process; (1) Implementing the INN-GTODIM approach for MAGDM scenarios that utilize INSs, showcasing its adaptability to complex decision-making environments; (1) Applying the INN-GTODIM approach specifically to the domain of CNS evaluation, and comparing its performance against existing approaches to highlight its strengths and improvements; (4) Providing a detailed comparative analysis, which clearly demonstrates that the INN-GTODIM approach significantly enhances the effectiveness of CNS evaluations.

Keywords: Multiple-attribute group decision making (MAGDM); Interval neutrosophic sets (INSs); GTODIM approach; Computer network security evaluation

1. Introduction and background

Computer network security (CNS) evaluation refers to the systematic approach of assessing the security within a computer network, including identifying existing security threats and vulnerabilities, as well as evaluating the effectiveness of current security measures[1]. This process

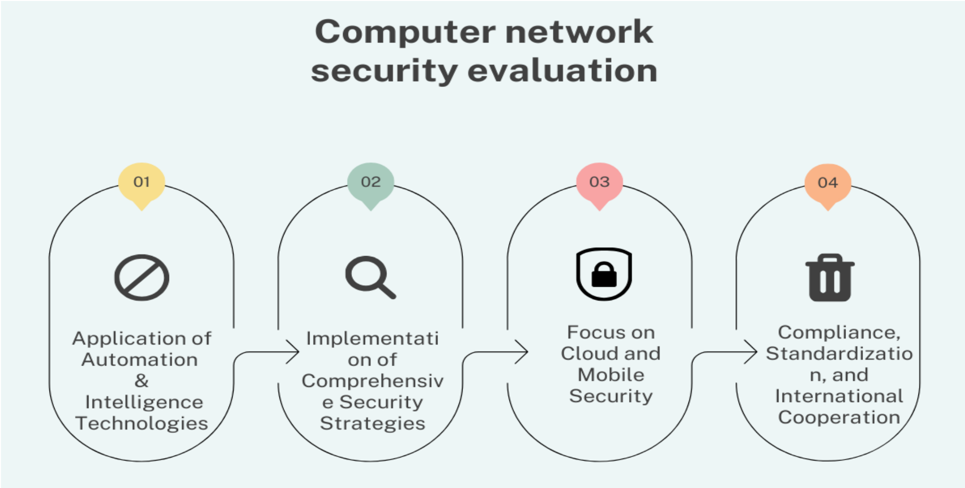

Figure 1. main elements of computer network security (CNS) evaluation

involves a comprehensive examination of various aspects of the network, such as hardware, software, data transmission and storage security, and network access controls[2]. The purpose of CNS evaluation is to ensure the security of network resources, prevent data breaches, and maintain the integrity and availability of the network system. The concept of CNS evaluation has evolved with the development of computer network technology and the increase in network security threats. Initially, network security focused primarily on the security of physical devices and basic access controls. However, as the Internet became widespread and network technology increased in complexity, the scope of network security evaluations also expanded, gradually including more dimensions of security checks[3]. The development of CNS evaluation can be summarized into four key points shown in Figure 1. First, the continuous advancements in artificial intelligence, network security evaluations increasingly rely on automated tools and intelligent algorithms. These technologies enhance the efficiency and accuracy of evaluations, automatically detecting abnormal behavior in the network and swiftly identifying potential security threats[4]. Second, network security no longer relies on single techniques or measures, but employs multi-level, multi-strategy comprehensive security measures. This includes physical security, system security, application security, data security, and other aspects, forming an all-around protection system[5]. Third, with the widespread adoption of cloud computing and mobile devices, cloud security and mobile security have become particularly important. Network security evaluations now incorporate considerations such as data encryption, access control, and endpoint protection to address the security challenges posed by these emerging technologies[6]. Forth, as global regulations on data protection and network security become stricter, such as the EU's GDPR, compliance has become a key component of network security evaluations. The application of various international and industry standards, along with cross-industry and cross-border cooperation, enhances the ability to withstand network threats. The aforementioned points outline the evolution of CNS evaluations from simple measures to the current comprehensive, multi-dimensional assessments, reflecting the continual updates and development in evaluation approaches and focuses as technology progresses and network threats increase.

MAGDM is a decision-making method involving multiple decision-makers who collaboratively evaluate a set of alternatives that perform differently across various attributes or criteria[7]. This method is widely used in complex decision scenarios such as policy formulation, business strategic planning, and engineering management [8]. In the process of MAGDM, the first step is to define the objectives of the decision problem and identify the relevant evaluation criteria. These criteria might include dimensions such as cost, benefit, risk, sustainability, and more[9-11]. The group of decision-makers typically consists of experts from diverse backgrounds, providing a range of perspectives and expertise. The decision-making process usually involves several steps: defining the problem and decision criteria; collecting relevant data and information to assess each alternative against these criteria; and using appropriate decision-making methods like the Analytic Hierarchy Process (AHP), TOPSIS, entropy [28] or VIKOR method[12-16]. These methods help to quantify and integrate the preferences and evaluations of decision-makers. A key challenge in MAGDM is managing the consistency and divergence of opinions among decision-makers. This often requires coordination and negotiation to achieve a consensus or near-consensus decision. Additionally, fairness and transparency in the decision-making process are crucial to ensure that all key stakeholders' opinions are adequately considered. Ultimately, the decision outcomes formed through the group decision-making process not only reflect multi-dimensional data analysis but also integrate diverse human experiences and judgments, making the final decisions more comprehensive and reliable. The use of MAGDM tools enhances the efficiency and quality of decisions, helping decision-makers find optimal solutions in complex environments.

Neutrosophic theory [17] is particularly well-suited for handling unreliable, vague, or incomplete data. In the context of evaluating service performance in library and information institutions from the perspective of user experience, uncertainties often arise from factors like user feedback, service usage patterns, and satisfaction levels. By employing single-value neutrosophic sets (SVNSs) [18] and interval neutrosophic sets (INSs) [19], this theory offers a more flexible and comprehensive way to represent these uncertainties compared to traditional fuzzy sets. Smarandache [20] constructed a practical applications of Soft Set with extensions to HyperSoft Set, IndetermSoft Set, IndetermHyperSoft Set and TreeSoft Set. Mohamed and Elsayed [21] constructed the MADM approach based on bipolar Neutrosophic sets for evaluating financial markets in Egypt. Salem, Mohamed and Smarandache [22] integrated vague T2NSs with OWCM-RAM for intelligent medical 4.0 evaluator framework. The field of CNS evaluation is increasingly being addressed through MAGDM approaches. Notably, approaches such as GTODIM [23] and TOPSIS [15] have been adapted to tackle challenges inherent in MAGDM. The use of INSs[19], which are computed by three probabilistic components: truth-membership, indeterminacy-membership, and falsity-membership, effectively captures the vague and uncertain data often encountered in CNS evaluations, which include numerous qualitative assessments.

1.1. Contribution

This paper highlights the synergistic benefits of integrating GTODIM approach. This integration leverages the psychological insights into decision-makers' behavior provided by GTODIM in assessing the proximity to ideal solutions—both positive and negative. This manuscript introduces a novel approach, the INN-GTODIM approach, specifically tailored for handling MAGDM scenarios within the framework of INSs. A practical numerical study concerning CNS evaluations is demonstrating the efficacy of INN-GTODIM approach.

1.2. Research objective

The primary research objectives and motivations of this study are outlined:

- Deriving weight information through the application of average method, enhancing the robustness of the decision-making process.

- Implementing the INN-GTODIM approach for MAGDM scenarios that utilize INSs, showcasing its adaptability to complex decision-making environments
- Applying the INN-GTODIM approach specifically to the domain of CNS evaluation, and comparing its performance against existing approaches to highlight its strengths and improvements.
- Providing a detailed comparative analysis, which clearly demonstrates that the INN-GTODIM approach significantly enhances the effectiveness of CNS evaluations. This comprehensive approach ensures that the proposed approach not only addresses the multifaceted nature of decision-making in network security but also advances the field by integrating nuanced psychological insights.

1.3.Paper outline

This work is organized as follows: Section 2 explains the fundamental concepts of INSs. Section 3 develops the INN-GTODIM approach within the framework of INSs, incorporating average method. Section 4 presents a practical example regarding CNS evaluation, along with a comparative analysis. Section 5 discusses managerial applications of the INN-GTODIM approach. Section 6 provides concluding remarks. Finally, Section 7 outlines future directions for research and application.

2. Fundamental Concepts and Definitions

In this section, we provide a foundational overview of INSs as presented by Wang et al.[19]. INS represent a significant advancement in neutrosophic theory, extending traditional neutrosophic sets by allowing for interval-valued representations of truth, indeterminacy, and falsity membership functions. The formal definitions and properties outlined in this section lay the groundwork for understanding the structure and application of INSs, which are instrumental to the theoretical and practical contributions of this work.

Definition 1. The INSs are expressed as follows:

$$LA=\left\{\left(\phi, LT_A(\phi), LI_A(\phi), LF_A(\phi)\right)\middle|\phi\in\Phi\right\} \tag{1}$$

where the $LT_A(\phi), LI_A(\phi), LF_A(\phi)$ depicts the truth-membership, indeterminacy-membership and falsity-membership, $LT_A(\phi), LI_A(\phi), LF_A(\phi)\subseteq[0,1]$ and satisfies $0\le\sup LT_A(\phi)+\sup LI_A(\phi)+\sup LF_A(\phi)\le 3$.

The INN) is depicted: $LA=([LTL_A, LTR_A],[LIL_A, LIR_A],[LFL_A, LFR_A])$, where $LT_A, LI_A, LF_A\subseteq[0,1]$, and $0\le LTR_A+LIR_A+LFR_A\le 3$ [19].

The evolution of INNs usually use score value to act as a practical measure of their "truth" degree across intervals [24]. The score value is essential in deciding the relative magnitude of INNs by taking into account the intervals of truth, indeterminacy, and falsity degrees (refer to definition 2). Additionally, the accuracy value was measured to give another perspective on INNs by seizing the degree to which truth dominates over falsity within the neutrosophic intervals (refer to definition 3).

Definition 2. Let $LA=\left(\left[LTL_A, LTR_A\right],\left[LIL_A, LIR_A\right],\left[LFL_A, LFR_A\right]\right)$ be INN, score value is expressed as follows:

$$SV\left(LA\right)=\frac{\left(2+LTL_A-LIL_A-LFL_A\right)+\left(2+LTR_A-LIR_A-LFR_A\right)}{6},\ SV\left(LA\right)\in\left[0,1\right]. \quad (2)$$

Definition 3. Let $LA=\left(\left[LTL_A, LTR_A\right],\left[LIL_A, LIR_A\right],\left[LFL_A, LFR_A\right]\right)$ be INN, accuracy value is computed as follows:

$$AV\left(LA\right)=\frac{\left(LTL_A+LTR_A\right)-\left(LFL_A+LFR_A\right)}{2},\ AV\left(LA\right)\in\left[-1,1\right]. \quad (3)$$

Huang et al. [25] explored the concept of order relations between two INNs, providing a formal framework for comparing their values. interpreting the order relations is essential for applications where the ranking and preference of neutrosophic numbers are necessary (Refer to Definition 4). This framework facilitates decision-making processes by establishing criteria for determining which INN is greater or lesser, thereby enhancing the utility of neutrosophic methods in various domains.

Definition 4. Let $LA=\left(\left[LTL_A, LTR_A\right],\left[LIL_A, LIR_A\right],\left[LFL_A, LFR_A\right]\right)$ and $LB=\left(\left[LTL_B, LTR_B\right],\left[LIL_B, LIR_B\right],\left[LFL_B, LFR_B\right]\right)$ be INNs,

$$SV\left(LA\right)=\frac{\left(2+LTL_A-LIL_A-LFL_A\right)+\left(2+LTR_A-LIR_A-LFR_A\right)}{6}$$ and

$$SV\left(LB\right)=\frac{\left(2+LTL_B-LIL_B-LFL_B\right)+\left(2+LTR_B-LIR_B-LFR_B\right)}{6},$$ and

$$AV\left(LA\right)=\frac{\left(LTL_A+LTR_A\right)-\left(LFL_A+LFR_A\right)}{2}$$ and

$$AV\left(LB\right)=\frac{\left(LTL_B+LTR_B\right)-\left(LFL_B+LFR_B\right)}{2},$$ then if $SV\left(LA\right)<SV\left(LB\right)$, $LA<LB$; if $SV\left(LA\right)=SV\left(LB\right)$, (1) if $AV\left(LA\right)=AV\left(LB\right)$, $LA=LB$; (2) if $AV\left(LA\right)<AV\left(LB\right)$, $LA<LB$.

The operations on INNs are fundamental to leveraging their capabilities in modeling uncertainty and ambiguity **[26]**. These operations include addition, subtraction, multiplication, and division, each defined to preserve the inherent structure of the neutrosophic intervals (refer to Definition 5).

Definition 5. Let $LA=\left(\left[LTL_A, LTR_A\right],\left[LIL_A, LIR_A\right],\left[LFL_A, LFR_A\right]\right)$ and

$LB=\left(\left[LTL_B,LTR_B\right],\left[LIL_B,LIR_B\right],\left[LFL_B,LFR_B\right]\right)$ be INNs, the operations are expressed as follows:

(1) $$LA\oplus LB=\begin{pmatrix}\left(LTL_A+LTL_B-LTL_ALTL_B,LTR_A+LTR_B-LTR_ALTR_B\right),\\ \left[LIL_ALIL_B,LIR_ALIR_B\right],\left[LFL_ALFL_B,LFR_ALFR_B\right]\end{pmatrix};$$

(2) $$LA\otimes LB=\begin{pmatrix}\left[LTL_ALTL_B,LTR_ALTR_B\right],\\ \left[LIL_A+LIL_B-LIL_ALIL_B,LIR_A+LIR_B-LIR_ALIR_B\right],\\ \left[LFL_A+LFL_B-LFL_ALFL_B,LFR_A+LFR_B-LFR_ALFR_B\right]\end{pmatrix};$$

(3) $$\lambda LA=\begin{pmatrix}\left[1-\left(1-LTL_A\right)^{\lambda},1-\left(1-LTR_A\right)^{\lambda}\right],\\ \left[\left(LIL_A\right)^{\lambda},\left(LIR_A\right)^{\lambda}\right],\left[\left(LFL_A\right)^{\lambda},\left(LFR_A\right)^{\lambda}\right]\end{pmatrix},\lambda>0;$$

(4) $$\left(LA\right)^{\lambda}=\begin{pmatrix}\left[\left(LTL_A\right)^{\lambda},\left(LTR_A\right)^{\lambda}\right],\left[\left(LIL_A\right)^{\lambda},\left(LIR_A\right)^{\lambda}\right],\\ \left[1-\left(1-LFL_A\right)^{\lambda},1-\left(1-LFR_A\right)^{\lambda}\right]\end{pmatrix},\lambda>0.$$

Definition 6[27]. Let $LA=\left(\left[LTL_A,LTR_A\right],\left[LIL_A,LIR_A\right],\left[LFL_A,LFR_A\right]\right)$ and $LB=\left(\left[LTL_B,LTR_B\right],\left[LIL_B,LIR_B\right],\left[LFL_B,LFR_B\right]\right)$, the INN Hamming distance (INNHD) is expressed as follows:

$$INNHD\left(LA,LB\right)=\frac{1}{6}\begin{pmatrix}\left|LTL_A-LTL_B\right|+\left|LTR_A-LTR_B\right|+\left|LIL_A-LIL_B\right|+\\ \left|LIR_A-LIR_B\right|+\left|LFL_A-LFL_B\right|+\left|LFR_A-LFR_B\right|\end{pmatrix} \quad (4\text{-A})$$

Definition 6[27]. Let $LA=\left(\left[LTL_A,LTR_A\right],\left[LIL_A,LIR_A\right],\left[LFL_A,LFR_A\right]\right)$ and $LB=\left(\left[LTL_B,LTR_B\right],\left[LIL_B,LIR_B\right],\left[LFL_B,LFR_B\right]\right)$, the INN Euclidean distance (INNED) is computed as follows:

$$INNED\left(SA,SB\right)=\sqrt{\frac{1}{6}\begin{pmatrix}\left|LTL_A-LTL_B\right|^2+\left|LTR_A-LTR_B\right|^2+\left|LIL_A-LIL_B\right|^2+\\ \left|LIR_A-LIR_B\right|^2+\left|LFL_A-LFL_B\right|^2+\left|LFR_A-LFR_B\right|^2\end{pmatrix}} \quad (4\text{-B})$$

The INNWA approach [26] are expressed as follows:

Definition 7. Let $LA_j=\left(\left[LTL_j,LTR_j\right],\left[LIL_j,LIR_j\right],\left[LFL_j,LFR_j\right]\right)$ be INNs, the INNWA is expressed as follows:

$$
\begin{aligned}
&\operatorname{INNWA}\left(LA_1, LA_2, \ldots, LA_n\right) \\
&= lw_1 LA_1 \oplus lw_2 LA_2 \ldots \oplus lw_n LA_n = \underset{j=1}{\overset{n}{\oplus}} lw_j LA_j \\
&= \left(\begin{array}{l}
\left[1-\prod_{j=1}^{n}\left(1-LTL_{ij}\right)^{lw_j}, 1-\prod_{j=1}^{n}\left(1-LTR_{ij}\right)^{lw_j}\right], \\
\left[\prod_{j=1}^{n}\left(LFL_{ij}\right)^{lw_j}, \prod_{j=1}^{n}\left(LFR_{ij}\right)^{lw_j}\right], \left[\prod_{j=1}^{n}\left(LTL_{ij}\right)^{lw_j}, \prod_{j=1}^{n}\left(LTR_{ij}\right)^{lw_j}\right]
\end{array}\right)
\end{aligned} \tag{5}
$$

where $lw = \left(lw_1, lw_2, ..., lw_n\right)^T$ be weight of LA_j, $lw_j > 0, \sum_{j=1}^{n} lw_j = 1$ [26].

3. Research Methodology

In this section, we introduce our proposed methodology for addressing MAGDM within the framework of INNs. The approach is designed to effectively handle uncertainty and ambiguity, making it well-suited for complex decision-making environments.

3.1. INN-MAGDM description

Then, INN-GTODIM approach is computed for MAGDM. Let $LA = \{LA_1, LA_2, \cdots, LA_m\}$ be alternatives and $LG = \{LG_1, LG_2, \cdots, LG_n\}$ be attributes with weight $l\omega = \{l\omega_1, l\omega_2, \cdots, l\omega_n\}$, $l\omega_j \in [0,1]$, $\sum_{j=1}^{n} l\omega_j = 1$ and experts $LE = \{LE_1, LE_2, \cdots, LE_q\}$ with weight $lw = \{lw_1, lw_2, \cdots, lw_t\}$. Then, INN-GTODIM approach is applied to MAGDM following the steps shown in Figure 2.

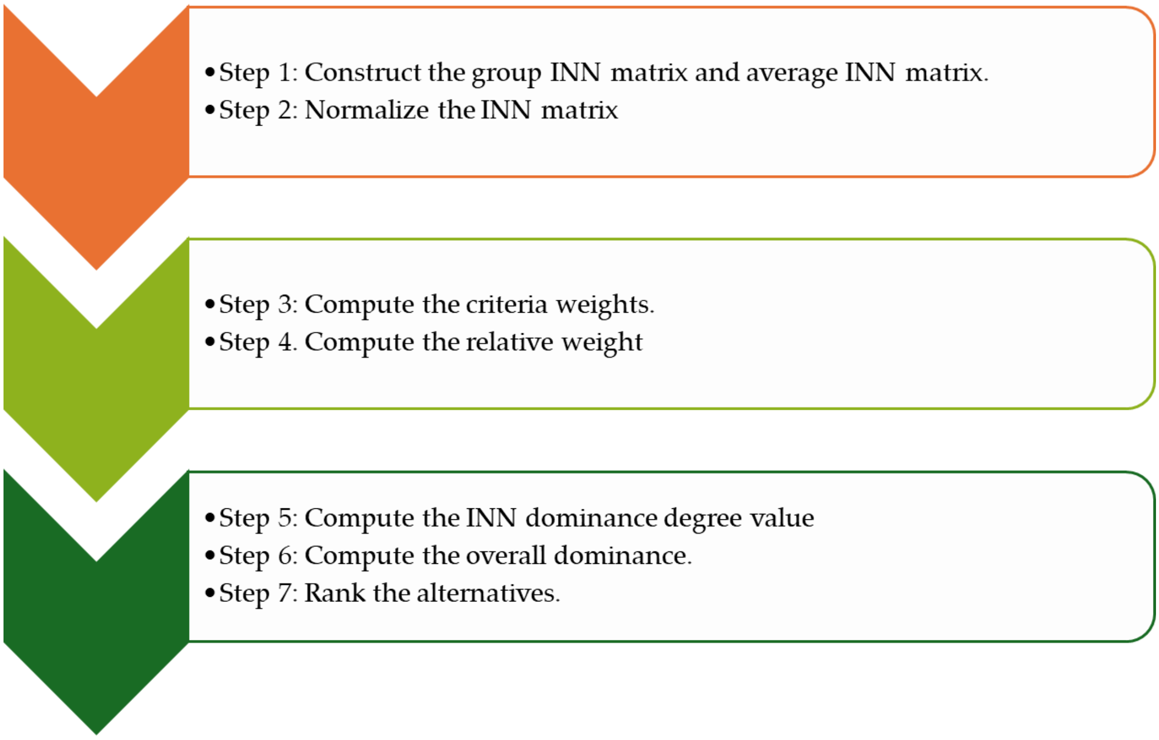

Figure. 2. The framework of INN-GTODIM approach for MAGDM.

Step 1. calculate the INN-matrix $LR^t = \left[LR_{ij}^t\right]_{m\times n} = \left(\left[LTL_{ij}^t, LTR_{ij}^t\right], \left[LIL_{ij}^t, LIR_{ij}^t\right], \left[LFL_{ij}^t, LFR_{ij}^t\right]\right)_{m\times n}$ and average-matrix $LR = \left[LR_{ij}\right]_{m\times n}$ based on INNWA approach:

$$\begin{aligned} LR_{ij} &= \left(\left[LTL_{ij}, LTR_{ij}\right], \left[LIL_{ij}, LIR_{ij}\right], \left[LFL_{ij}, LFR_{ij}\right]\right) \\ &= lw_1 LR_{ij}^1 \oplus lw_2 LR_{ij}^2 \oplus \cdots \oplus lw_t LR_{ij}^t \\ &= \begin{pmatrix} \left[1-\prod_{k=1}^{t}\left(LTL_{ij}^t\right)^{lw_j}, 1-\prod_{k=1}^{t}\left(LTR_{ij}^t\right)^{lw_j}\right], \\ \left[\prod_{k=1}^{t}\left(LFL_{ij}^t\right)^{lw_j}, \prod_{k=1}^{t}\left(LFR_{ij}^t\right)^{lw_j}\right], \\ \left[\prod_{k=1}^{t}\left(1-LTL_{ij}^t\right)^{lw_j}, \prod_{k=1}^{t}\left(1-LTR_{ij}^t\right)^{lw_j}\right] \end{pmatrix} \end{aligned} \tag{6}$$

Step 2. Normalize the $LR = \left[LR_{ij}\right]_{m\times n}$ into $NLRSN = \left[NLR_{ij}\right]_{m\times n}$.

For benefit attributes:

$$\begin{aligned} NLR_{ij} &= \left(\left[LTL_{ij}^N, LTR_{ij}^N\right], \left[LIL_{ij}^N, LIR_{ij}^N\right], \left[LFL_{ij}^N, LFR_{ij}^N\right]\right) \\ &= LR_{ij} = \left(\left[LTL_{ij}, LTR_{ij}\right], \left[LIL_{ij}, LIR_{ij}\right], \left[LFL_{ij}, LFR_{ij}\right]\right) \end{aligned} \tag{7}$$

For cost attributes:

$$\begin{aligned} NLR_{ij} &= \left(\left[LTL_{ij}^{N}, LTR_{ij}^{N} \right], \left[LIL_{ij}^{N}, LIR_{ij}^{N} \right], \left[LFL_{ij}^{N}, LFR_{ij}^{N} \right] \right) \\ = LR_{ij} &= \left(\left[LFL_{ij}, LFR_{ij} \right], \left[LIL_{ij}, LIR_{ij} \right], \left[LTL_{ij}, LTR_{ij} \right] \right) \end{aligned} \tag{8}$$

Step 4. Illustrate relative weight:

$$rl\omega_j = l\omega_j \Big/ \max_j l\omega_j , \tag{12}$$

Step 5. Illustrate the INN dominance degree values (INNDDV).

(1) The INNDDV of LA_i over LA_t under LG_j is computed in light with INNHD and INNED:

$$INNDDV_j\left(LA_i, LA_t\right) = \begin{cases} \sqrt{\dfrac{rlw_j \times \dfrac{INNHD\left(NLR_{ij}, NLR_{tj}\right) + INNED\left(NLR_{ij}, NLR_{tj}\right)}{2}}{\sum_{j=1}^{n} rlw_j}} & \text{if } SV\left(NLR_{ij}\right) > SV\left(NLR_{tj}\right) \\ 0 & \text{if } SV\left(NLR_{ij}\right) = SV\left(NLR_{tj}\right) \\ -\dfrac{1}{\theta}\sqrt{\dfrac{\sum_{j=1}^{n} rl\omega_j \times \dfrac{INNHD\left(NLR_{ij}, NLR_{tj}\right) + INNED\left(NLR_{ij}, NLR_{tj}\right)}{2}}{rl\omega_j}} & \text{if } SV\left(NLR_{ij}\right) < SV\left(NLR_{tj}\right) \end{cases} \tag{13}$$

The values of θ is determined for Ref.[29].

(2)The $INNDDV_j\left(LA_i\right)\left(j = 1, 2, \cdots, n\right)$ under LG_j is computed as follows:

$$INNDDV_j\left(LA_i\right) = \left[INNDDV_j\left(LA_i, LA_t\right) \right]_{m \times m}$$

$$= \begin{array}{c} \\ LA_1 \\ LA_2 \\ \vdots \\ LA_m \end{array} \begin{array}{c} \begin{array}{cccc} LA_1 & LA_2 & \cdots & LA_m \end{array} \\ \begin{bmatrix} 0 & INNDDV_j\left(LA_1, LA_2\right) & \cdots & INNDDV_j\left(LA_1, LA_m\right) \\ INNDDV_j\left(LA_2, LA_1\right) & 0 & \cdots & INNDDV_j\left(LA_2, LA_m\right) \\ \vdots & \vdots & \cdots & \vdots \\ INNDDV_j\left(LA_m, LA_1\right) & INNDDV_j\left(LA_m, LA_2\right) & \cdots & 0 \end{bmatrix} \end{array}$$

(3) Illustrate the overall INNDDV of LA_i :

$$INNDDV_j\left(LA_i\right) = \sum_{t=1}^{m} INNDDV_j\left(LA_i, LA_t\right) \tag{14}$$

(4) The overall INNDDV matrix is computed as follows:

$$INNDDV = \left(INNDDV_{ij}\right)_{m\times n} = \begin{bmatrix} & LG_1 & LG_2 & \cdots & LG_n \\ LA_1 & \sum_{t=1}^{m} INNDDV_1(LA_1, LA_t) & \sum_{t=1}^{m} INNDDV_2(LA_1, LA_t) & \cdots & \sum_{t=1}^{m} INNDDV_n(LA_1, LA_t) \\ LA_2 & \sum_{t=1}^{m} INNDDV_1(LA_2, LA_t) & \sum_{t=1}^{m} INNDDV_2(LA_2, LA_t) & \cdots & \sum_{t=1}^{m} INNDDV_n(LA_2, LA_t) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ LA_m & \sum_{t=1}^{m} INNDDV_1(LA_m, LA_t) & \sum_{t=1}^{m} INNDDV_2(LA_m, LA_t) & \cdots & \sum_{t=1}^{m} INNDDV_n(LA_m, LA_t) \end{bmatrix} \quad (15)$$

Step 6. Compute the overall dominance degree.

$$y_i = \frac{INNDDV_i - \min INNDDV_i}{\max INNDDV_i - \min INNDDV_i} \quad (16)$$

Step 7. Rank the alternatives.

4. Results and Discussions

In this section, we present and analyse the results obtained from each stage of our approach. Detailed tabular results illustrate the outcomes of key steps, providing a comprehensive view of the method's performance and intermediate calculations. In addition, we conduct comparative analysis to evaluate the efficiency of our approach (figure 2) relative to existing methods, enabling a deeper understanding of its strengths and potential areas for improvement.

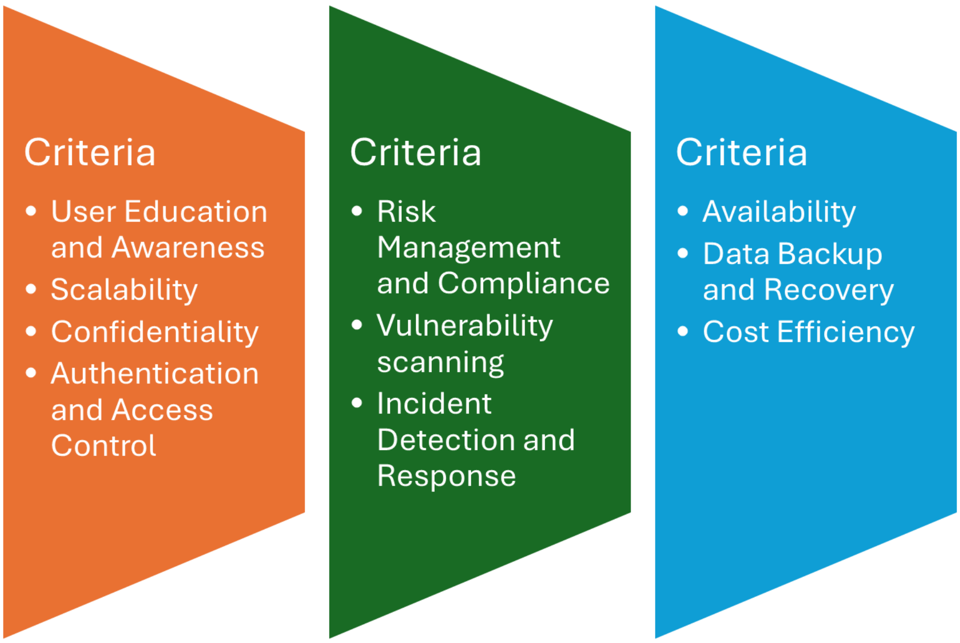

Figure 3. The ten attributes of the system.

As the fields of science and information technology continue to advance, the integration of internet and computer network technologies into critical sectors like politics, economics, and defense has become more widespread. This increasing prevalence has emphasized the vital issue of network security. Today's information systems are exposed to significant risks and severe threats, with cyber \attackers taking advantage of the complexities and vulnerabilities within computer network architectures. In China, although there are numerous systems designed to assess the CNS, only a few are in active use, with most focusing primarily on detecting network vulnerabilities. These systems typically fall short in providing detailed risk assessments or predictive insights regarding the status of network security, leading to a gap in comprehensive protection against potential threats across various industries. The existing frameworks for network security assessment are not effectively integrated with detection technologies, resulting in a lack of solid infrastructure and supportive platforms for conducting thorough tests and evaluations of network information security. This gap underscores the pressing need for a holistic network security assessment system that embraces a wide range of detection methods and risk evaluation strategies. Network information security is an interdisciplinary domain that encompasses network technology, communication technology, cryptography, information security, applied mathematics, and information theory. Its primary objective is to protect the hardware, software, and data within network systems from both accidental and intentional threats, thereby maintaining their integrity and ensuring their consistent and dependable operation. The smooth functioning of a network system is contingent upon the reliability of various components, including hardware, operating systems, application software, the surrounding environment, and communication devices. Evaluating network security involves scrutinizing a plethora of qualitative indicators, as the compromise or failure of any single component can introduce vulnerabilities. Therefore, the selection of indicators for network security evaluation is an intricate task that requires an exhaustive and comprehensive analysis of numerous factors to ensure that the indicators chosen are both representative and all-encompassing. This meticulous approach is essential to effectively safeguard network systems against the evolving landscape of cyber threats and vulnerabilities. The CNS evaluation is MAGDM. Five potential computer network systems are chosen with four attributes, shown in Figure 3.

Table 1. Linguistic Terms and INNs

Linguistic Terms	INNs
Exceedingly Terrible - LET	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])
Very Terrible – LVT	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
Terrible – LT	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])
Medium – LM	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
Well – LW	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])
Very Well – LVW	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])
Exceedingly Well - LEW	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])

The approach known as INN-GTODIM is demonstrated as a method to address the evaluation of CNS.

In Step 1, we calculate the INN-matrix, based on Table 1 as with Ref.[30, 31], $R^t = \left[s\phi_{ij}^t\right]_{5\times4} = \left(\left[STL_{ij}^t, STR_{ij}^t\right], \left[SIL_{ij}^t, SIR_{ij}^t\right], \left[SFL_{ij}^t, SFR_{ij}^t\right]\right)_{5\times4}$, and the corresponding values is tabulated in Table 2.

Table 2. The decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_2	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])
A_3	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
A_4	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])
A_5	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])
A_6	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])
A_7	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])
A_8	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_9	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])
A_{10}	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_2	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])
A_3	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
A_4	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])
A_5	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])
A_6	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])
A_7	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])
A_8	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_9	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])
A_{10}	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
A_2	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])
A_3	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])
A_4	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
A_5	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])
A_6	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])
A_7	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_8	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])
A_9	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.25, 0.4], [0.4, 0.5], [0.55, 0.7])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])
A_{10}	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.75, 0.9], [0.6, 0.7], [0.05, 0.2])	([0.65, 0.8], [0.5, 0.6], [0.15, 0.3])	([0.45, 0.6], [0.3, 0.4], [0.25, 0.5])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])	([0.15, 0.3], [0.5, 0.6], [0.65, 0.8])	([0.05, 0.2], [0.6, 0.7], [0.75, 0.9])	([0.4, 0.6], [0.1, 0.2], [0.4, 0.6])

Step 2. We normalize the decision matrix as shown in Table 3.

Table 3. The normalized decision matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
A_1	0.080046	0.085227	0.086538	0.098528	0.110727	0.12252	0.113532	0.122112	0.080233	0.091435
A_2	0.111369	0.119318	0.097222	0.078143	0.086505	0.092182	0.09289	0.094609	0.115116	0.08912
A_3	0.100928	0.097727	0.090812	0.116648	0.088812	0.094516	0.102064	0.086909	0.112791	0.109954
A_4	0.087007	0.089773	0.095085	0.082673	0.088812	0.094516	0.09633	0.09901	0.098837	0.107639
A_5	0.107889	0.105682	0.100427	0.100793	0.116494	0.114352	0.106651	0.09901	0.089535	0.107639
A_6	0.087007	0.093182	0.101496	0.093998	0.096886	0.099183	0.105505	0.119912	0.094186	0.128472
A_7	0.12297	0.094318	0.104701	0.097395	0.100346	0.101517	0.108945	0.09571	0.104651	0.082176
A_8	0.110209	0.117045	0.102564	0.105323	0.107266	0.092182	0.097477	0.086909	0.106977	0.086806
A_9	0.100928	0.119318	0.102564	0.107588	0.093426	0.087515	0.081422	0.113311	0.117442	0.096065
A_{10}	0.091647	0.078409	0.11859	0.118913	0.110727	0.101517	0.095183	0.082508	0.080233	0.100694

Step 3. We compute the criteria weights as shown in Figure 4.

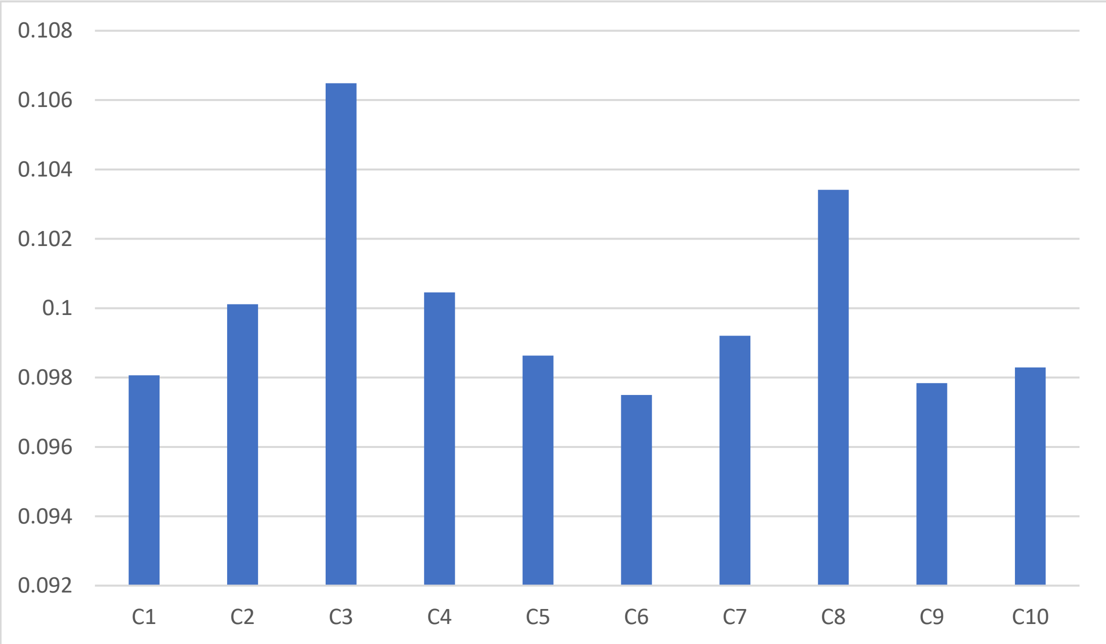

Figure 4. The criteria weights.

Step 4. We compute the relative weight.

Step 5. We compute the dominance degree.

Step 6. We compute the total dominance degree.

Step 7. We ordered alternatives as shown in Figure 5.

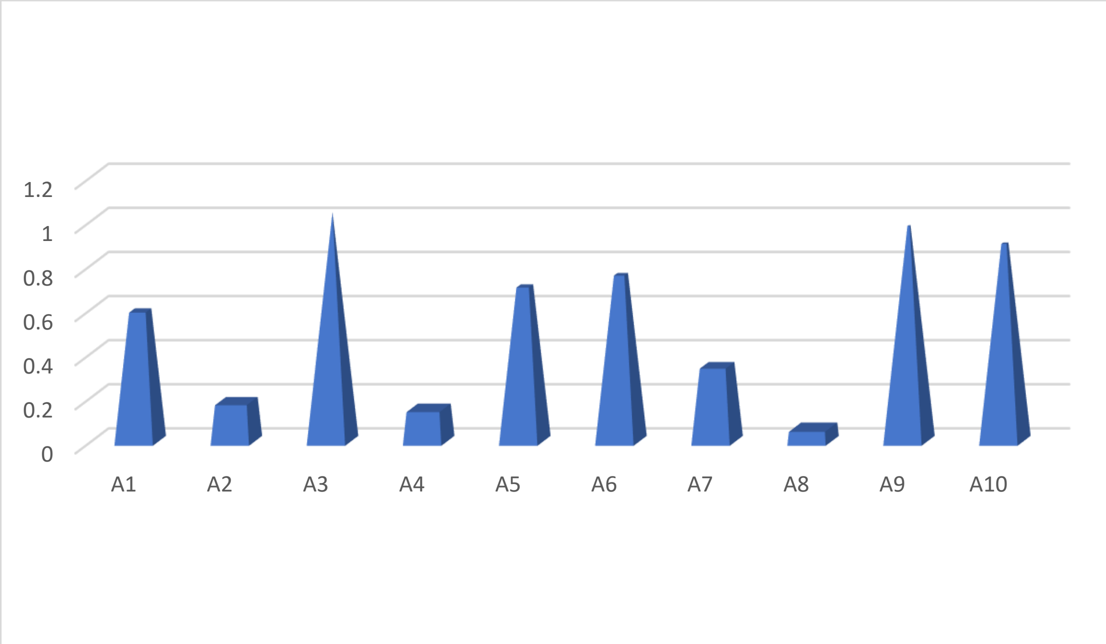

Figure 5. The rank of alternatives.

5. Managerial Applications

- The INN-GTODIM approach allows organizations to effectively assess network security risks, enabling better allocation of security resources. This ensures that critical areas receive the necessary attention and funding, maximizing protection against potential threats.
- By systematically identifying vulnerabilities and potential threats, the approach helps managers develop targeted risk management strategies. This proactive stance can significantly reduce the likelihood of cyber-attacks and data breaches.
- The integrated evaluation framework aids decision-makers by providing a structured method to analyze multiple attributes related to network security. This enhances their ability to make informed decisions in complex and uncertain environments.
- Organizations can use the results from the INN-GTODIM approach to benchmark their network security performance against industry standards and best practices. This can drive continuous improvement efforts and ensure compliance with regulatory requirements.
- The approach facilitates better emergency response planning by identifying potential security weaknesses. This preparation is crucial for maintaining business continuity and ensuring that data integrity is preserved during crises.
- Implementing the INN-GTODIM approach can serve as a basis for training programs aimed at enhancing employee awareness about network security risks and the importance of evaluation processes.
- The insights gained from network security evaluations can inform long-term strategic planning, helping organizations to adapt their security measures in response to evolving threats and technological advancements.

By incorporating the INN-GTODIM approach into managerial practices, organizations can enhance their overall security posture and resilience in the face of increasing cyber threats.

6. Conclusion

This research study introduces the INN-GTODIM approach, which synthesizes various techniques to effectively address the challenges of multiple-attribute group decision making (MAGDM) within the context of interval neutrosophic sets (INSs). This approach combines the strengths of INSs with the structured evaluation processes of GTODIM, creating a comprehensive framework for assessing computer network security (CNS).

To demonstrate the effectiveness of the INN-GTODIM approach, we present a detailed numerical case study focused specifically on evaluating CNS. This case study not only illustrates the application of the approach but also validates its effectiveness in providing a thorough and nuanced analysis of network security issues. The demonstration highlights how this integrated approach can adeptly manage the complexities and uncertainties inherent in network security evaluations, offering a valuable tool for decision-makers in the field.

7. Future Directions

- Explore the use of the INN-GTODIM approach in other fields beyond network security, such as healthcare, education, or environmental management, to evaluate its versatility.
- Investigate ways to refine the integration of INSs with decision-making techniques to further improve the robustness and reliability of the assessments.
- Develop mechanisms to integrate real-time data into the evaluation framework, allowing for dynamic assessments that adapt to changing conditions and uncertainties.
- Create intuitive software tools that implement the INN-GTODIM approach, making it accessible for practitioners and decision-makers who may not have technical expertise.
- Conduct comparative analyses with other decision-making models to benchmark the performance of the INN-GTODIM approach in various scenarios.
- Offer training programs and workshops to educate stakeholders on the application of this integrated approach, fostering a deeper understanding of its potential benefits.
- Initiate longitudinal studies to assess the long-term effectiveness of the approach in decision-making processes and its impact on outcomes over time.

These future directions aim to enhance the applicability and effectiveness of the INN-GTODIM approach in addressing complex decision-making challenges across various domains.

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Received: July 21, 2024. Accepted: Oct 24, 2024