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RESEARCH ARTICLE

INN-LogTODIM-GRA Framework for Service Quality Evaluation of International Logistics Enterprises From the Perspective of Cross Border E-Commerce Supply Chain

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ABSTRACT In the process of cross-border e-commerce (CBEC) development, CBEC logistics plays a crucial role as a booster. However, the numerous problems exposed in China's CBEC logistics process have to some extent limited the development of CBEC. Further research on CBEC logistics will guide the healthy development of CBEC platforms. The service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is a multiple-attribute group decision-making (MAGDM) issue. Recently, the Logarithmic TODIM (LogTODIM) and grey relational analysis (GRA) technique has been employed to come up with MAGDM issues. The interval neutrosophic sets (INSs) are employed as a tool for portraying uncertain decision information during the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain. In this paper, the interval neutrosophic number Logarithmic TODIM-GRA (INN-LogTODIM-GRA) technique is managed to come up with the MAGDM under INSs. Finally, a numerical example study for service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is employed to validate the proposed technique. The main contribution of this paper is managed: (1) The information entropy is constructed to obtain weight values under INSs; (2) an integrated INN-LogTODIM-GRA technique is constructed to manage the MAGDM issue; (3) An illustrative example for service quality evaluation of international logistics enterprises from the perspective of EBEC supply chain has accomplished to verify the INN-LogTODIM-GRA technique.

INDEX TERMS Multiple-attribute group decision-making (MAGDM), interval neutrosophic sets (INSs), LogTODIM, GRA, service quality evaluation.

I. INTRODUCTION

According to the "2016-2017 China CBEC Market Research Report" released by iResearch Consulting, the overall transaction size of China's import and export CBEC reached 6.3 trillion yuan in 2016. In 2016, the scale of China's overseas Taobao users reached 41 million. By 2018, China's overseas e-commerce users are expected to reach 74 million, and the scale of CBEC transactions will reach 8 trillion yuan. The scale of CBEC users in China will further expand, and the competition in the CBEC industry will become more intense [1], [2], [3]. At the time of the rise of the CBEC industry, China has become an economic powerhouse with both overall scale and development speed, ranking among the top in the world [4], [5], [6], [7]. Without a doubt, CBEC has become a powerful weapon that can promote China's economic transformation and continuously drive economic growth at a high speed [8], [9], [10]. The State Council of China has also begun to actively try and encourage some regions to take the lead. Starting from 2012, it has approved

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pilot cities for CBEC. So far, thirteen cities nationwide have obtained the promotion and operation of CBEC business pilot projects. In the future, more and more cities will participate in the feast of CBEC. The development of the international logistics industry and the e-commerce industry is closely related. In the context of "Internet+", international trade is booming [11], [12], [13]. With the proposal of the "the Belt and Road" strategy, the demand for CBEC services has further expanded. CBEC has become a new trade connection platform. The competition in CBEC industry is essentially the competition of international logistics service capabilities. The rapid development of the e-commerce industry can often bring huge development opportunities to the logistics industry. Similarly, the development of a large span can also bring significant changes to the overall environment of the logistics industry [14], [15], [16], [17]. The changing environment and changing customers bring more new challenges to international logistics enterprises. If international logistics service providers do not have a familiar understanding and grasp of the changing market, they are easily eliminated by the market. The rapid development of CBEC has brought enormous room for improvement in the service capabilities of international logistics service providers. This is a fact that is already evident to all. It can be foreseen that in the next round of rapid development of CBEC, international logistics enterprises will face new development opportunities and also face new severe challenges [18], [19], [20]. This undoubtedly further increases the demand for international logistics service capabilities. The status of international logistics services is becoming increasingly important. Global procurement and distribution, international warehousing and transportation, and rapid response to competitor strategies and customer needs cannot be separated from an efficient international logistics service system. In addition, from the perspective of China's export trade, a survey shows that in 2015, the top five CBEC markets in the world had a demand for purchasing goods from China through CBEC models of nearly 70 billion yuan [21], [22], [23], [24]. By 2018, this procurement demand will rapidly expand to around 150 billion yuan. The rapid development of new business models such as CBEC and market procurement trade has gradually become a new hotspot in the development of foreign trade. Correspondingly, it is a huge challenge faced by China's international logistics service providers in terms of service capabilities, as the level of international logistics services cannot fully meet domestic demand. With the continuous deepening of people's understanding of the importance of logistics, improving the service performance level of international logistics is becoming increasingly important [25], [26], [27], [28].

In daily life, due to the ambiguity and incompleteness of information, decision-makers often cannot use quantitative information to evaluate things, and tend to use natural language terminology to evaluate things, which leads to uncertainty issues in decision-making [29], [30], [31], [32]. Therefore, improving the ability of artificial intelligence to process natural language information and enabling it to mimic human thinking patterns to solve complex practical problems is our primary task today [33], [34], [35]. The MAGDM problem is an important component of decision theory [36], [37], [38]. Decision theory is the process of selecting the optimal solution from a limited number of influencing factors in order to achieve a specific goal based on set information [39], [40], [41], [42], [43], [44]. The theory and techniques of MAGDM have been widely applied in many fields such as engineering, technology, economics, management, and military [42], [45], [46], [47], [48], [49]. However, due to factors such as difficulty in data collection and increasing complexity in the decision-making process, obtaining attribute values becomes increasingly difficult, and decision-makers have certain limitations when making judgments [50], [51], [52], [53], [54]. And as the research content gradually deepens, when applying theoretical research to dealing with practical problems, due to the complexity and uncertainty of the actual problems themselves, decision-makers often cannot quantitatively evaluate decision information, and instead tend to use language terminology for qualitative expression [55], [56], [57], [58], [59]. Therefore, it is necessary to conduct in-depth research and theoretical innovation on MAGDM problems, which has certain practical significance [60], [61], [62], [63]. The service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is MAGDM. Based on the TODIM technique [64], [65], [66], Leoneti and Gomes [67] put up with the Logarithmic TODIM (LogTODIM) technique. Recently, the LogTODIM [67] and GRA technique [68], [69], [70], [71] has been employed to manage MAGDM issues. The INSs [72] are employed as a tool for portraying uncertain decision information during the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain. Until now, no or few techniques have been managed on information entropy and LogTODIM-GRA under INSs. Therefore, an integrated interval neutrosophic number Logarithmic TODIM-GRA (INN-LogTODIM-GRA) technique is constructed to manage the MAGDM issues. An illustrative example for service quality evaluation of international logistics enterprises from the perspective of EBEC supply chain is constructed to verify the validity and reliability of INN-LogTODIM-GRA technique. The prime motivation and objectives of this paper are managed: (1) The information entropy based on score values and accuracy value are constructed to obtain weight values under INSs; (2) an integrated INN-LogTODIM-GRA technique is constructed to manage the MAGDM issue; (3) An illustrative example for service quality evaluation of international logistics enterprises from the perspective of EBEC supply chain has accomplished to verify the INN-LogTODIM-GRA technique.

The research frame work of this paper is portrayed below. In Section II, the INSs are portrayed. In Section III, INN-LogTODIM-GRA model is portrayed under INSs. Section IV portrayed the illustrative example for service quality evaluation of international logistics enterprises from the perspective of EBEC supply chain and some comparative analysis. Some remarks are managed in Section V.

II. PRELIMINARIES

Wang et al. [73] managed the SVNSs

Definition 1 ([73]): The SVNSs PA inΦ is managed:

$$PA = \{(\phi, PT_A(\phi), PI_A(\phi), PF_A(\phi)) \,|\, \phi \in \Phi\} \quad (1)$$

where the $PT_A(\phi), PI_A(\phi), PF_A(\phi)$ depicts the truth-membership (TM), indeterminacy-membership (IM) and falsity-membership (FM), $PT_A(\phi), PI_A(\phi), PF_A(\phi) \in [0,1]$ and satisfies $0 \le PT_A(\phi) + PI_A(\phi) + PF_A(\phi) \le 3$.

Wang et al. [72] produced the INSs.

Definition 2 ([72]): The INSs $\tilde{PA}$ in Φ is managed:

$$\tilde{PA} = \left\{(\phi, PT_{\tilde{A}}(\phi), PI_{\tilde{A}}(\phi), PF_{\tilde{A}}(\phi)) \,|\, \phi \in \Phi\right\} \quad (2)$$

where the $PT_{\tilde{A}}(\phi), PI_{\tilde{A}}(\phi), PF_{\tilde{A}}(\phi)$ depicts the TM, IM and FM, $PT_{\tilde{A}}(\phi), PI_{\tilde{A}}(\phi), PF_{\tilde{A}}(\phi) \subseteq [0,1]$ and meets $0 \le \sup PT_{\tilde{A}}(\phi) + \sup PI_{\tilde{A}}(\phi) + \sup PF_{\tilde{A}}(\phi) \le 3$.

The interval neutrosophic number (INN) is portrayed as $\tilde{PA} = (PT_{\tilde{A}}, PI_{\tilde{A}}, PF_{\tilde{A}}) = \begin{pmatrix} [PTL_{\tilde{A}}, PTR_{\tilde{A}}], \\ [PIL_{\tilde{A}}, PIR_{\tilde{A}}], \\ [PFL_{\tilde{A}}, PFR_{\tilde{A}}] \end{pmatrix}$, where $PT_{\tilde{A}}, PI_{\tilde{A}}, PF_{\tilde{A}} \subseteq [0,1]$, and $0 \le PTR_{\tilde{A}} + PIR_{\tilde{A}} + PFR_{\tilde{A}} \le 3$.

Definition 3 ([74]): Let $\tilde{PA} = ([PTL_{\tilde{A}}, PTR_{\tilde{A}}], [PIL_{\tilde{A}}, PIR_{\tilde{A}}], [PFL_{\tilde{A}}, PFR_{\tilde{A}}])$, the INN score value (INNSV) is managed:

$$INNSV\left(\tilde{PA}\right) = \frac{\begin{pmatrix} (2 + PTL_{\tilde{A}} - PIL_{\tilde{A}} - PFL_{\tilde{A}}) \\ + (2 + PTR_{\tilde{A}} - PIR_{\tilde{A}} - PFR_{\tilde{A}}) \end{pmatrix}}{6}, \quad INNSV\left(\tilde{PA}\right) \in [0,1]. \quad (3)$$

Definition 4 ([74]): Let $\tilde{PA} = ([PTL_{\tilde{A}}, PTR_{\tilde{A}}], [PIL_{\tilde{A}}, PIR_{\tilde{A}}], [PFL_{\tilde{A}}, PFR_{\tilde{A}}])$, the INN accuracy value (INNAV) is managed:

$$INNAV\left(\tilde{PA}\right) = \frac{2 + (PTL_{\tilde{A}} + PTR_{\tilde{A}}) - (PFL_{\tilde{A}} + PFR_{\tilde{A}})}{4}, \quad INNAV\left(\tilde{PA}\right) \in [-1,1]. \quad (4)$$

Huang et al. [75] constructed the order for INNs.

Definition 5 ([74]): Let $\tilde{PA} = ([PTL_{\tilde{A}}, PTR_{\tilde{A}}], [PIL_{\tilde{A}}, PIR_{\tilde{A}}], [PFL_{\tilde{A}}, PFR_{\tilde{A}}])$ and

$$\tilde{PB} = ([PTL_{\tilde{B}}, PTR_{\tilde{B}}], [PIL_{\tilde{B}}, PIR_{\tilde{B}}], [PFL_{\tilde{B}}, PFR_{\tilde{B}}]),$$

$$INNSV\left(\tilde{PA}\right) = \frac{\begin{pmatrix} (2 + PTL_{\tilde{A}} - PIL_{\tilde{A}} - PFL_{\tilde{A}}) \\ + (2 + PTR_{\tilde{A}} - PIR_{\tilde{A}} - PFR_{\tilde{A}}) \end{pmatrix}}{6}$$

and

$$INNSV\left(\tilde{PB}\right) = \frac{\begin{pmatrix} (2 + PTL_{\tilde{B}} - PIL_{\tilde{B}} - PFL_{\tilde{B}}) \\ + (2 + PTR_{\tilde{B}} - PIR_{\tilde{B}} - PFR_{\tilde{B}}) \end{pmatrix}}{6},$$

and $INNAV\left(\tilde{PA}\right) = \frac{2+(PTL_{\tilde{A}}+PTR_{\tilde{A}})-(PFL_{\tilde{A}}+PFR_{\tilde{A}})}{4}$ and $INNAV\left(\tilde{PB}\right) = \frac{2+(PTL_{\tilde{B}}+PTR_{\tilde{B}})-(PFL_{\tilde{B}}+PFR_{\tilde{B}})}{4}$, then if $INNSV\left(\tilde{PA}\right) < INNSV\left(\tilde{PB}\right)$, then $\tilde{PA} < \tilde{PB}$; if $INNSV\left(\tilde{PA}\right) = INNSV\left(\tilde{PB}\right)$, then (1) if $INNAV\left(\tilde{PA}\right) = INNAV\left(\tilde{PB}\right)$, then $\tilde{PA} = \tilde{PB}$; (2) if $INNAV\left(\tilde{PA}\right) < INNAV\left(\tilde{PB}\right)$, then $\tilde{PA} < \tilde{PB}$.

Definition 6 ([76]): Let $\tilde{PA} = ([PTL_{\tilde{A}}, PTR_{\tilde{A}}], [PIL_{\tilde{A}}, PIR_{\tilde{A}}], [PFL_{\tilde{A}}, PFR_{\tilde{A}}])$ and $\tilde{PB} = ([PTL_{\tilde{B}}, PTR_{\tilde{B}}], [PIL_{\tilde{B}}, PIR_{\tilde{B}}], [PFL_{\tilde{B}}, PFR_{\tilde{B}}])$, the operation laws are managed, as shown in the equation at the bottom of the next page.

Definition 7 ([77]): $\tilde{PA} = ([PTL_{\tilde{A}}, PTR_{\tilde{A}}], [PIL_{\tilde{A}}, PIR_{\tilde{A}}], [PFL_{\tilde{A}}, PFR_{\tilde{A}}])$ and $\tilde{PB} = ([PTL_{\tilde{B}}, PTR_{\tilde{B}}], [PIL_{\tilde{B}}, PIR_{\tilde{B}}], [PFL_{\tilde{B}}, PFR_{\tilde{B}}])$, then the INN Hamming distance is managed, as in (5), shown at the bottom of the next page.

The INNWG technique [76] are managed:

Definition 8 ([76]): Let $\tilde{PA}_j = ([PTL_j, PTR_j], [PIL_j, PIR_j], [PFL_j, PFR_j])$ be INNs, the INNWG technique is:

$$\begin{aligned} & \mathrm{INNWG}\left(\tilde{PA}_1, \tilde{PA}_2, \ldots, \tilde{PA}_n\right) \\ &= \left(\tilde{PA}_1\right)^{pw_1} \otimes \left(\tilde{PA}_2\right)^{pw_2}, \ldots \otimes \left(\tilde{PA}_n\right)^{pw_n} = \bigotimes_{j=1}^{n} \left(\tilde{PA}_j\right)^{pw_j} \\ &= \begin{pmatrix} \left[\prod_{j=1}^{n} (PTL_j)^{pw_j}, \prod_{j=1}^{n} (PTR_j)^{pw_j}\right], \\ \left[1 - \prod_{j=1}^{n} (1 - PFL_j)^{pw_j}, 1 - \prod_{j=1}^{n} (1 - PFR_j)^{pw_j}\right], \\ \left[1 - \prod_{j=1}^{n} (1 - PTL_j)^{pw_j}, 1 - \prod_{j=1}^{n} (1 - PTR_j)^{pw_j}\right] \end{pmatrix} \end{aligned} \quad (6)$$

where $pw = (pw_1, pw_2, \ldots, pw_n)^T$ be weight values of $\tilde{PA}_j$, $pw_j > 0$, $\sum_{j=1}^{n} pw_j = 1$.

III. INN-LOGTODIM-GRA TECHNIQUE FOR MAGDM WITH ENTROPY WEIGHT

Then, INN-LogTODIM-GRA technique is managed for MAGDM. Let $PA = \{PA_1, PA_2, \cdots, PA_m\}$ be alternatives, and the attributes set $PG = \{PG_1, PG_2, \cdots, PG_n\}$ with weight values pw, where $pw_j \in [0,1]$, $\sum_{j=1}^{n} pw_j = 1$ and a set of invited experts $PE = \{PE_1, PE_2, \cdots, PE_q\}$ with weight values be $\{p\omega_1, p\omega_2, \cdots, p\omega_q\}$, where $p\omega_k \in [0,1]$, $\sum_{k=1}^{q} p\omega_k = 1$.

Then, INN-LogTODIM-GRA technique is characterized for MAGDM. The calculating research steps are characterized:

A. INN-MAGDM INFORMATION PROCESSING

Step 1: Establish the INN-matrix $PR^t = \left[PR_{ij}^t\right]_{m\times n} = \left(\left[PTL_{ij}^k, PTR_{ij}^k\right], \left[PIL_{ij}^k, PIR_{ij}^k\right], \left[PFL_{ij}^k, PFR_{ij}^k\right]\right)_{m\times n}$ and obtain the average matrix $PR = \left[PR_{ij}\right]_{m\times n}$:

$$PR = \left[PR_{ij}^k\right]_{m\times n} = \begin{matrix} \\ PA_1 \\ PA_2 \\ \vdots \\ PA_m \end{matrix} \begin{matrix} \begin{matrix} PG_1 & PG_2 & \ldots & PG_n \end{matrix} \\ \begin{bmatrix} PR_{11}^k & PR_{12}^k & \ldots & PR_{1n}^k \\ PR_{21}^k & PR_{22}^k & \ldots & PR_{2n}^k \\ \vdots & \vdots & \vdots & \vdots \\ PR_{m1}^k & PR_{m2}^k & \ldots & PR_{mn}^k \end{bmatrix} \end{matrix} \tag{7}$$

$$PR = \left[PR_{ij}\right]_{m\times n} = \begin{matrix} \\ PA_1 \\ PA_2 \\ \vdots \\ PA_m \end{matrix} \begin{matrix} \begin{matrix} PG_1 & PG_2 & \ldots & PG_n \end{matrix} \\ \begin{bmatrix} PR_{11} & PR_{12} & \ldots & PR_{1n} \\ PR_{21} & PR_{22} & \ldots & PR_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ PR_{m1} & PR_{m2} & \ldots & PR_{mn} \end{bmatrix} \end{matrix} \tag{8}$$

Based on INNWG, the $PR = \left[PR_{ij}\right]_{m\times n} = \begin{pmatrix} \left[PTL_{ij}, PTR_{ij}\right], \\ \left[PIL_{ij}, PIR_{ij}\right], \\ \left[PFL_{ij}, PFR_{ij}\right] \end{pmatrix}_{m\times n}$ is constructed as follows:

$$\begin{aligned} PR_{ij} &= \left(PR_{ij}^1\right)^{p\omega_1} \otimes \left(PR_{ij}^2\right)^{p\omega_2}, \ldots \otimes \left(PR_{ij}^q\right)^{p\omega_q} \\ &= \underset{k=1}{\overset{q}{\otimes}} \left(PR_{ij}^k\right)^{p\omega_j} \\ &= \begin{pmatrix} \left[\prod_{k=1}^{q}\left(PTL_{ij}^k\right)^{p\omega_k}, \prod_{k=1}^{q}\left(PTR_{ij}^k\right)^{p\omega_k}\right], \\ \left[1-\prod_{k=1}^{q}\left(PIL_{ij}^k\right)^{p\omega_k}, 1-\prod_{k=1}^{q}\left(PIR_{ij}^k\right)^{p\omega_k}\right], \\ \left[1-\prod_{k=1}^{q}\left(PFL_{ij}^k\right)^{p\omega_k}, 1-\prod_{k=1}^{q}\left(PFR_{ij}^k\right)^{p\omega_k}\right] \end{pmatrix} \end{aligned} \tag{9}$$

Step 2: Normalize the $PR = \left[PR_{ij}\right]_{m\times n}$ into $NPR = \left[NPR_{ij}\right]_{m\times n}$.

For benefit attributes:

$$\begin{aligned} &NPR_{ij} \\ &= \left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) \\ &= PR_{ij} = \left(\left[PTL_{ij}, PTR_{ij}\right], \left[PIL_{ij}, PIR_{ij}\right], \left[PFL_{ij}, PFR_{ij}\right]\right) \end{aligned} \tag{10}$$

For cost attributes:

$$\begin{aligned} &NPR_{ij} \\ &= \left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) \\ &= \left(\left[PFL_{ij}, PFR_{ij}\right], \left[PIL_{ij}, PIR_{ij}\right], \left[PTL_{ij}, PTR_{ij}\right]\right) \end{aligned} \tag{11}$$

B. CONSTRUCT THE ATTRIBUTES WEIGHT

Step 3 Construct the attributes weight through employing information entropy.

Entropy [78] is employed portray the weight values. Firstly, the normalized INN-matrix $n\phi_{ij}$ is portrayed as in (12), shown at the bottom of the next page.

Then, the INNM Shannon entropy $INNMSE = (INNMSE_1, INNMSE_2, \cdots, INNMSE_n)$ is portrayed by Eq. (14):

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

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

$$(1) P\tilde{A} \oplus P\tilde{B} = \begin{pmatrix} \left(PTL_{\tilde{A}} + PTL_{\tilde{B}} - PTL_{\tilde{A}}PTL_{\tilde{B}}, PTR_{\tilde{A}} + PTR_{\tilde{B}} - PTR_{\tilde{A}}PTR_{\tilde{B}}\right), \\ \left[PIL_{\tilde{A}}PIL_{\tilde{B}}, PIR_{\tilde{A}}PIR_{\tilde{B}}\right], \left[PFL_{\tilde{A}}PFL_{\tilde{B}}, PFR_{\tilde{A}}PFR_{\tilde{B}}\right] \end{pmatrix};$$

$$(2)\ P\tilde{A} \otimes P\tilde{B} = \begin{pmatrix} \left[PTL_{\tilde{A}}PTL_{\tilde{B}}, PTR_{\tilde{A}}PTR_{\tilde{B}}\right], \\ \left[PIL_{\tilde{A}} + PIL_{\tilde{B}} - PIL_{\tilde{A}}PIL_{\tilde{B}}, PIR_{\tilde{A}} + PIR_{\tilde{B}} - PIR_{\tilde{A}}PIR_{\tilde{B}}\right], \\ \left[PFL_{\tilde{A}} + PFL_{\tilde{B}} - PFL_{\tilde{A}}PFL_{\tilde{B}}, PFR_{\tilde{A}} + PFR_{\tilde{B}} - PFR_{\tilde{A}}PFR_{\tilde{B}}\right] \end{pmatrix};$$

$$(3)\ \zeta P\tilde{A} = \begin{pmatrix} \left[1-\left(1-PTL_{\tilde{A}}\right)^{\zeta}, 1-\left(1-PTR_{\tilde{A}}\right)^{\zeta}\right], \\ \left[\left(PIL_{\tilde{A}}\right)^{\zeta}, \left(PIR_{\tilde{A}}\right)^{\zeta}\right], \left[\left(PFL_{\tilde{A}}\right)^{\zeta}, \left(PFR_{\tilde{A}}\right)^{\zeta}\right] \end{pmatrix}, \zeta > 0;$$

$$(4)\ \left(P\tilde{A}\right)^{\zeta} = \begin{pmatrix} \left[\left(PTL_{\tilde{A}}\right)^{\zeta}, \left(PTR_{\tilde{A}}\right)^{\zeta}\right], \left[\left(PIL_{\tilde{A}}\right)^{\zeta}, \left(PIR_{\tilde{A}}\right)^{\zeta}\right], \\ \left[1-\left(1-PFL_{\tilde{A}}\right)^{\zeta}, 1-\left(1-PFR_{\tilde{A}}\right)^{\zeta}\right] \end{pmatrix}, \zeta > 0.$$

$$INNHD\left(P\tilde{A}, P\tilde{B}\right) = \frac{1}{6}\begin{pmatrix} \left|PTL_{\tilde{A}} - PTL_{\tilde{B}}\right| + \left|PTR_{\tilde{A}} - PTR_{\tilde{B}}\right| + \left|PIL_{\tilde{A}} - PIL_{\tilde{B}}\right| + \\ \left|PIR_{\tilde{A}} - PIR_{\tilde{B}}\right| + \left|PFL_{\tilde{A}} - PFL_{\tilde{B}}\right| + \left|PFR_{\tilde{A}} - PFR_{\tilde{B}}\right| \end{pmatrix} \tag{5}$$

Then, the weight values $pw = (pw_1, pw_2, \cdots, pw_n)$ is portrayed:

$$pw_j = \frac{1 - INNMSE_j}{\sum_{j=1}^{n} (1 - INNMSE_j)}, \quad j = 1, 2, \cdots, n. \tag{14}$$

C. INN-LOGTODIM-GRA TECHNIQUE FOR MAGDM

Then, the INN-LogTODIM-GRA technique is portrayed for MAGDM.

Step 4: Portray relative weight values of PG_j as:

$$rpw_j = pw_j / \max_j pw_j, \tag{15}$$

Step 5: The INN dominance degree (INNDD)$INNDD_j(PA_i, PA_t)$ of PA_i over PA_t for PG_j is portrayed by Eqs. (17), as in (16), shown at the bottom of the page, where $\lambda \in [1, 5]$ and $\rho \in N^+$ is constructed according to the agent's perception [67].

The $INNDD_j(PA_i)$ for PG_j is portrayed, as shown in the equation at the bottom of the page. The overall INNDD of PA_i over other alternatives is constructed for PG_j:

$$INNDD_j(PA_i) = \sum_{t=1}^{m} INNDD_j(PA_i, PA_t) \tag{17}$$

with all INNDD of PG_j, the overall INNDD is portrayed as in (18), shown at the bottom of the page.

Step 6: Portray the INN positive ideal alternative (INNPIA) and INN negative ideal alternative (INNNIA):

$$INNPIA = (INNPIA_1, INNPIA_1, \cdots, INNPIA_n) \tag{19}$$

$$INNNIA = (INNNIA_1, INNNIA_1, \cdots, INNNIA_n) \tag{20}$$

$$INNPIA_j = \max_{j=1}^{n} INNDD_{ij}, INNNIA_j = \min_{j=1}^{n} INNDD_{ij} \tag{21}$$

Step 7: Compute the INN grey rational coefficients (INNGRC) from the INNPIA and INNNIA as in

$$INNM_{ij} = \frac{\begin{pmatrix} INNSV\left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) + \\ INNAV\left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) \end{pmatrix}}{\sum_{i=1}^{m} \begin{pmatrix} INNSV\left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) + \\ INNAV\left(\left[NPTL_{ij}, NPTR_{ij}\right], \left[NPIL_{ij}, NPIR_{ij}\right], \left[NPFL_{ij}, NPFR_{ij}\right]\right) \end{pmatrix}}, \tag{12}$$

$$INNDD_j(PA_i, PA_t) = \begin{cases} \dfrac{rpw_j \times \log\left(1 + 10\rho INNHD\left(NPR_{ij}, NPR_{tj}\right)\right)}{\sum_{j=1}^{n} rpw_j} & \text{if } INNSV\left(NPR_{ij}\right) > INNSV\left(NPR_{tj}\right) \\ 0 & \text{if } INNSV\left(NPR_{ij}\right) = INNSV\left(NPR_{tj}\right) \\ -\dfrac{rpw_j \times \lambda \log\left(1 + 10\rho INNHD\left(NPR_{ij}, NPR_{tj}\right)\right)}{\sum_{j=1}^{n} rpw_j} & \text{if } INNSV\left(NPR_{ij}\right) < INNSV\left(NPR_{tj}\right) \end{cases} \tag{16}$$

$$INNDD_j(PA_i) = \left[INNDD_j(PA_i, PA_t)\right]_{m \times m}$$
$$= \begin{array}{c} \\ PA_1 \\ PA_2 \\ \vdots \\ PA_m \end{array} \begin{array}{c} \begin{array}{cccc} PA_1 & PA_2 & \cdots & PA_m \end{array} \\ \begin{bmatrix} 0 & INNSD_j(PA_1, PA_2) & \cdots & INNSD_j(PA_1, PA_m) \\ INNSD_j(PA_2, PA_1) & 0 & \cdots & INNSD_j(PA_2, PA_m) \\ \vdots & \vdots & \cdots & \vdots \\ INNSD_j(PA_m, PA_1) & INNSD_j(PA_m, PA_2) & \cdots & 0 \end{bmatrix} \end{array}$$

$$INNDD = \left(INNDD_{ij}\right)_{m \times n}$$
$$= \begin{bmatrix} & PG_1 & PG_2 & \cdots & PG_n \\ PA_1 & \sum_{t=1}^{m} INNDD_1(PA_1, PA_t) & \sum_{t=1}^{m} INNDD_2(PA_1, PA_t) & \cdots & \sum_{t=1}^{m} INNDD_n(PA_1, PA_t) \\ PA_2 & \sum_{t=1}^{m} INNDD_1(PA_2, PA_t) & \sum_{t=1}^{m} INNDD_2(PA_2, PA_t) & \cdots & \sum_{t=1}^{m} INNDD_n(PA_2, PA_t) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ PA_m & \sum_{t=1}^{m} INNDD_1(PA_m, PA_t) & \sum_{t=1}^{m} INNDD_2(PA_m, PA_t) & \cdots & \sum_{t=1}^{m} INNDD_n(PA_m, PA_t) \end{bmatrix} \tag{18}$$

(22) and (23), shown at the bottom of the page, ρ is distinguishing coefficient, generally, $\rho = 0.5$.

Step 8: Calculate the INN grey relation degree (INNGRD) of from INNPIA and INNNIA and INN relative relational degree (INNRRD) from INNPIA. The alternative has the maximum INNRRD would be most desirable one. As in (24)–(26), shown at the bottom of the page.

IV. AN EMPIRICAL EXAMPLE AND COMPARATIVE ANALYSIS

A. AN EMPIRICAL EXAMPLE FOR SERVICE QUALITY EVALUATION OF INTERNATIONAL LOGISTICS ENTERPRISES FROM THE PERSPECTIVE OF CBEC SUPPLY CHAIN

The 2019 China CBEC Market Data Monitoring Report points out that the scale of China's CBEC market reached 10.5 trillion yuan in 2019, an increase of 16.66% compared to 2018. Then, cross-border logistics, as a key link in CBEC transactions, has also rapidly managed. According to data from the National Postal Administration, the Hong Kong, Macao, and Taiwan express delivery business volume completed 1.44 billion pieces in 2019, a year-on-year increase of 29.9%; Our country achieved a business revenue of 74.73 billion yuan, a year-on-year increase of 27.6%. This means that CBEC is conducive to promoting the rapid growth of cross-border logistics, and a complete cross-border logistics system provides strong support for the development of CBEC. For CBEC enterprises, it is crucial to stimulate consumers' willingness to repurchase and improve their loyalty. Logistics services are an important indicator to measure consumers' shopping experience. The 2019 China E-commerce User Experience and Complaint Monitoring Report released by the Network Economic and Social E-commerce Research Center shows that CBEC complaints account for 7.13%, and hot complaint issues include shipping issues, after-sales service, and difficulty in returning and exchanging goods. The quality of cross-border logistics services, as a key link in overseas online shopping, has a significant driving effect on the improvement of product repeat purchase rate. Cross border logistics requires special processes such as customs and commodity inspection. Goods returned or exchanged need to be declared again, export tax refunds processed, and import tariffs paid. The complex process makes reverse logistics difficult, which to some extent affects the quality of cross-border logistics services. However, if the return or exchange phenomenon in the online shopping environment is properly handled, it will actively promote consumer repurchase behavior. At the same time, CBEC enterprises urgently need to actively maintain the relationship between themselves and consumers, ensure the quality of logistics services and service remediation work to reshape consumers' willingness to repurchase. For merchants, the quality of cross-border logistics services greatly affects consumers' tendency to purchase again and their recommendation behavior to other consumers. Therefore, improving the quality of cross-border logistics services, providing consumers with a good shopping experience, and consolidating and expanding the cross-border commodity market are urgent issues that need to be addressed in current CBEC and logistics.

$$INNGRC_{ij}^{INNPIA} = \frac{\min\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right|}{\left|INNDD_{ij} - INNPIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right|} \tag{22}$$

$$INNGRC_{ij}^{INNNIA} = \frac{\min\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right|}{\left|INNDD_{ij} - INNNIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right|} \tag{23}$$

$$\begin{aligned} INNGRD_{i}^{INNPIA} &= \sum_{j=1}^{n} pw_j INNGRD_{ij}^{INNPIA} \\ &= \sum_{j=1}^{n} pw_j \times \frac{\min\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right|}{\left|INNDD_{ij} - INNPIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNPIA_j\right|} \end{aligned} \tag{24}$$

$$\begin{aligned} INNGRD_{i}^{INNNIA} &= \sum_{j=1}^{n} pw_j INNGRD_{ij}^{INNNIA} \\ &= \sum_{j=1}^{n} pw_j \times \frac{\min\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right|}{\left|INNDD_{ij} - INNNIA_j\right| + \rho \max\limits_{1\le i\le m}\left|INNDD_{ij} - INNNIA_j\right|} \end{aligned} \tag{25}$$

$$INNRRD_{i}^{INNPIA} = \frac{INNGRD_{i}^{INNPIA}}{INNGRD_{i}^{INNPIA} + INNGRD_{i}^{INNNIA}} \tag{26}$$

TABLE 1. Linguistic scale and INNs.

Linguistic Terms	INNs
Exceedingly Terrible-PET	([0.05,0.2], [0.6,0.7], [0.75,0.9])
Very Terrible-PVT	([0.15,0.3], [0.5,0.6], [0.65,0.8])
Terrible-PT	([0.25,0.4], [0.4,0.5], [0.55,0.7])
Medium-PM	([0.4,0.6], [0.1,0.2], [0.4,0.6])
Well-PW	([0.45,0.6], [0.3,0.4], [0.25,0.5])
Very Well-PVW	([0.65,0.8], [0.5,0.6], [0.15,0.3])
Exceedingly Well-PEW	([0.75,0.9], [0.6,0.7], [0.05,0.2])

TABLE 2. Evaluation values through PE_1.

	PG_1	PG_2	PG_3	PG_4
PA_1	PVT	PM	PM	PT
PA_2	PVT	PVW	PVT	PVW
PA_3	PVW	PW	PVW	PW
PA_4	PVW	PT	PVT	PM
PA_5	PM	PVW	PM	PVT

TABLE 3. Evaluation values through PE_2.

	PG_1	PG_2	PG_3	PG_4
PA_1	PM	PT	PT	PM
PA_2	PW	PVW	PM	PW
PA_3	PVT	PVW	PVW	PW
PA_4	PVW	PVT	PVT	PT
PA_5	PW	PM	PT	PM

They have important practical significance in promoting the coordinated development of CBEC and logistics. The service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is a MAGDM. Therefore, the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is portrayed to prove the model managed. There are five potential international logistics enterprises $PA_i (i = 1, 2, 3, 4, 5)$ to choose. The experts select four attributes to portray the five potential international logistics enterprises: ① PG_1 is service reliability of international logistics enterprises; ② PG_2 is service economy of international logistics

TABLE 4. Evaluation values through PE_3.

	PG_1	PG_2	PG_3	PG_4
PA_1	PW	PVW	PM	PT
PA_2	PVT	PVT	PVT	PM
PA_3	PM	PT	PT	PW
PA_4	PW	PVW	PVW	PW
PA_5	PM	PW	PM	PW

TABLE 5. The $PR = \left[PR_{ij}\right]_{5\times 4}$.

	PG_1	PG_2
PA_1	([0.63, 0.68], [0.36, 0.42], [0.47, 0.52])	([0.87, 0.92], [0.32, 0.43], [0.57, 0.57])
PA_2	([0.73, 0.82], [0.57, 0.65], [0.43, 0.58])	([0.69, 0.78], [0.82, 0.95], [0.46, 0.53])
PA_3	([0.63, 0.76], [0.42, 0.56], [0.42, 0.69])	([0.76, 0.84], [0.79, 0.84], [0.37, 0.42])
PA_4	([0.64, 0.69], [0.48, 0.53], [0.46, 0.65])	([0.79, 0.82], [0.53, 0.62], [0.41, 0.43])
PA_5	([0.84, 0.87], [0.28, 0.35], [0.49, 0.56])	([0.85, 0.96], [0.49, 0.53], [0.45, 0.48])
	PG_4	PG_3
PA_1	([0.58, 0.64], [0.39, 0.46], [0.54, 0.62])	([0.82, 0.85], [0.19, 0.23], [0.46, 0.58])
PA_2	([0.68, 0.72], [0.47, 0.53], [0.42 0.47])	([0.46, 0.56], [0.15, 0.42], [0.43, 0.62])
PA_3	([0.61, 0.72], [0.32, 0.41], [0.75, 0.82])	([0.84, 0.87], [0.57, 0.63], [0.54, 0.56])
PA_4	([0.38, 0.45], [0.54, 0.65], [0.67, 0.85])	([0.59, 0.65], [0.52, 0.58], [0.42, 0.54])
PA_5	([0.25, 0.37], [0.21, 0.29], [0.38, 0.41])	([0.74, 0.83], [0.37, 0.46], [0.49, 0.51])

enterprises; ③ PG_3 is service security of international logistics enterprises; ④ PG_4 is service responsiveness of international logistics enterprises. All attributes are beneficial one. The five possible international logistics enterprises $PA_i\ (i = 1, 2, 3, 4, 5)$ are to be portrayed with INNs with the four attributes through three experts $PE_k\ (k = 1, 2, 3)$. These three experts include the senior management personnel of logistics enterprises, logistics management decision consulting expert and professor of logistics management at university with corresponding weight values is $(0.35, 0.35, 0.30)$. The Table 1 is referenced for [79] and [80].

The INN-LogTODIM-GRA technique is portrayed to manage the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain.

Step 1: Construct the INN matrix $PR^t = \left[PR^t_{ij}\right]_{5\times 4} = \left(\left[PTL^t_{ij}, PTR^t_{ij}\right], \left[PIL^t_{ij}, PIR^t_{ij}\right], \left[PFL^t_{ij}, PFR^t_{ij}\right]\right)_{5\times 4}$ (See Table 2-4).

Then through INNWG technique, the $PR = \left[PR_{ij}\right]_{5\times 4}$ is portrayed (See Table 5) by Eq.(9).

Step 2: Normalize the $PR = \left[PR_{ij}\right]_{5\times 4}$ into $NPR = \left[NPR_{ij}\right]_{5\times 4}$ (See Table 6) by Eqs. (10)-(11).

Step 3: Portray the weight values (See Table 7) by Eqs. (12)-(14):

Step 4: Portray the relative weight values (See Table 8) by Eq. (15):

Step 5: Portray the $INNDD = \left(INNDD_{ij}\right)_{5\times 4}$(See table 9) by Eq. (18):

TABLE 6. The $NPR = [NPR_{ij}]_{5\times4}$.

	PG_1	PG_2
PA_1	([0.63, 0.68], [0.36, 0.42], [0.47, 0.52])	([0.87, 0.92], [0.32, 0.43], [0.57, 0.57])
PA_2	([0.73, 0.82], [0.57, 0.65], [0.43, 0.58])	([0.69, 0.78], [0.82, 0.95], [0.46, 0.53])
PA_3	([0.63, 0.76], [0.42, 0.56], [0.42, 0.69])	([0.76, 0.84], [0.79, 0.84], [0.37, 0.42])
PA_4	([0.64, 0.69], [0.48, 0.53], [0.46, 0.65])	([0.79, 0.82], [0.53, 0.62], [0.41, 0.43])
PA_5	([0.84, 0.87], [0.28, 0.35], [0.49, 0.56])	([0.85, 0.96], [0.49, 0.53], [0.45, 0.48])
	PG_4	PG_3
PA_1	([0.58, 0.64], [0.39, 0.46], [0.54, 0.62])	([0.82, 0.85], [0.19, 0.23], [0.46, 0.58])
PA_2	([0.68, 0.72], [0.47, 0.53], [0.42 0.47])	([0.46, 0.56], [0.15, 0.42], [0.43, 0.62])
PA_3	([0.61, 0.72], [0.32, 0.41], [0.75, 0.82])	([0.84, 0.87], [0.57, 0.63], [0.54, 0.56])
PA_4	([0.38, 0.45], [0.54, 0.65], [0.67, 0.85])	([0.59, 0.65], [0.52, 0.58], [0.42, 0.54])
PA_5	([0.25, 0.37], [0.21, 0.29], [0.38, 0.41])	([0.74, 0.83], [0.37, 0.46], [0.49, 0.51])

TABLE 7. The weight values.

	PG_1	PG_2	PG_3	PG_4
pw	0.2356	0.2077	0.2955	0.2612

TABLE 8. The relative values.

	PG_1	PG_2	PG_3	PG_4
rpw	0.7973	0.7029	1.0000	0.8839

TABLE 9. The $INNDD = (INNDD_{ij})_{5\times4}$.

	PG_1	PG_2	PG_3	PG_4
PA_1	-0.3841	-0.0764	1.1569	0.8977
PA_2	0.4590	0.3963	-1.2838	-0.8158
PA_3	-0.7165	0.5961	1.3171	-0.1674
PA_4	0.6096	-1.4252	-0.0445	-0.2550
PA_5	-1.5825	1.0555	-0.7684	-0.9158

Step 6: Portray the INNPIA and INNNIA (See table 10) by Eqs. (19)-(21).

Step 7: Calculate the $INNGRC_{ij}^{INNPIA}$ and $INNGRC_{ij}^{INNNIA}$ (See table 11-12) by Eqs. (22)-(13).

TABLE 10. The INNPIA and INNNIA.

	PG_1	PG_2	PG_3	PG_4
INNPIA	0.6096	1.0555	1.3171	0.8977
INNNIA	-1.5825	-1.4252	-1.2838	-0.9158

TABLE 11. The $INNGRC_{ij}^{INNPIA}$.

	FG_1	FG_2	FG_3	FG_4
PA_1	0.5245	0.5229	0.8903	1.0000
PA_2	0.8792	0.6530	0.3333	0.3461
PA_3	0.4525	0.7297	1.0000	0.4599
PA_4	1.0000	0.3333	0.4885	0.4403
PA_5	0.3333	1.0000	0.3841	0.3333

TABLE 12. The $INNGRC_{ij}^{INNNIA}$.

	FG_1	FG_2	FG_3	FG_4
PA_1	0.4777	0.4791	0.3476	0.3333
PA_2	0.3493	0.4051	1.0000	0.9007
PA_3	0.5586	0.3803	0.3333	0.5478
PA_4	0.3333	1.0000	0.5120	0.5785
PA_5	1.0000	0.3333	0.7162	1.0000

Step 8: Portray the $INNGRD_i^{INNPIA}$, $INNGRD_i^{INNNIA}$ and $INNRRD_i^{INNPIA}$ (See table 13) by Eqs. (24)-(26).

Thus, the best international logistics enterprise is PA_1.

B. COMPARATIVE ANALYSIS

Then, the INN-LogTODIM-GRA technique is compared with INNWA technique [76] and INNWG technique [76], INN-VIKOR technique [81], INN-CODAS technique [82], INN-EDAS technique [79], INN-Taxonomy technique [83], INN-TODIM technique [84], INN-MULTIMOORA technique [85] and INN-TODIM-TOPSIS technique [86]. The comparative decision results are portrayed in Table 14.

From the above analysis, it could be portrayed that the order of these techniques is slightly different, however, all the decision techniques have the same optimal international logistics enterprises and worst international logistics enterprises. This verifies the INN-LogTODIM-GRA technique is reasonable and effective. Thus, the main advantages of the proposed INN-LogTODIM-GRA technique are outlined: (1) the proposed INN-LogTODIM-GRA technique not only handles DMs' psychological behavior, but also portrays the shape similarity from INNPIA and INNNIA during the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain. (2) the proposed INN-LogTODIM-GRA technique analyze the behavior of the

TABLE 13. The $INNGRD_i^{INNPIA}$, $INNGRD_i^{INNNIA}$ and $INNRRD_i^{INNPIA}$.

Alternative	$INNGRD_i^{INNPIA}$	$INNGRD_i^{INNNIA}$	$INNRRD_i^{INNPIA}$	Order
PA_1	0.7564	0.4018	0.6531	1
PA_2	0.5317	0.6972	0.4326	4
PA_3	0.6738	0.4522	0.5984	2
PA_4	0.5642	0.5886	0.4894	3
PA_5	0.4868	0.7777	0.3850	5

TABLE 14. Order of the different techniques.

	Order
INNWA technique [76]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$
INNWG technique [76]	$PA_1 > PA_3 > PA_2 > PA_4 > PA_5$
INN-VIKOR technique [81]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$
INN-CODAS technique [82]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$
INN-EDAS technique [79]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$
INN-Taxonomy technique [83]	$PA_1 > PA_3 > PA_2 > PA_4 > PA_5$
INN-TODIM technique [84]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$
INN-TODIM-TOPSIS technique [86]	$PA_1 > PA_3 > PA_4 > PA_2 > PA_5$

LogTODIM and GRA as MAGDM techniques when they are hybridized.

V. CONCLUSION

With the continuous acceleration of economic globalization, trade between countries has become increasingly frequent. International cross-border intermodal transportation, as an economic, green, and efficient transportation organization technique, is highly sought after in the international freight market and has become an important bridge of international trade. More and more logistics enterprises are also starting to transform towards multimodal cross-border transportation techniques and carry out international multimodal cross-border logistics services. However, the development of international multimodal cross-border intermodal transportation in China is still in its early stages, with weak service awareness and low service quality levels among enterprises, which has become an important factor restricting the healthy development of the industry. In the future, if enterprises want to succeed in fierce market competition, service quality is the key to victory. Therefore, this article conducts evaluation research on the quality of cross-border logistics services for international multimodal transportation. The service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is a MAGDM problem. Recently, the LogTODIM and GRA technique has been employed to manage MAGDM issues. The INSs are employed as a tool for portraying uncertain decision information during the service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain. In this paper, the INN-LogTODIM-GRA technique is constructed to come up with the MAGDM under INSs. Finally, a numerical example study for service quality evaluation of international logistics enterprises from the perspective of CBEC supply chain is employed to validate the proposed technique.

Although this article has conducted research on the evaluation of international logistics service capacity in the CBEC environment, analyzed the influencing factors of international logistics service quality in the CBEC environment, established an evaluation index system, and used fuzzy technique to portray the comprehensive evaluation model. Combined with examples for evaluation and analysis, targeted countermeasures and suggestions have been proposed for the evaluation results, which has certain practical significance. However, due to its limited research level and ability, there are still many shortcomings in this article, and the content that needs further improvement and improvement mainly includes the following aspects: (1) This article focuses on the evaluation of international logistics service quality in the CBEC environment, focusing on the international logistics service quality in the CBEC environment, and using ordinary product characteristics as a representative for analysis and evaluation. Therefore, the universality of this study is insufficient. Because international logistics services adapt to many environments, and some international logistics service products are special commodities, there are corresponding evaluation requirements, such as the "the Belt and Road" environment, fresh cross-border products, etc. Subsequent research can also evaluate the quality of international logistics services from other perspectives. (2) In the selection of international logistics service quality evaluation index system in the context of CBEC, although the evaluation index system used in this article is proposed based on a review of relevant theories and literature, it is somewhat convincing, but there are also imperfect situations. In further research, the evaluation index system should be continuously revised and improved based on the actual situation. (3) The evaluation index system for international logistics service quality in the CBEC environment studied in this article was obtained through screening based on expert questionnaire surveys. The data obtained from the survey has certain limitations and subjectivity, and the rationality of the questionnaire design has not been pre investigated through quantitative analysis. Further research is needed to improve it.

REFERENCES

[1] G. Troiano, L. Nibali, H. Petsos, P. Eickholz, M. H. A. Saleh, P. Santamaria, J. Jian, S. Shi, H. Meng, K. Zhurakivska, H. Wang, and A. Ravidà, "Development and international validation of logistic regression and machine-learning models for the prediction of 10-year molar loss," *J. Clin. Periodontol.*, vol. 50, no. 3, pp. 348–357, Mar. 2023.

[2] W. Wang and Q. Wu, "Research on the coordinated development of coastal port logistics and international trade: Based on six coastal provinces of China," *Sustainability*, vol. 15, no. 1, p. 121, Dec. 2022.

[3] Y. Zhao, S. Wang, X. Liu, and X. Tang, "Effect of the logistics industry on the promotion of China's position in the global value chain: An international trade perspective," *Int. Rev. Econ. Finance*, vol. 86, pp. 834–847, Jul. 2023.

[4] J. Kaswengi and C. Lambey-Checchin, "How logistics service quality and product quality matter in the retailer–customer relationship of food drive-throughs: The role of perceived convenience," *Int. J. Phys. Distrib. Logistics Manage.*, vol. 50, no. 5, pp. 535–555, Dec. 2019.

[5] I. Meidutė-Kavaliauskienė, V. Vasilienė-Vasiliauskienė, and A. V. Vasiliauskas, "Identification of sectoral logistics service quality gaps by applying servqual method," *Transport*, vol. 35, no. 4, pp. 419–434, Nov. 2020.

[6] M. F. Sorkun, I. Ö. Y. Hüseyinoğlu, and G. Börühan, "Omni-channel capability and customer satisfaction: Mediating roles of flexibility and operational logistics service quality," *Int. J. Retail Distrib. Manage.*, vol. 48, no. 6, pp. 629–648, Apr. 2020.

[7] T. Thanawatchaikul and T. Supeekit, "Causal relationship study among total quality management criteria for logistics service provider business excellence," in *Proc. IEEE 7th Int. Conf. Ind. Eng. Appl. (ICIEA)*, Apr. 2020, pp. 525–532.

[8] J. Xie and C. Chen, "Supply chain and logistics optimization management for international trading enterprises using IoT-based economic logistics model," *Oper. Manage. Res.*, vol. 15, nos. 3–4, pp. 711–724, Dec. 2022.

[9] B.-R. Yan, Q.-L. Dong, Q. Li, and M. Li, "A study on risk measurement of logistics in international trade: A case study of the RCEP countries," *Sustainability*, vol. 14, no. 5, p. 2640, Feb. 2022.

[10] X. Zhang, C. Liu, and Y. Peng, "Accessibility-based location of international multimodal logistics hubs: A case in China," *Transp. Res. Rec., J. Transp. Res. Board*, vol. 2676, no. 12, pp. 564–585, Dec. 2022.

[11] Y. Shen, J. Liu, and W. Tian, "Interaction between international trade and logistics carbon emissions," *Energy Rep.*, vol. 8, pp. 10334–10345, Nov. 2022.

[12] M.-J. Song and H.-Y. Lee, "The relationship between international trade and logistics performance: A focus on the South Korean industrial sector," *Res. Transp. Bus. Manage.*, vol. 44, Sep. 2022, Art. no. 100786.

[13] Y. Wang, "Optimal design of international trade logistics based on Internet of Things technology," *Comput. Intell. Neurosci.*, vol. 2022, pp. 1–11, Apr. 2022.

[14] I. Dovbischuk, "Sustainability in logistics service quality: Evidence from Agri-food supply chain in Ukraine," *Sustainability*, vol. 15, no. 4, p. 3534, Feb. 2023.

[15] C. Liu, J. Lv, P. Hou, and D. Lu, "Disclosing products' freshness level as a non-contractible quality: Optimal logistics service contracts in the fresh products supply chain," *Eur. J. Oper. Res.*, vol. 307, no. 3, pp. 1085–1102, Jun. 2023.

[16] Y. M. Tang, K. Y. Chau, W. T. Kuo, and X. X. Liu, "IoT-based information system on cold-chain logistics service quality (ICCLSQ) management in logistics 4.0," *Inf. Syst. Frontiers*, to be published. [Online]. Available: https://doi.org/10.1007/s10796-023-10393-7

[17] W. J. Xuan and M. Deng, "Logistics service quality sentiment analysis with deeper attention LSTM model with aspect embedding," *Tehnicki Vjesnik-Tech. Gazette*, vol. 30, pp. 634–641, Feb. 2023.

[18] Y. Zhang, X. Chen, L. Gao, Y. Dong, and W. Pedryczc, "Consensus reaching with trust evolution in social network group decision making," *Expert Syst. Appl.*, vol. 188, Feb. 2022, Art. no. 116022.

[19] B. Zheng, H. Wang, A.-M. Golmohammadi, and A. Goli, "Impacts of logistics service quality and energy service of business to consumer (B2C) online retailing on customer loyalty in a circular economy," *Sustain. Energy Technol. Assessments*, vol. 52, Aug. 2022, Art. no. 102333.

[20] A. Dabees, M. Barakat, S. S. Elbarky, and A. Lisec, "A framework for adopting a sustainable reverse logistics service quality for reverse logistics service providers: A systematic literature review," *Sustainability*, vol. 15, no. 3, p. 1755, Jan. 2023.

[21] M. Ma, L. Shen, and X. Sun, "Optimization of e-commerce logistics service quality considering multiple consumption psychologies," *Frontiers Psychol.*, vol. 13, p. 12, Sep. 2022.

[22] K.-Y. Oh, S.-Y. Kang, and Y.-G. Oh, "The moderating effects of eco-friendliness between logistics service quality and customer satisfaction in cross-border e-commerce: Evidence from overseas direct purchasers in Korea," *Sustainability*, vol. 14, no. 22, p. 15084, Nov. 2022.

[23] P.-J. Wu, L.-T. Lin, and C.-C. Huang, ''Diagnosing the service quality of perishable-food logistics: Temperature-sensitive milk delivery,'' *Asia Pacific J. Marketing Logistics*, vol. 34, no. 9, pp. 1943–1955, Sep. 2022.
[24] S. Yang, ''Construction of rural E-commerce logistics service quality evaluation system and IoT applications under the background of new retail,'' *Wireless Commun. Mobile Comput.*, vol. 2022, pp. 1–11, Oct. 2022.
[25] Y. Ju, H. Hou, and J. Yang, ''Integration quality, value co-creation and resilience in logistics service supply chains: Moderating role of digital technology,'' *Ind. Manage. Data Syst.*, vol. 121, no. 2, pp. 364–380, Dec. 2020.
[26] A. Gupta, R. K. Singh, and S. K. Mangla, ''Evaluation of logistics providers for sustainable service quality: Analytics based decision making framework,'' *Ann. Oper. Res.*, vol. 315, no. 2, pp. 1617–1664, Aug. 2022.
[27] A. Gupta, R. K. Singh, K. Mathiyazhagan, P. K. Suri, and Y. K. Dwivedi, ''Exploring relationships between service quality dimensions and customers satisfaction: Empirical study in context to Indian logistics service providers,'' *Int. J. Logistics Manage.*, to be published. [Online]. Available: https://doi.org/10.1108/IJLM-02-2022-0084
[28] K.-C. Hu, K.-C. Chia, M. Lu, and Y.-L. Liang, ''Using importance–performance analysis, goal difficulty and the Kano model to prioritize improvements in the quality of home delivery logistics services,'' *Int. J. Logistics Manage.*, vol. 33, no. 2, pp. 477–498, Apr. 2022.
[29] R. Mallick, S. Pramanik, and B. C. Giri, ''Neutrosophic MAGDM based on critic-EDAS strategy using geometric aggregation operator,'' *Yugoslav J. Oper. Res.*, 2023, doi: 10.2298/YJOR221017016M.
[30] C. Poliziani, F. Rupi, J. Schweizer, M. N. Postorino, and S. Nocera, ''Modeling cyclist behavior using entropy and GPS data,'' *Int. J. Sustain. Transp.*, vol. 17, no. 6, pp. 639–648, Jun. 2023.
[31] S. Pramanik, S. Das, R. Das, and B. C. Tripathy, ''Neutrosophic BWM-TOPSIS strategy under SVNS environment,'' *Neutrosophic Sets Syst.*, vol. 56, no. 1, pp. 178–189, 2023.
[32] G. Wan, Y. Rong, and H. Garg, ''An efficient spherical fuzzy MEREC-CoCoSo approach based on novel score function and aggregation operators for group decision making,'' *Granular Comput.*, vol. 8, pp. 1481–1503, 2023.
[33] D. García-Zamora, B. Dutta, S. Massanet, J. V. Riera, and L. Martínez, ''Relationship between the distance consensus and the consensus degree in comprehensive minimum cost consensus models: A polytope-based analysis,'' *Eur. J. Oper. Res.*, vol. 306, no. 2, pp. 764–776, Apr. 2023.
[34] H. Garg, K. Ullah, K. Ali, M. Akram, and M. N. Abid, ''Multi-attribute decision-making based on sine trigonometric aggregation operators for T-spherical fuzzy information,'' *Soft Comput.*, 2023, doi: 10.1007/s00500-00023-08899-y.
[35] S. J. Ghoushchi, H. Garg, S. R. Bonab, and A. Rahimi, ''An integrated SWARA-CODAS decision-making algorithm with spherical fuzzy information for clean energy barriers evaluation,'' *Expert Syst. Appl.*, vol. 223, Aug. 2023, Art. no. 119884.
[36] R. Mallick and S. Pramanik, ''TrNN-EDAS strategy for MADM with entropy weight under trapezoidal neutrosophic number environment,'' in *Neutrosophic Operational Research: Methods and Applications*, F. Smarandache and M. Abdel-Basset, Eds. Cham, Switzerland: Springer, 2021, pp. 575–592.
[37] X.-H. Pan, Y.-M. Wang, and S.-F. He, ''A new regret theory-based risk decision-making method for renewable energy investment under uncertain environment,'' *Comput. Ind. Eng.*, vol. 170, Aug. 2022, Art. no. 108319.
[38] J. Ali and H. Garg, ''On spherical fuzzy distance measure and TAOV method for decision-making problems with incomplete weight information,'' *Eng. Appl. Artif. Intell.*, vol. 119, Mar. 2023, Art. no. 105726.
[39] S. Pramanik, P. P. Dey, B. C. Giri, and F. Smarandache, ''An extended TOPSIS for multi-attribute decision making problems with neutrosophic cubic information,'' *Neutrosophic Sets Syst.*, vol. 17, pp. 20–28, Jan. 2017.
[40] P. Biswas, S. Pramanik, and B. C. Giri, ''TOPSIS strategy for multi-attribute decision making with trapezoidal neutrosophic numbers,'' *Neutrosophic Sets Syst.*, vol. 19, pp. 29–39, Apr. 2018.
[41] R.-X. Liang, S.-S. He, J.-Q. Wang, K. Chen, and L. Li, ''An extended MABAC method for multi-criteria group decision-making problems based on correlative inputs of intuitionistic fuzzy information,'' *Comput. Appl. Math.*, vol. 38, no. 3, p. 112, Sep. 2019.
[42] R. Wang and X. Rong, ''Extended group decision making method for quality evaluation of mental health education of college students with hesitant triangular fuzzy information,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 2, pp. 2835–2845, Aug. 2023.
[43] X. Zhang, ''Research on core competitiveness evaluation of small and medium sized enterprises with hesitant triangular fuzzy multiple attribute decision making,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 2, pp. 3321–3331, Aug. 2023.
[44] Y. Zhang, ''Research on the teaching quality evaluation of painting majors in universities based on the 2-tuple linguistic Pythagorean fuzzy sets,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 4, pp. 5671–5683, Oct. 2023, doi: 10.3233/jifs-232226.
[45] K. Du and Y. Du, ''Research on performance evaluation of intangible assets operation and management in sports events with double-valued neutrosophic sets,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 2, pp. 2813–2822, Aug. 2023.
[46] Y. Han and X. Xu, ''TODIM-VIKOR method for performance evaluation of school-enterprise cooperation in vocational colleges under 2-tuple linguistic Pythagorean fuzzy sets,'' *J. Intell. Fuzzy Syst.*, vol. 45, pp. 2826–2834, Jan. 2023.
[47] Y. Li, ''Study on fuzzy comprehensive competitiveness evaluation of urban exhibition industry with hesitant fuzzy information,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 1, pp. 1313–1323, Jul. 2023.
[48] B. Mao, T. Feng, H. Su, and X. Ma, ''A novel approach to employment quality evaluation of college graduates with probabilistic linguistic MAGDM,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 3, pp. 3875–3886, Aug. 2023.
[49] J. Wang, ''Extended TODIM method based on VIKOR for quality evaluation of higher education scientific research management under interval-valued Pythagorean fuzzy sets,'' *J. Intell. Fuzzy Syst.*, vol. 45, no. 4, pp. 5277–5289, Oct. 2023, doi: 10.3233/jifs-232621.
[50] Z. Turskis, S. Dzitac, A. Stankiuviene, and R. Šukys, ''A fuzzy group decision-making model for determining the most influential persons in the sustainable prevention of accidents in the construction SMEs,'' *Int. J. Comput. Commun. Control*, vol. 14, no. 1, pp. 90–106, Feb. 2019.
[51] K. Ullah, N. Hassan, T. Mahmood, N. Jan, and M. Hassan, ''Evaluation of investment policy based on multi-attribute decision-making using interval valued T-spherical fuzzy aggregation operators,'' *Symmetry*, vol. 11, no. 3, p. 357, Mar. 2019.
[52] S. Zeng, X. Peng, T. Baležentis, and D. Streimikiene, ''Prioritization of low-carbon suppliers based on Pythagorean fuzzy group decision making with self-confidence level,'' *Econ. Res.-Ekonomska Istraživanja*, vol. 32, no. 1, pp. 1073–1087, Jan. 2019.
[53] J. Giráldez-Cru, M. Chica, O. Cordón, and F. Herrera, ''Modeling agent-based consumers decision-making with 2-tuple fuzzy linguistic perceptions,'' *Int. J. Intell. Syst.*, vol. 35, no. 2, pp. 283–299, Feb. 2020.
[54] M. Jahangiri, H. Molaeifar, F. Rajabi, and S. Banaee, ''Occupational stressors among farmers in Iran using fuzzy multiple criteria decision-making methods,'' *J. Agromed.*, vol. 25, no. 1, pp. 28–37, Jan. 2020.
[55] K. Rahman, S. Abdullah, A. Ali, and F. Amin, ''Approaches to multi-attribute group decision making based on induced interval-valued Pythagorean fuzzy Einstein hybrid aggregation operators,'' *Bull. Brazilian Math. Soc., New Ser.*, vol. 50, no. 4, pp. 845–869, Dec. 2019.
[56] M. Shakeel, S. Abduulah, M. Shahzad, T. Mahmood, and N. Siddiqui, ''Averaging aggregation operators with Pythagorean trapezoidal fuzzy numbers and their application to group decision making,'' *J. Intell. Fuzzy Syst.*, vol. 36, no. 2, pp. 1899–1915, Mar. 2019.
[57] Shumaiza, M. Akram, A. N. Al-Kenani, and J. C. R. Alcantud, ''Group decision-making based on the VIKOR method with trapezoidal bipolar fuzzy information,'' *Symmetry*, vol. 11, no. 10, p. 1313, Oct. 2019.
[58] M. S. Sindhu, T. Rashid, A. Kashif, and J. L. G. Guirao, ''Multiple criteria decision making based on probabilistic interval-valued hesitant fuzzy sets by using LP methodology,'' *Discrete Dyn. Nature Soc.*, vol. 2019, pp. 1–12, Apr. 2019.
[59] O. Sohaib, M. Naderpour, W. Hussain, and L. Martinez, ''Cloud computing model selection for e-commerce enterprises using a new 2-tuple fuzzy linguistic decision-making method,'' *Comput. Ind. Eng.*, vol. 132, pp. 47–58, Jun. 2019.
[60] N. Alkan and C. Kahraman, ''Circular intuitionistic fuzzy TOPSIS method: Pandemic hospital location selection,'' *J. Intell. Fuzzy Syst.*, vol. 42, no. 1, pp. 295–316, Dec. 2021.
[61] E. Çakir, Z. Ulukan, C. Kahraman, C. Ö. Sağlam, B. K. Pak, and B. Pekcan, ''Intuitionistic fuzzy multi-objective milk-run modelling under time window constraints,'' *J. Intell. Fuzzy Syst.*, vol. 42, no. 1, pp. 47–62, Dec. 2021.
[62] C. Kahraman, S. C. Onar, and B. Öztayşi, ''A novel spherical fuzzy CRITIC method and its application to prioritization of supplier selection criteria,'' *J. Intell. Fuzzy Syst.*, vol. 42, no. 1, pp. 29–36, Dec. 2021.

[63] S. Ç. Onar, C. Kahraman, and B. Öztayşi, "A new hesitant fuzzy KEMIRA approach: An application to adoption of autonomous vehicles," *J. Intell. Fuzzy Syst.*, vol. 42, no. 1, pp. 109–120, Dec. 2021.

[64] L. Gomes and M. Lima, "TODIM: Basics and apllication to multicriteria ranking of projects with environmental impacts," *Found. Control Eng.*, vol. 16, pp. 113–127, Jan. 1991.

[65] S. Pramanik and R. Mallick, "TODIM strategy for multi-attribute group decision making in trapezoidal neutrosophic number environment," *Complex Intell. Syst.*, vol. 5, no. 4, pp. 379–389, Dec. 2019.

[66] S. Pramanik, S. Dalapati, S. Alam, and T. Roy, "NC-TODIM-based MAGDM under a neutrosophic cubic set environment," *Information*, vol. 8, no. 4, p. 149, Nov. 2017.

[67] A. B. Leoneti and L. F. A. M. Gomes, "A novel version of the TODIM method based on the exponential model of prospect theory: The Exp-TODIM method," *Eur. J. Oper. Res.*, vol. 295, no. 3, pp. 1042–1055, Dec. 2021.

[68] J. Deng, "Introduction to grey system theory," *J. Grey Syst.*, vol. 1, pp. 1–24, Jan. 1989.

[69] G. Wei, "New method of grey relational analysis to multiple attribute decision making with intervals," *Syst. Eng. Electron.*, vol. 28, pp. 1358–1359, Sep. 2006.

[70] J. Zhang, D. Wu, and D. L. Olson, "The method of grey related analysis to multiple attribute decision making problems with interval numbers," *Math. Comput. Model.*, vol. 42, nos. 9–10, pp. 991–998, Nov. 2005.

[71] S. Pramanik and K. Mondal, "Interval neutrosophic multi-attribute decision-making based on grey relational analysis," *Neutrosophic Sets Syst.*, vol. 9, pp. 13–22, Jan. 2015.

[72] H. Wang, F. Smarandache, Y. Q. Zhang, and R. Sunderraman, *Interval Neutrosophic Sets and Logic: Theory and Applications in Computing*. Phoenix, AZ, USA: Hexis, 2005.

[73] H. Wang, F. Smarandache, Y. Q. Zhang, and R. Sunderraman, "Single valued neutrosophic sets," *Multispace Multistruct*, to be published.

[74] J.-J. Peng, J.-Q. Wang, J. Wang, H.-Y. Zhang, and X.-H. Chen, "Simplified neutrosophic sets and their applications in multi-criteria group decision-making problems," *Int. J. Syst. Sci.*, vol. 47, no. 10, pp. 2342–2358, 2016.

[75] Y.-H. Huang, G.-W. Wei, and C. Wei, "VIKOR method for interval neutrosophic multiple attribute group decision-making," *Information*, vol. 8, no. 4, p. 144, Nov. 2017.

[76] H.-Y. Zhang, J.-Q. Wang, and X.-H. Chen, "Interval neutrosophic sets and their application in multicriteria decision making problems," *Sci. World J.*, vol. 2014, pp. 1–15, Feb. 2014.

[77] J. Ye, "Similarity measures between interval neutrosophic sets and their applications in multicriteria decision-making," *J. Intell. Fuzzy Syst.*, vol. 26, no. 1, pp. 165–172, 2014.

[78] C. E. Shannon, "A mathematical theory of communication," *Bell Syst. Tech. J.*, vol. 27, no. 3, pp. 379–423, Jul. 1948.

[79] A. Karasan and C. Kahraman, "A novel interval-valued neutrosophic EDAS method: Prioritization of the united nations national sustainable development goals," *Soft Comput.*, vol. 22, no. 15, pp. 4891–4906, Aug. 2018.

[80] F. Li, "Research and evaluation on comprehensive obstacle-avoiding behavior for unmanned vehicles based on the interval neutrosophic number multiple attribute group decision making," *J. Intell. Fuzzy Syst.*, vol. 44, no. 6, pp. 10721–10732, Jun. 2023.

[81] R. Bausys and E. K. Zavadskas, "Multicriteria decision making approach by VIKOR under interval neutrosophic set environment," *Econ. Comput. Econ. Cybern. Stud. Res.*, vol. 49, pp. 33–48, Oct. 2015.

[82] E. Bolturk and A. Karasan, "Interval valued neutrosophic CODAS method for renewable energy selection," in *Proc. Data Sci. Knowl. Eng. Sens. Decis. Support*, Sep. 2018, pp. 1026–1033.

[83] Y. Lei, "A decision support method for designing the blended teaching effectiveness evaluation of english courses in universities based on interval-valued neutrosophic information," *J. Intell. Fuzzy Syst.*, vol. 45, no. 2, pp. 3267–3277, Aug. 2023.

[84] Y. Hong, D. Xu, K. Xiang, H. Qiao, X. Cui, and H. Xian, "Multi-attribute decision-making based on preference perspective with interval neutrosophic sets in venture capital," *Mathematics*, vol. 7, no. 3, p. 257, Mar. 2019.

[85] L. Peng and D. Xu, "A multi-criteria decision-making with regret theory-based MULTIMOORA method under interval neutrosophic environment," *J. Intell. Fuzzy Syst.*, vol. 44, no. 3, pp. 4059–4077, Mar. 2023.

[86] H. Chen, Z. Su, and X. Xu, "A generalized integrated group decision-making framework for computer network security evaluation with interval neutrosophic information," *J. Intell. Fuzzy Syst.*, vol. 45, no. 5, pp. 8945–8957, Nov. 2023, doi: 10.3233/jifs-233181.

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