Complex Interval-Valued q-Rung Orthopair 2-Tuple Linguistic Aggregation Operators and Their Application in Multi-Attribute Decision-Making

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ABSTRACT
This study aims to study the conception of the complex interval-valued q-rung orthopair 2-tuple linguistic set (CIVQRO2-TLS), which is a new powerful mixture to handle unreliable and vague data in realistic decision concerns. We also explore its fundamental properties as well as important laws. In the occurrence of the above theory, we discover some useful aggregation methods for the CIVQRO2-TLS, including the CIVQRO2-TLWA, CIVQRO2-TLOWA, CIVQRO2-TLHA, CIVQRO2-TLWG, CIVQRO2-TLWG, and CIVQRO2-TLHG operators. To demonstrate the beneficial features of the invented works, a multi-attribute decision-making (MADM) system is presented and exposed to the supremacy of the presented operators with the help of several examples. In last, we elaborate on the advantages, comparative analysis, and graphical interpretation of the invented approaches.

Introduction
The main theme of MADM is to select the outstanding opportunity in excellence to the limited objects in the presence of the many criteria. In our genuine life, we continuously grapple with distinct sorts of decision-making strategies wherein our focus is to investigate how to make an accurate decision. Roughly, the strategy of decision-making takes imprecision in the data without determining the vagueness and inconsistent in it. To describe the ambiguity in the data, the main concept of IFS (Atanassov 1986), a revised version of the FS (Zadeh 1965), incorporates the two sorts of terms, called the truth grade (TG) \( \mu_{Z_{CQ}}(x) \) and falsity grade (FG) \( \eta_{Z_{CQ}}(x) \), then the prominent tool of IFS is of the mathematical shape: \( \eta_{Z_{CQ}}(x) \). Thus, IFS has easily evaluated complicated and incorporated data that occurred in genuine life troubles. The IVIFS invented by Atanassov and Gargov (1989) is also of the most important mathematical...
structure of the FS, but the resultant values of the IVIFS are in the shape of interval whose both bounds lie within the unit interval. Lots of well-known scholars have done work on IFS and IVIFS in distinct directions (Bouchet et al. 2020; Garg and Kumar 2019, 2020; Kumar and Garg 2018; Zeng, Ali, and Mahmood 2021; Zeng et al. 2022c; Zhang et al. 2021) in recent years. In many dilemmas, the function of IFS can’t be working perfectly, for instance, an expert from some enterprises given the pair of data $(0.7, 0.4)$, for TG and FG, it is clear that $(0.7, 0.4)$. After continuing a lot of hardworking to find the solution for the above trouble, Yager (2013) investigated the PFS, by improving the representation range of IFS that: $0 \leq \mu_{Z_{CQ}}(x) + \eta_{Z_{CQ}}(x) \leq 1$. Later, the IVPFS is discussed by Garg (2017) by considering the interval situation. At present, a lot of individuals employed the conceptions of PFS and IVPFS in disparate specialties and areas (Ejegwa, Onyeka, and Adah 2021; Haktanır and Kahraman 2019; Liang, Darko, and Xu 2018; Peng and Li 2019; Sajjad Ali Khan et al. 2018; Zeng et al. 2022b). Moreover, Yager (2016) deliberated the QROFS with $0 \leq \mu_{Z_{CQ}}(x) + \eta_{Z_{CQ}}(x) \leq 1$. The parameter $q_{SC}$ used in the tool of QROFS, can help to generalize the representation range of IFS and PFS. Until now, the QROFS and its discrete structures, the IVQROFS (Joshi et al. 2018), have gained a lot of attention from researchers in various problems of chemistry, transportation engineering, biology, sociology, electrical engineering, economics, etc. (Garg and Chen 2020; Hussain, Ali, and Mahmood 2019; Liu and Liu 2018; Liu and Wang 2018).

To generalize the unit disc of FSs to unit interval situation, a lot of researchers have worked new extensions and suggested several new fuzzy tools by generalizing the unit disc in the range of FSs. Invented by Alkouri and Salleh (2012), the CIFS, a modified structure of the CFS (Ramot et al. 2002), depends on two terms in the shape of TG $\mu_{Z_{CQ}} = \mu_{Z_{\text{ref}}} e^{i2\pi(\mu_{Z_{\text{ref}}})}$ and FG $\mu_{Z_{CQ}} = \mu_{Z_{\text{ref}}} e^{i2\pi(\mu_{Z_{\text{ref}}})}$, then the prominent tool of CIFS is of the shape: $0 \leq \mu_{Z_{CQ}}(x) + \eta_{Z_{CQ}}(x) \leq 1$ and $0 \leq \mu_{Z_{CQ}}(x) + \eta_{Z_{CQ}}(x) \leq 1$. Some important and beneficial implementations of CIFS and CIVIFS are then studied in diverse disciplines (Akram and Naz 2019; Garg and Rani 2019; Rani and Garg 2017). Moreover, Ullah et al. (2020a) expanded the conception of CIFS to invent the CPFS with $0 \leq \mu_{Z_{\text{ref}}}^2(x) + \eta_{Z_{\text{ref}}}^2(x) \leq 1$ and $0 \leq \mu_{Z_{\text{ref}}}^2(x) + \eta_{Z_{\text{ref}}}^2(x) \leq 1$. In many dilemmas, the tool of CPFS can’t be working perfectly, for instance, an expert from some enterprises given the pair of data $(0.9 e^{i2\pi(0.8)}, 0.8 e^{i2\pi(0.7)})$, for TG and FG, it is clear that $0.9^2 + 0.8^2 = 0.81 + 0.64 = 1.45 > 1$, and $0.9^2 + 0.8^2 = 0.81 + 0.64 = 1.45 > 1$. To settle this Liu, Ali, and
Mahmood (2019, 2020) diagnosed the novel and well-known theory of CQROFS with a new strategy \(0 \leq \mu_{Z_{aip}}^q(x) + \eta_{Z_{aip}}^q(x) \leq 1\) and \(0 \leq \mu_{Z_{aip}}(x) + \eta_{Z_{aip}}(x) \leq 1\). Furthermore, Garg, Ali, and Mahmood (2020b) developed the CIVQROFS on the basis of the presence of the above-invented works, whose construct composes the grade of truth and falsity, with the real part and imaginary part in the form of a subset of the unit interval. So far, several researchers have contributed the development of CIVQROFS in the region of diverse disciplines (Ali and Mahmood 2020b; Garg et al. 2020a).

To depict the ambiguity and awkward data in genuine life procedures, the 2-tuple linguistic (2-TL) is introduced by Herrera and Martinez (2001). 2-TL theory plays a beneficial role in the environment of fuzzy sets theory and due to its beneficial worth, a lot of individuals made contributions in the development of 2-TL theory. For instance, Herrera and Martinez (2000) combined the FS with 2-TL, introduced the conception of fuzzy 2-TLS. Beg and Rashid (2016), Liu and Chen (2018) put forth the intuitionistic 2-TL set by taking the advantages of IFS. Faizi, Rashid, and Zafar (2018), (2020) invented some useful aggregation operators for intuitionistic 2-TLS. Wei et al. (2017) elaborated the Pythagorean 2-TLS and explored its application. He et al. (2019) exposed the Taxonomy method for Pythagorean 2-TLS. Ju et al. (2020) diagnosed the q-rung orthopair 2-TLS. Finally, the interval-valued q-rung orthopair 2-TLS deliberated explored by Wang, Garg, and Li (2019).

Our perspective behind the introduction to CIVQRO2-TLS is given below:

1. CIVQROFS is a perfect blend of QROFS and CPFS. It assigns interval grades to the elements, which posses parametric characterization. However, it isn’t utilized to portray qualitative expression with 2-TLS, which is more convenient for decision makers to express their subjective preferences during decision (Herrera and Martinez 2000). In order to combine the both properties of the above discussed models and to handle the existing drawbacks, we shall put forward the CIVQRO2-TLS.

2. The 2-TLS has been explored so far in kinds of extensions of fuzzy set theory. However, it is no discussion over the degrees of interval-valued truth grade and the interval-valued grade of falsity in the literature. This motivated us to initiate the mathematical mixture of CIVQRO2 and 2-TLS.

Keeping all these facts in our mind, the main contributions of this study to the current literature deliberated in the following way:
(1) To present the conception of the CIVQRO2-TLS and its fundamental laws.
(2) To discover the conceptions of CIVQRO2-TLWA, CIVQRO2-TLOWA, CIVQRO2-TLHA, CIVQRO2-TLWG, CIVQRO2-TLOWG, CIVQRO2-TLHG operators and diagnose their important properties.
(3) A MADM system is developed based on the proposed operators, and its application is carried out in the CIVQRO2-TL situation with the help of several examples.
(4) To elaborate on the advantages, comparative analysis, and graphical interpretation of the invented approaches are presented.

The rest contents of this manuscript are deliberated in the following manner: Section 2 reviews some related fundamental theories of CQROFS, CIVQROFS, and 2-TLS. Section 3 discusses the conception of the CIVQRO2-TLS and its important operational laws. In section 4, we discover the thought of CIVQRO2-TLWA, CIVQRO2-TLOWA, CIVQRO2-TLHA, CIVQRO2-TLWG, CIVQRO2-TLOWG, CIVQRO2-TLHG and diagnosed their fundamental properties. In section 5, we demonstrate the beneficial features of the invented works, a MADM system is then presented, and its supremacy of the diagnosed operators is discussed with the help of several examples. In last, we elaborate on the advantages, comparative analysis, and graphical interpretation of the invented approaches. The conclusion of this scenario is described in section 6.

Preliminaries

Firstly, some mathematical terms used in the current studies are deliberated in Table 1.

Using the above terminologies, we reviews several basic theories.

| Symbols | Meanings | Symbols | Meanings |
|---------|----------|---------|----------|
| $q_{CQ}, Y_{CQ} \geq 1$ | Positive integers | $X_{UW}$ | Universal set |
| $\mu_{Z_{CQ}}(x)$ | Complex-valued truth grade | $\eta_{Z_{CQ}}(x)$ | Falsity grade |
| $\mu_{Z_{CQ}} e^{2\pi i (\eta_{Z_{CQ}})}$ | Complex-valued falsity grade |
| $\mu_{Z_{CQ}}$ | A real part of truth grade | $\mu_{Z_{CQ}}$ | A real part of falsity grade |
| $\mu_{Z_{CQ}}$ | The imaginary part of truth grade | $\eta_{Z_{CQ}}$ | The imaginary part of falsity grade |
| $Z_{CQ}$ | Complex q-rung orthopair fuzzy sets | $\Psi_{Sf}$ | Score function |
| $\Psi_{Sf}$ | Accuracy function | $Z_{CIVT}$ | Complex interval-valued q-rung orthopair fuzzy 2-tuple linguistic sets |
| $\hat{s}_{SL}$ | Linguistic term | $\hat{s}_{SL}, a_{SL}$ | 2-tuple linguistic set |
| $x$ | Element of the universal set | $\omega_{W}$ | Weight vector |
Definition 1 (Liu, Ali, and Mahmood 2019). In the consideration of the universal set $X_{UNI}$, a CQROFS $X_{UNI}$ is deliberated by:

$$Z_{CQ} = \left\{ \left( \mu_{Z_{CQ}}(x), \eta_{Z_{CQ}}(x) \right) : x \in X_{UNI} \right\}$$

The complex mathematical form of TG and TG is stated: $\mu_{Z_{CQ}} = \mu_{Z_{RP}} e^{i2\pi(\mu_{Z_{IP}})}$ and $\mu_{Z_{CQ}} = \mu_{Z_{RP}} e^{i2\pi(\mu_{Z_{IP}})}$, with $0 \leq \mu_{Z_{RP}} + \eta_{Z_{RP}}(x) \leq 1$ and $0 \leq \mu_{Z_{RP}}(x) + \eta_{Z_{RP}}(x) \leq 1$. Additionally, the mathematical shape of refusal grade is stated: $\pi_{Z_{CQ}} = \left( 1 - \left( \mu_{Z_{RP}} + \eta_{Z_{RP}}(x) \right) \right)^{i2\pi} \left( 1 - \left( \mu_{Z_{IRP}} + \eta_{Z_{IRP}}(x) \right) \right)^{i2\pi} \frac{1}{\pi SC} \frac{\pi SC}{\pi SC}$. The mathematical term of CQROFNs is of the shape: $Z_{CQ} = \left( \mu_{Z_{RP}} e^{i2\pi(\mu_{Z_{IP}})} , \eta_{Z_{RP}} e^{i2\pi(\eta_{Z_{IP}})} \right)$.

Definition 2 (Garg, Ali, and Mahmood 2020b). In the consideration of the universal set $X_{UNI}$, a CIVQROFS $CIVQ$ is deliberated by:

$$Z_{CIVQ} = \left\{ \left( \mu_{Z_{CIVQ}}(x), \eta_{Z_{CIVQ}}(x) \right) : x \in X_{UNI} \right\}$$

The complex mathematical form of interval-valued TG and interval-valued TG is stated: $\mu_{Z_{CIVQ}} = [\mu_{Z_{RP}}, \mu_{Z_{RP}}]^i2\pi [\mu_{Z_{IP}}, \mu_{Z_{IP}}]$ and $\mu_{Z_{CIVQ}} = [\mu_{Z_{RP}}, \mu_{Z_{RP}}]^i2\pi [\mu_{Z_{IP}}, \mu_{Z_{IP}}]$, with $0 \leq \mu_{Z_{IP}} + \eta_{Z_{IP}}(x) \leq 1$ and $0 \leq \mu_{Z_{IP}}(x) + \eta_{Z_{IP}}(x) \leq 1$. Additionally, the mathematical shape of refusal grade is stated:

$$\pi_{Z_{CIVQ}} = \left[ \left( 1 - \left( \mu_{Z_{IP}} + \eta_{Z_{IP}} \right) \right)^{i2\pi} \left( 1 - \left( \mu_{Z_{IP}} + \eta_{Z_{IP}} \right) \right)^{i2\pi} \frac{1}{\pi SC} \frac{\pi SC}{\pi SC} \right]$$

Moreover, the mathematical term of CIVQROFNs is of the shape: $Z_{CIVQ} = \left[ \mu_{Z_{RP}}, \mu_{Z_{RP}}^+, \eta_{Z_{RP}}, \eta_{Z_{RP}}^+ \right] e^{i2\pi \left[ \mu_{Z_{IP}}, \mu_{Z_{IP}}^+ \right]} e^{i2\pi \left[ \eta_{Z_{IP}}, \eta_{Z_{IP}}^+ \right]}$. Moreover, for any two CIVQROFNs

$$Z_{CIVQ} = \left[ \mu_{Z_{RP}}, \mu_{Z_{RP}}^+ \right] e^{i2\pi \left[ \mu_{Z_{IP}}, \mu_{Z_{IP}}^+ \right]} e^{i2\pi \left[ \eta_{Z_{IP}}, \eta_{Z_{IP}}^+ \right]}$$

and

$$Z_{CIVQ-2} = \left[ \left[ \mu_{Z_{RP-2}}, \mu_{Z_{RP-2}}^+ \right] e^{i2\pi \left[ \mu_{Z_{IP-2}}, \mu_{Z_{IP-2}}^+ \right]} e^{i2\pi \left[ \eta_{Z_{IP-2}}, \eta_{Z_{IP-2}}^+ \right]} \right]$$
\[ Z_{CIVT-1} \oplus CIVT Z_{CIVT-2} = \]
\[ \left( \begin{array}{c}
\left[ \left( \mu - q_{Z_{AP-1}} + \mu - q_{Z_{AP-2}} - \mu - q_{Z_{AP-1}} \mu - q_{Z_{AP-2}} \right)^{\frac{1}{2}} \right] \mathcal{A} \pi 
\left[ \left( \mu + q_{Z_{AP-1}} + \mu + q_{Z_{AP-2}} - \mu + q_{Z_{AP-1}} \mu + q_{Z_{AP-2}} \right)^{\frac{1}{2}} \right]
\end{array} \right) \]
\[ \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \right] e^{\mathcal{A} \pi \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \right]} \]
\[ (3) \]

\[ Z_{CIVT-1} \oplus CIVT Z_{CIVT-2} = \]
\[ \left( \begin{array}{c}
\left[ \left( \eta^{-q_{Z_{AP-1}}} \eta^{-q_{Z_{AP-2}}} - \eta^{-q_{Z_{AP-1}}} \eta^{-q_{Z_{AP-2}}} \right)^{\frac{1}{2}} \right] \mathcal{A} \pi
\left[ \left( \eta^{+q_{Z_{AP-1}}} \eta^{+q_{Z_{AP-2}}} - \eta^{+q_{Z_{AP-1}}} \eta^{+q_{Z_{AP-2}}} \right)^{\frac{1}{2}} \right]
\end{array} \right) \]
\[ \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \right] e^{\mathcal{A} \pi \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \eta_{Z_{AP-1}} \eta_{Z_{AP-2}} \right]} \]
\[ (4) \]

\[ Y_{SC} Z_{CIVT-1} = \]
\[ \left( \begin{array}{c}
\left[ \left( 1 - (1 - \mu_{Z_{AP-1}} q_{SC}) \right)^{\frac{1}{2}} \right] \mathcal{A} \pi
\left[ \left( 1 - (1 - \mu_{Z_{AP-1}} q_{SC}) \right)^{\frac{1}{2}} \right]
\end{array} \right) \]
\[ \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \right] e^{\mathcal{A} \pi \left[ \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \eta_{Z_{AP-1}} \right]} \]
\[ (5) \]

\[ Z_{CIVT-1} Y_{SC} = \]
\[ \left( \begin{array}{c}
\left[ \left( 1 - (1 - \eta_{Z_{AP-1}} q_{SC}) \right)^{\frac{1}{2}} \right] \mathcal{A} \pi
\left[ \left( 1 - (1 - \eta_{Z_{AP-1}} q_{SC}) \right)^{\frac{1}{2}} \right]
\end{array} \right) \]
\[ \left[ \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \right] e^{\mathcal{A} \pi \left[ \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \mu_{Z_{AP-1}} \right]} \]
\[ (6) \]

The score function (SF) and accuracy function (AF) is stated by (Garg, Ali, and Mahmood 2020b):
\[ \Gamma_{SF}(Z_{CIVQ-1}) = \frac{1}{4} \left( \left( \mu_{Z_{RP-1}}^+ + \mu_{Z_{IP-1}}^+ - \eta_{Z_{RP-1}}^- \right) \eta_{Z_{IP-1}}^- - \left( \mu_{Z_{RP-1}}^- + \mu_{Z_{IP-1}}^- - \eta_{Z_{RP-1}}^+ \right) \eta_{Z_{IP-1}}^+ \right) \]  
\[ \Psi_{SF}(Z_{CIVQ-1}) = \frac{1}{4} \left( \left( \mu_{Z_{RP-1}}^+ + \mu_{Z_{IP-1}}^+ + \eta_{Z_{RP-1}}^- \right) \eta_{Z_{IP-1}}^- - \left( \mu_{Z_{RP-1}}^- + \mu_{Z_{IP-1}}^- + \eta_{Z_{RP-1}}^+ \right) \eta_{Z_{IP-1}}^+ \right) \]  

For CIVQROFNs \( Z_{CIVQ-1} \) and \( Z_{CIVQ-2} \), two techniques for comparison are dominated as (Garg, Ali, and Mahmood 2020b);

1. If \( \Gamma_{SF}(Z_{CIVQ-1}) > \Gamma_{SF}(Z_{CIVQ-2}) \), then \( \Gamma_{SF}(Z_{CIVQ-1}) > \Gamma_{SF}(Z_{CIVQ-2}) \);
   - If \( Z_{CIVQ-1} = Z_{CIVQ-2} \), then
   - If \( Z_{CIVQ-1} = Z_{CIVQ-2} \), then \( Z_{CIVQ-1} > Z_{CIVQ-2} \);

**CIVQROF2-TLS**

This study aims to present the conception of the CIVQRO2-TLS and its fundamental laws.

**Definition 3**: In the consideration of the universal set \( X_{UNI} \), a CIVQRO2-TLS \( X_{UNI} \) is deliberated by:

\[ Z_{CIVT} = \{ (\hat{s}_{SLT}, \alpha_{SC}), (\mu_{Z_{CIVQ}}(x), \eta_{Z_{CIVQ}}(x)) : x \in X_{UNI} \} \]  

The complex mathematical form of TG and TG is stated: \( \mu_{Z_{CIVQ}} = \left[ \mu_{Z_{RP}}^+, \mu_{Z_{RP}}^- \right] e^{i2\pi \left[ \mu_{Z_{RP}}^+ \mu_{Z_{RP}}^- \right]} \) and \( \eta_{Z_{CIVQ}} = \left[ \eta_{Z_{RP}}^+, \eta_{Z_{RP}}^- \right] e^{i2\pi \left[ \eta_{Z_{RP}}^+ \eta_{Z_{RP}}^- \right]} \), with \( 0 \leq \mu_{Z_{RP}}^+ + \eta_{Z_{RP}}^- \leq 1 \) and \( 0 \leq \mu_{Z_{RP}}^- + \eta_{Z_{RP}}^+ \leq 1 \), and \( (\hat{s}_{SLT}, \alpha_{SC}) \) is 2-TLS. Additionally, the mathematical shape of refusal grade is stated:

\[ \pi_{Z_{CIVQ}} = \left[ \left( \frac{1}{1 - \left( \mu_{Z_{RP}}^+ + \eta_{Z_{RP}}^- \right)} \right) \right]^{-\frac{1}{\eta_{Z_{RP}}^-}} \cdot e^{i2\pi \left[ \mu_{Z_{RP}}^+ \eta_{Z_{RP}}^- \right]} \]  

The mathematical term of CIVQRO2-TLN is of the shape:

\[ Z_{CIVT} = \left( \hat{s}_{SLT}, \alpha_{SC}, \right), \left[ \left[ \mu_{Z_{RP}}^+, \mu_{Z_{RP}}^- \right] e^{i2\pi \left[ \mu_{Z_{RP}}^+ \mu_{Z_{RP}}^- \right]} \right] \left[ \eta_{Z_{RP}}^+, \eta_{Z_{RP}}^- \right] e^{i2\pi \left[ \eta_{Z_{RP}}^+ \eta_{Z_{RP}}^- \right]} \right) \)
CIVQRO2-TLNs $Z_{CIVT} = \left( \tilde{s}_{S_{LT}}, \alpha_{SC} \right), \left( \mu_{Z_{RP}}, \mu_{Z_{RP}}^+ \right) e^{i2\pi \left[ \mu_{Z_{IP}}, \mu_{Z_{IP}}^+ \right]}, \left[ \eta_{Z_{RP}}, \eta_{Z_{RP}}^+ \right] e^{i2\pi \left[ \eta_{Z_{IP}}, \eta_{Z_{IP}}^+ \right]}$ and

$Z_{CIVT-2} = \left( \left( \tilde{s}_{S_{LT-2}}, \alpha_{SC-2} \right), \left( \mu_{Z_{RP-2}}, \mu_{Z_{RP-2}}^+ \right) e^{i2\pi \left[ \mu_{Z_{IP-2}}, \mu_{Z_{IP-2}}^+ \right]}, \left[ \eta_{Z_{RP-2}}, \eta_{Z_{RP-2}}^+ \right] e^{i2\pi \left[ \eta_{Z_{IP-2}}, \eta_{Z_{IP-2}}^+ \right]} \right)$, then:

$Z_{CIVT-1 \oplus CIVT Z_{CIVT-2}} = \Delta_{LT} \left( \frac{1}{2} \right) \left( \tilde{s}_{S_{LT-1}}, \alpha_{SC-1} \right), \Delta_{LT} \left( \frac{1}{2} \right) \left( \tilde{s}_{S_{LT-2}}, \alpha_{SC-2} \right) - \Delta_{LT} \left( \frac{1}{2} \right) \left( \tilde{s}_{S_{LT-1}}, \alpha_{SC-1} \right) - \Delta_{LT} \left( \frac{1}{2} \right) \left( \tilde{s}_{S_{LT-2}}, \alpha_{SC-2} \right), \left[ \mu_{Z_{RP-1}}, \mu_{Z_{RP-1}}^+ \right] e^{i2\pi \left[ \mu_{Z_{IP-1}}, \mu_{Z_{IP-1}}^+ \right]}, \left[ \eta_{Z_{RP-1}}, \eta_{Z_{RP-1}}^+ \right] e^{i2\pi \left[ \eta_{Z_{IP-1}}, \eta_{Z_{IP-1}}^+ \right]}$ (10)

$Z_{CIVT-1 \oplus CIVT Z_{CIVT-2}} = \Delta_{LT} \left( \frac{1}{2} \right) \left( \tilde{s}_{S_{LT-1}}, \alpha_{SC-1} \right), \left[ \mu_{Z_{RP-1}}, \mu_{Z_{RP-1}}^+ \right] e^{i2\pi \left[ \mu_{Z_{IP-1}}, \mu_{Z_{IP-1}}^+ \right]}, \left[ \eta_{Z_{RP-1}}, \eta_{Z_{RP-1}}^+ \right] e^{i2\pi \left[ \eta_{Z_{IP-1}}, \eta_{Z_{IP-1}}^+ \right]}$ (11)
Moreover, the SF and AF for CIVQRO2-TLS are defined as:

\[
\Gamma_{SF}(Z_{CIVT-1}) = \tilde{s}\left(\frac{1}{4} (\alpha_{LT-1} + \alpha_{SC-1}) \times \left( \begin{array}{c}
\mu^{+q_{SC}}_{Z_{BIP-1}} + \mu^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} \\
\mu^{+q_{SC}}_{Z_{BIP-1}} + \mu^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}}
\end{array} \right) \right)\]

\[
(13)
\]

\[
\Gamma_{SF}(Z_{CIVT-1}) = \tilde{s}\left(\frac{1}{4} (\alpha_{LT-1} + \alpha_{SC-1}) \times \left( \begin{array}{c}
\mu^{+q_{SC}}_{Z_{BIP-1}} + \mu^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} \\
\mu^{+q_{SC}}_{Z_{BIP-1}} + \mu^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}} - \eta^{+q_{SC}}_{Z_{BIP-1}}
\end{array} \right) \right)\]

\[
(14)
\]

For any two CIVQRO2-TLNs \(Z_{CIVT-1}\) and \(Z_{CIVT-1}\):

1. If \(\Gamma_{SF}(Z_{CIVT-1}) > \Gamma_{SF}(Z_{CIVT-2})\), then \(\Gamma_{SF}(Z_{CIVT-1}) > \Gamma_{SF}(Z_{CIVT-2})\);
2. If \(Z_{CIVT-1} = Z_{CIVT-2}\), then
   - If \(\Psi_{AF}(Z_{CIVT-1}) > \Psi_{AF}(Z_{CIVT-1})\), then \(\Psi_{AF}(Z_{CIVT-1}) > \Psi_{AF}(Z_{CIVT-1})\);
   - If \(\Psi_{AF}(Z_{CIVT-1}) = \Psi_{AF}(Z_{CIVT-1})\), then \(\Psi_{AF}(Z_{CIVT-1}) = \Psi_{AF}(Z_{CIVT-1})\).
**Example 1:** For any two CIVQRO2-TLNs $Z_{\text{CIVT}-1} = (\bar{s}_3, 0.4), ([0.4, 0.6]e^{i2\pi [0.4, 0.6]}, [0.1, 0.4]e^{i2\pi [0.1, 0.4]})$ and $Z_{\text{CIVT}-2} = (\bar{s}_4, 0.2), ([0.3, 0.5]e^{i2\pi [0.3, 0.5]}, [0.2, 0.4]e^{i2\pi [0.2, 0.4]})$ with $Z_{\text{CIVT}-2} = (\bar{s}_4, 0.2), ([0.3, 0.5]e^{i2\pi [0.3, 0.5]}, [0.2, 0.4]e^{i2\pi [0.2, 0.4]})$ by using the values of scalers $q_{SC} = 3$ and $q_{SC} = 3$, then by using Eq. (10) to Eq. (13), we have

$$Z_{\text{CIVT}-1 \otimes \text{CIVT}} Z_{\text{CIVT}-2} = \left( \Delta_{LT} \left( \bar{s}_3, 0.4 \right) + \Delta_{LT}^{-1} \left( \bar{s}_4, 0.2 \right) - \frac{\Delta_{LT}^2 \left( \bar{s}_3, 0.4 \right) \Delta_{LT}^2 \left( \bar{s}_4, 0.2 \right)}{6}, \right)$$

$$\begin{bmatrix}
(0.4^3 + 0.3^3 - 0.4^3 \times 0.3^3 \frac{1}{3})_1; e^{i2\pi \left(0.4^3 + 0.3^3 - 0.4^3 \times 0.3^3 \frac{1}{3}\right)}; \\
(0.6^3 + 0.5^3 - 0.6^3 \times 0.5^3 \frac{1}{3})_1; e^{i2\pi \left(0.6^3 + 0.5^3 - 0.6^3 \times 0.5^3 \frac{1}{3}\right)}; \\
[0.1 \times 0.2, 0.4 \times 0.4] e^{i2\pi [0.1 \times 0.2, 0.4 \times 0.4]}
\end{bmatrix},$$

$$= \left( 0.4469, 0.6797 \right) e^{i2\pi [0.4469, 0.6797]},$$

$$= \left( 0.02, 0.16 \right) e^{i2\pi [0.02, 0.16]}.$$
As a new mixture of the CIVQROFS and 2-TLS that can easily handle awkward and complicated sort of data occurring in genuine life, the beneficial aspects of the CIVQRO2-TLS compared to with the existing fuzzy tools are discussed in the presence of Table 2.

Moreover, some special cases of the CIVQRO2-TLS are deliberated as follows:

1. Using \( q_{sc} = 1 \) in CIVQRO2-TLS, then we get complex interval-valued intuitionistic fuzzy 2-tuple linguistic set;
2. Using \( q_{SC} = 2 \) in CIVQRO2-TLS, the complex interval-valued Pythagorean fuzzy 2-tuple linguistic set is obtained.
3. Using \( \alpha_{SC} = 0 \) with \( \alpha_{SC} = 0 \) in CIVQRO2-TLS, the complex interval-valued q-rung orthopair fuzzy linguistic set is constructed.
4. Using \( \alpha_{SC} = 0 \) with \( \alpha_{SC} = 0 \) in CIVQRO2-TLS, then we get complex interval-valued intuitionistic fuzzy linguistic set.
5. Using \( \alpha_{SC} = 0 \) with \( \alpha_{SC} = 0 \) in CIVQRO2-TLS, then we get complex interval-valued Pythagorean fuzzy linguistic set.
6. Using \( \mu_{Z_{RP}} = \mu_{Z_{RP}}^+, \eta_{Z_{RP}} = \eta_{Z_{RP}}^+, \mu_{Z_{IP}} = \mu_{Z_{IP}}^+, \eta_{Z_{IP}} = \eta_{Z_{IP}}^+ \) with \( q_{SC} > 0 \) in CIVQRO2-TLS, then we get CQROFS.

| Methods | Truth grade | Falsity grade | Interval-valued | 2-tuple linguistic | Two-dimension |
|---------|-------------|---------------|-----------------|-------------------|---------------|
| IFS     | ✓           | ✓             | x               | x                 | x             |
| PFS     | ✓           | ✓             | x               | x                 | x             |
| QROFS   | ✓           | ✓             | x               | x                 | x             |
| IVIFS   | ✓           | ✓             | ✓               | ✓                 | ✓             |
| IVPFs   | ✓           | ✓             | ✓               | ✓                 | ✓             |
| IVQROFS | ✓           | ✓             | ✓               | ✓                 | ✓             |
| CIF5    | ✓           | ✓             | x               | x                 | ✓             |
| CPFS    | ✓           | ✓             | x               | x                 | ✓             |
| CQROFS  | ✓           | ✓             | ✓               | ✓                 | ✓             |
| CIVIFS  | ✓           | ✓             | x               | x                 | ✓             |
| CIVPFs  | ✓           | ✓             | x               | x                 | ✓             |
| CIVQROFS| ✓           | ✓             | x               | x                 | ✓             |
| Proposed work | ✓ | ✓ | ✓ | ✓ | ✓ |
Using $q_{SC} > 0$ with $q_{SC} = 1$ in CIVQRO2-TLS, then we get CIFS.

(8) Using $q_{SC} = 1$ with $q_{SC} > 0$ in CIVQRO2-TLS, then we get QROFS.

(9) Using $q_{SC} > 0$ with $q_{SC} = 1$ in CIVQRO2-TLS, then we get IFS.

(10) Ect.

From the presence of the above analysis, we can see that most of existing fuzzy tools are the specific cases of the CIVQRO2-TLS, therefore the CIVQRO2-TLS is massive generalized and more dominant as compared to prevailing works.

**Aggregation operators for CIVQRO2-TL information**

In the occurrence of the above theory, in this section we discover the thought of CIVQRO2-TLWA, CIVQRO2-TLOWA, CIVQRO2-TLHA, CIVQRO2-TLWG, CIVQRO2-TLOWG and CIVQRO2-TLHG operators. Throughout this scenario, let $q_{SC} = 1$ be the weight vector with $\sum_{j=1}^{n} w_{W-j} = 1$, $w_{W-j} \in [0, 1]$ for the family of CIVQRO2-TLNs

$$Z_{CIVT-j} = \left( \begin{pmatrix} \tilde{s}_{SLT-j}, \alpha_{SC-j} \\ \mu_{Z_{LP-j}}^{+}, \mu_{Z_{LP-j}}^{-} \\ \eta_{Z_{LP-j}}^{+}, \eta_{Z_{LP-j}}^{-} \end{pmatrix} e^{i2\pi \left[ \mu_{Z_{LP-j}}, \mu_{Z_{LP-j}}^{+}, \mu_{Z_{LP-j}}^{-} \right]} \right), j = 1, 2, 3, \ldots n.$$

**Definition 4:** The CIVQRO2-TLWA operator is originated by;

$$CIVQRO2-TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \oplus_{j=1}^{n} (w_{W-j}Z_{CIVT-j})$$

(16)

In the consideration of Eq. (16), we exposed several results.

**Theorem 1:** Constructed on Eq. (16), we get;
\[
CIVQRO2 - TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) =
\begin{align*}
\Delta_{LT}\left(t \left(1 - \prod_{j=1}^{n} \left(1 - \frac{\Delta_{LT}(j)}{t} \right)^{w_{j}}\right)\right),
\end{align*}
\]

\[
\begin{align*}
&\left[\left(1 - \prod_{j=1}^{n} \left(1 - \mu_{Z_{CIVT-j}} q_{SC} \right)^{w_{j}}\right)^{\frac{1}{q_{SC}}}\right]
&\cdot e^{i2\pi \left[\prod_{j=1}^{n} \eta_{Z_{CIVT-j}}\right]} \prod_{j=1}^{n} \eta_{Z_{CIVT-j}}
&\bigg[\frac{1}{q_{SC}}\bigg]\left[\prod_{j=1}^{n} \eta_{Z_{CIVT-j}}\right]^{w_{j}},
\end{align*}
\]

(17)

Using \( q_{SC} = 1 \) and \( q_{SC} = 1 \) in Eq. (17), we get the CIV2-TLS and CIVP2-TLS, respectively. Furthermore, the idempotency, boundedness, and monotonicity in the presence of the CIVQRO2-TLWA operator are described as follows.

**Proposition 1:** If \( Z_{CIVT-j} = Z_{CIVT} \), then
\[
CIVQRO2 - TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = Z_{CIVT}
\] (18)

**Proposition 2:** If \( \min Z_{CIVT-j} = Z_{CIVT}^{-} \) and \( \min Z_{CIVT-j} = Z_{CIVT}^{-} \), then
\[
Z_{CIVT}^{-} \leq CIVQRO2 - TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) \leq Z_{CIVT}^{+}
\] (19)

**Proposition 3:** If \( Z_{CIVT-j} \geq Z_{CIVT-j}' \), then
\[
CIVQRO2 - TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n})
\geq CIVQRO2 - TLWA(Z_{CIVT-1}', Z_{CIVT-2}', \ldots, Z_{CIVT-n}')
\] (20)

**Definition 6:** The CIVQRO2-TLOWA operator is originated by:
\[
CIVQRO2 - TLOWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n})
= \bigoplus_{j=1}^{n} \left( w_{j} Z_{CIVT-o(j)} \right)
\] (21)

where \((o(1), o(2), \ldots, o(n))\) is a permutation with a condition that is \( Z_{CIVT-o(j-1)} \geq Z_{CIVT-o(j)} \). In the consideration of Eq. (21), we exposed following several results.
Theorem 2: Constructed on Eq. (21), we get:

\[
CIVRO2 - TLOWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \left( \Delta_{LT} \left( t \left( 1 - \prod_{j=1}^{n} \left( 1 - \frac{\Delta_{LT}^{j} \left( \mu_{Z_{ap-o(j)}}, \mu_{SC-o(j)} \right)}{t} \right) \right) \right) \right) \left( \prod_{j=1}^{n} \eta_{Z_{ap-o(j)}}, \eta_{SC-o(j)} \right) \right)
\]

For \( q_{SC} = 1 \) and \( q_{SC} = 1 \) in Eq. (22), we get CIVI2-TLS and CIVP2-TLS. Furthermore, the idempotency, boundedness, and monotonicity of the CIVRO2-TLOWA operator are analyzed below.

Proposition 4: If \( Z_{CIVT-j} = Z_{CIVT} \), then

\[
CIVRO2 - TLOWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = Z_{CIVT}
\]

Proposition 5: If \( CIVRO2 - TLOWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = Z_{CIVT} \) and \( \max Z_{CIVT-j} = Z_{CIVT}^{++} \), then

\[
Z_{CIVT}^{-} \leq CIVRO2 - TLOWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) \leq Z_{CIVT}^{++}
\]

Proposition 6: If \( Z_{CIVT-j} \geq Z_{CIVT-j}^{+} \), then

\[
CIVRO2 - TLWA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) \geq CIVRO2 - TLWA(Z_{CIVT-1}^{+}, Z_{CIVT-2}^{+}, \ldots, Z_{CIVT-n}^{+})
\]

Definition 7: The CIVRO2-TLHA operator is originated by:

\[
CIVRO2 - TLHA(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \oplus_{j=1}^{n} \left( \overline{Z_{CIVT-o(j)}} \right)
\]

Where \( (o(1), o(2), \ldots, o(n)) \) is a permutation with a condition that is \( (o(1), o(2), \ldots, o(n)) \). In the consideration of Eq. (26), we exposed several results.

Theorem 3: Constructed on Eq. (26), we get
CIVQRO2 − TLHA\( (Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \)
\[
\Delta_{LT} \left( t \left( 1 - \prod_{j=1}^{n} \left( 1 - \frac{\Delta_{LT}^{-1} \left( \frac{\eta_{Z_{j}} q_{SC}}{\mu_{Z_{j}}} \right)}{\mu_{Z_{j}}} \right)^{\omega_{W-j}} \right) \right) \right),
\]
\[
\left( \begin{array}{c}
\left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right) \left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right) \\
\left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right) \left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right)
\end{array} \right) \\
\left( \begin{array}{c}
\left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right) \\
\left( 1 - \prod_{j=1}^{n} \left( 1 - \eta_{Z_{j}} q_{SC} \right)^{\omega_{W-j}} \right)
\end{array} \right)
\]
\[
(27)
\]

For \( q_{SC} = 1 \) and \( q_{SC} = 2 \) in Eq. (27), we get CIVI2-TLS and CIVP2-TLS, which shows the specific cases of the explored ideas.

**Definition 7:** The CIVQRO2-TLWG operator is originated by:

\[
\text{CIVQRO2} − \text{TLWG}(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \bigotimes_{j=1}^{n} \left( Z_{CIVT-j} \right)^{\omega_{W-j}}
\]

\[
(28)
\]

**Theorem 4:** Constructed on Eq. (28), we get:

\[
\text{CIVQRO2} − \text{TLWG}(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \frac{\Delta_{LT} \left( t \left( n \Delta_{LT}^{-1} \left( \frac{\eta_{Z_{j}}}{\mu_{Z_{j}}} \right)^{\omega_{W-j}} \right) \right)}{\mu_{Z_{j}}},
\]

\[
\left( \begin{array}{c}
\prod_{j=1}^{n} \mu_{Z_{j}}^{\omega_{W-j}} \\
\prod_{j=1}^{n} \mu_{Z_{j}}^{\omega_{W-j}}
\end{array} \right) \left( \begin{array}{c}
\prod_{j=1}^{n} \eta_{Z_{j}} q_{SC}^{\omega_{W-j}} \\
\prod_{j=1}^{n} \eta_{Z_{j}} q_{SC}^{\omega_{W-j}}
\end{array} \right) \left( \begin{array}{c}
\prod_{j=1}^{n} \eta_{Z_{j}} q_{SC}^{\omega_{W-j}} \\
\prod_{j=1}^{n} \eta_{Z_{j}} q_{SC}^{\omega_{W-j}}
\end{array} \right)
\]

\[
(29)
\]

If \( q_{SC} = 1 \) and \( q_{SC} = 1 \) in Eq. (29), then we have the CIVI2-TLS and CIVP2-TLS. Furthermore, the idempotency, boundedness, and monotonicity in the presence of the CIVQRO2-TLWG operator are described below.
**Definition 8:** The CIVQRO2-TLOWG operator is originated by:

\[
CIVQRO2 - TLOWG(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \otimes_{j=1}^{n} (Z_{CIVT-o(j)})^{w_{j}}
\]

(30)

where \((o(1), o(2), \ldots, o(n))\) is a permutation with a condition that is \((o(1), o(2), \ldots, o(n))\).

**Theorem 5:** Constructed on Eq. (30), we get

\[
CIVQRO2 - TLOWG(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \Delta_{LT} \left( t \left( \prod_{j=1}^{n} \left( \Delta_{LT} \left( \frac{\Delta_{LT} \left( \eta_{1} \right) \eta_{o(j)} \left( \eta_{o(j)} \right)}{t} \right)^{w_{j}} \right) \right) \right),
\]

\[
\left[ \prod_{j=1}^{n} \left( 1 - \eta_{1} W_{o(j)}^{w_{j}} \right) \right]^{i2\pi} \left[ \prod_{j=1}^{n} \left( 1 - \eta_{2} W_{o(j)}^{w_{j}} \right) \right]^{1/\alpha_{SC}}
\]

(31)

For \(q_{SC} = 1\) and \(q_{SC} = 2\), in Eq. (31), we get CIVI2-TLS and CIVP2-TLS.

**Definition 10:** The CIVQRO2-TLHG operator is originated by:

\[
CIVQRO2 - TLHG(Z_{CIVT-1}, Z_{CIVT-2}, \ldots, Z_{CIVT-n}) = \otimes_{j=1}^{n} (\hat{Z}_{CIVT-o(j)})^{w_{j}}
\]

(32)

where \((o(1), o(2), \ldots, o(n))\) is a permutation with a condition that is \((o(1), o(2), \ldots, o(n))\). In the consideration of Eq. (32), we exposed several results.

**Theorem 6:** Constructed on Eq. (32), we get
\[ \text{CIVQRO2} - \text{TLHG}(Z_{\text{CIVT} - 1}, Z_{\text{CIVT} - 2}, \ldots, Z_{\text{CIVT} - n}) = \] 
\[
\Delta_{LT}\left( t \left( \prod_{j=1}^{n} \left( \frac{\Delta_{LT}^{i}}{\hat{\lambda}_{\text{W}_{j} - \text{W}_{i}, \text{W}_{j} - \text{W}_{i}}} \right) \right) \right),
\]
\[
\left[ \prod_{j=1}^{n} \hat{\mu}_{\text{W}_{j} - \text{W}_{i}}, \prod_{j=1}^{n} \hat{\mu}_{\text{W}_{j} - \text{W}_{i}} \right] e^{2\pi \left[ \prod_{j=1}^{n} \left( 1 - \hat{n}_{\text{W}_{j} - \text{W}_{i}} \right) \right] \left[ \prod_{j=1}^{n} \left( 1 - \hat{n}_{\text{W}_{j} - \text{W}_{i}} \right) \right]},
\]
\[
\left[ 1 - \prod_{j=1}^{n} \left( 1 - \hat{n}_{\text{W}_{j} - \text{W}_{i}} \right) \right] e^{2\pi \left[ \prod_{j=1}^{n} \left( 1 - \hat{n}_{\text{W}_{j} - \text{W}_{i}} \right) \right] \left[ \prod_{j=1}^{n} \left( 1 - \hat{n}_{\text{W}_{j} - \text{W}_{i}} \right) \right]},
\]
\[ (33) \]

Note that, the merits of idempotency, boundedness, and monotonicity of the proposed CIVQRO2-TLOWG and CIVQRO2-TLHG operators can be described as the previous analysis.

**Application in MADM problems**

In this study, we present a MADM method based on the proposed operators to solve complicated decision-making problem with CIVQRO2-TL information. To settle the above issues, we choose the family of alternatives and the family of attributes with respect to weight vectors to examine the reliability and proficiency of the explored approaches, whose expressions are follow as: \( Z_{\text{CIVT}} = \{ Z_{\text{CIVT} - 1}, Z_{\text{CIVT} - 2}, Z_{\text{CIVT} - 3}, \ldots, Z_{\text{CIVT} - n} \} \) and \( \mathcal{L}_{AT} = \{ \mathcal{L}_{AT - 1}, \mathcal{L}_{AT - 2}, \ldots, \mathcal{L}_{AT - n} \} \) with \( \varpi_{W} = \{ \varpi_{W - 1}, \varpi_{W - 2}, \ldots, \varpi_{W - n} \} \) by using the CIVQRO2-TL information

\[
Z_{\text{CIVT} - jk} = \left( \left\langle \hat{s}_{\text{LT} - jk}, \alpha_{\text{SC} - jk} \right\rangle, \left[ \hat{\mu}_{\text{LP} - jk}, \hat{\mu}_{\text{BP} - jk} \right], e^{2\pi \left[ \hat{\eta}_{\text{LP} - jk}, \eta_{\text{BP} - jk} \right]}, \left[ \hat{\mu}_{\text{LP} - jk}, \hat{\mu}_{\text{BP} - jk} \right], e^{2\pi \left[ \hat{\eta}_{\text{LP} - jk}, \eta_{\text{BP} - jk} \right]} \right) \right). \]

Then, the steps of the explored procedure are summarized as follow as:

**Stage 1:** Stabilize the data given in the form of decision framework, in the presence of the idea, if necessary, then
Otherwise, go to stage 2.

**Stage 2:** In the presence of the qualitative idea of CIVQRO2-TLWA and CIVQRO2-TLWG operators, we demonstrate the single value with the help of accumulated values of the given data.

**Stage 3:** The score value is diagnosed with the help of SF.

**Stage 4:** With the help of SF, we find the ranking results to choose the beneficial one.

### Numerical example

**Example 2:** The owners of the enterprise want to build-up some new branch of the enterprise. Therefore, a group of experts selected to evaluate four possible organizations in the shape of attributes: $\mathcal{L}_{AT-1}$: Development situation; $\mathcal{L}_{AT-1}$: Public influence; $\mathcal{L}_{AT-3}$: Eco-friendly influence; $\mathcal{L}_{AT-3}$: Advancement of civilization. Moreover, some alternatives in the shape of five different aspects/opinions: $Z_{CSF-1}$: Cost inspection; $Z_{CSF-1}$: Enhancement situation; $Z_{CSF-3}$: Political influence; $Z_{CSF-3}$: Ecological power; $Z_{CSF-5}$: General community. Let $\omega_W = (0.21, 0.09, 0.31, 0.39)^T$ be the weight vectors of attributes. This analysis includes some stages, which help investigate the beneficial optimal.

**Stage 1:** Construct the decision information in the form of CIVQRO2-TLNs, stated in Table 3.

Table 3 includes all the beneficial data, thus there is no need for standardization.
\(|\alpha^\text{CIVQRO2-TLWA}|\) and \(|\alpha^\text{CIVQRO2-TLWG}|\)

Stage 2: In the presence of the qualitative idea of CIVQRO2-TLWA and CIVQRO2-TLWG operators, we demonstrate the single value with the help of accumulated values of the given data for \(\omega_W = (0.21, 0.09, 0.31, 0.39)^T\), respectively:

\[
Z_{\text{CIV}}^{\text{TLA}_1} = (\hat{s}_3, -0.32), ([0.17, 0.31]e^{i2\pi[0.18,0.32]}, [0.45, 0.55]e^{i2\pi[0.46,0.56]});
\]

\[
Z_{\text{CIV}}^{\text{TLA}_1} = (\hat{s}_3, -0.32), ([0.17, 0.31]e^{i2\pi[0.18,0.32]}, [0.45, 0.55]e^{i2\pi[0.46,0.56]});
\]

\[
Z_{\text{CIV}}^{\text{TLA}_3} = (\hat{s}_3, -0.02), ([0.28, 0.39]e^{i2\pi[0.29,0.39]}, [0.41, 0.57]e^{i2\pi[0.42,0.58]});
\]

\[
Z_{\text{CIV}}^{\text{TLA}_3} = (\hat{s}_3, -0.02), ([0.28, 0.39]e^{i2\pi[0.29,0.39]}, [0.41, 0.57]e^{i2\pi[0.42,0.58]});
\]

\[
Z_{\text{CIV}}^{\text{TLA}_5} = (\hat{s}_4, -0.35), ([0.32, 0.51]e^{i2\pi[0.33,0.52]}, [0.21, 0.41]e^{i2\pi[0.22,0.42]});
\]

and

\[
Z_{\text{CIV}}^{\text{TLA}_1} = (\hat{s}_2, 0.1), ([0.13, 0.29]e^{i2\pi[0.131,0.291]}, [0.46, 0.56]e^{i2\pi[0.461,0.561]});
\]
\[ Z_{CIVT-1} = \left( \tilde{s}_2, 0.1 \right), \left( [0.13, 0.29]e^{i2\pi[0.131, 0.291]}, [0.46, 0.56]e^{i2\pi[0.461, 0.561]} \right) \];

\[ Z_{CIVT-3} = \left( \tilde{s}_3, -0.19 \right), \left( [0.17, 0.30]e^{i2\pi[0.18, 0.31]}, [0.52, 0.43]e^{i2\pi[0.521, 0.44]} \right) \];

\[ Z_{CIVT-5} = \left( \tilde{s}_3, -0.18 \right), \left( [0.21, 0.47]e^{i2\pi[0.21, 0.48]}, [0.32, 0.48]e^{i2\pi[0.33, 0.49]} \right) \];

**Stage 3:** The score values are calculated with the help of SF (for CIVQRO2-TLWA operator), we have:

\[
\begin{align*}
\Gamma_{SF}(Z_{CIVT-1}) &= \tilde{s}_{-0.05778}, \\
\Gamma_{SF}(Z_{CIVT-2}) &= \tilde{s}_{0.09924}, \\
\Gamma_{SF}(Z_{CIVT-3}) &= \tilde{s}_{0.09313}, \\
\Gamma_{SF}(Z_{CIVT-5}) &= \tilde{s}_{0.05779}
\end{align*}
\]

Some rules for CIVQRO2-TLWG operator, we get:

\[
\begin{align*}
\Gamma_{SF}(Z_{CIVT-1}) &= \tilde{s}_{-0.05778}, \\
\Gamma_{SF}(Z_{CIVT-2}) &= \tilde{s}_{0.09924}, \\
\Gamma_{SF}(Z_{CIVT-3}) &= \tilde{s}_{0.09313}, \\
\Gamma_{SF}(Z_{CIVT-5}) &= \tilde{s}_{0.05779}
\end{align*}
\]

**Stage 4:** With the help of SF, we find the ranking values is to find the beneficial one:

\[ Z_{CIVT-2} \geq Z_{CIVT-5} \geq Z_{CIVT-4} \geq Z_{CIVT-1} \geq Z_{CIVT-3}, \]

\[ Z_{CIVT-2} \geq Z_{CIVT-5} \geq Z_{CIVT-4} \geq Z_{CIVT-1} \geq Z_{CIVT-3}. \]

Therefore, \( Z_{CIVT-2} \) is the beneficial optimal for two operators.

**Advantages of the explored approach**

Keeping the advantages of the explored operators, in this study, we try to show the advantages of this investigated method through a more in-depth analysis. For this, we choose to use the complex interval-valued Pythagorean 2-tuple linguistic set (CIVP2-TLS) and CIVQRO2-TLS to represent the decision information and resolve them by using the WA and WG operators. The explored operators are more powerful and more capable to cope with awkward and complicated information in realistic decision issues. Firstly, the decision matrix in the form of CIVP2-TLNs is shown in Table 4. Then, the calculation results derived by proposed methods are discussed below.

In the presence of the qualitative idea of CIVQRO2-TLWA and CIVQRO2-TLWG operators, we demonstrate the single value with the help of accumulated values of the given data for \( Z_{CIVT-2} \).
Table 4. Decision matrix in the form of CIVP2-TLN.

| $L_{AT - 1}$ | $L_{AT - 2}$ |
|--------------|--------------|
| $Z_{CSF - 1}$ | $\langle \hat{\theta}_1, 0, 0.1, 0.6 e^{2\pi [0.11.0.21]} \rangle$ | $\langle \hat{\theta}_1, 0, 0.2, 0.7 e^{2\pi [0.21.0.4]} \rangle$ |
| $Z_{CSF - 2}$ | $\langle \hat{\theta}_3, 0, 0.4, 0.8 e^{2\pi [0.41.0.51]} \rangle$ | $\langle \hat{\theta}_3, 0, 0.3, 0.8 e^{2\pi [0.31.0.4]} \rangle$ |
| $Z_{CSF - 3}$ | $\langle \hat{\theta}_3, 0, 0.2, 0.3 e^{2\pi [0.21.0.31]} \rangle$ | $\langle \hat{\theta}_3, 0, 0.2, 0.3 e^{2\pi [0.21.0.31]} \rangle$ |
| $Z_{CSF - 4}$ | $\langle \hat{\theta}_3, 0, 0.4, 0.7 e^{2\pi [0.31.0.48]} \rangle$ | $\langle \hat{\theta}_3, 0, 0.2, 0.8 e^{2\pi [0.21.0.31]} \rangle$ |
| $Z_{CSF - 5}$ | $\langle \hat{\theta}_3, 0, 0.3, 0.5 e^{2\pi [0.31.0.5]} \rangle$ | $\langle \hat{\theta}_3, 0, 0.1, 0.3 e^{2\pi [0.31.0.31]} \rangle$ |

$Z_{CIVT - 1} = \langle \hat{\theta}_3, -0.32, [0.17, 0.61] e^{2\pi [0.18.0.32]}, [0.45, 0.55] e^{2\pi [0.46.0.56]} \rangle$;

$Z_{CIVT - 2} = \langle \hat{\theta}_3, 0.02, [0.40, 0.83] e^{2\pi [0.41.0.54]}, [0.17, 0.28] e^{2\pi [0.18.0.29]} \rangle$;

$Z_{CIVT - 3} = \langle \hat{\theta}_3, -0.02, [0.28, 0.79] e^{2\pi [0.29.0.39]}, [0.41, 0.57] e^{2\pi [0.42.0.58]} \rangle$;

$Z_{CIVT - 4} = \langle \hat{\theta}_3, 0.19, [0.35, 0.86] e^{2\pi [0.351.0.47]}, [0.16, 0.34] e^{2\pi [0.17.0.346]} \rangle$;

$Z_{CIVT - 5} = \langle \hat{\theta}_3, -0.35, [0.32, 0.81] e^{2\pi [0.33.0.52]}, [0.21, 0.41] e^{2\pi [0.22.0.42]} \rangle$;

and

$Z_{CIVT - 5} = \langle \hat{\theta}_3, -0.35, [0.32, 0.81] e^{2\pi [0.33.0.52]}, [0.21, 0.41] e^{2\pi [0.22.0.42]} \rangle$;

$Z_{CIVT - 2} = \langle \hat{\theta}_4, 0.47, [0.39, 0.82] e^{2\pi [0.391.0.52]}, [0.231, 0.322] e^{2\pi [0.24.0.33]} \rangle$;

$Z_{CIVT - 3} = \langle \hat{\theta}_3, -0.19, [0.17, 0.80] e^{2\pi [0.18.0.31]}, [0.52, 0.43] e^{2\pi [0.521.0.44]} \rangle$;

$Z_{CIVT - 4} = \langle \hat{\theta}_4, -0.3, [0.23, 0.74] e^{2\pi [0.231.0.441]}, [0.24, 0.41] e^{2\pi [0.25.0.342]} \rangle$;
\[ Z_{CIVT-5} = \left( (\bar{s}_3, -0.18), \left[ [0.21, 0.87]e^{i2\pi[0.21,0.48]}, [0.32, 0.48]e^{i2\pi[0.33,0.49]} \right] \right) \];

The score value is diagnosed with the help of SF (for CIVQRO2-TLWA), we have

\[
\Gamma_{SF}(Z_{CIVT-1}) = \bar{s}_{0.0288}, \quad \Gamma_{SF}(Z_{CIVT-2}) = \bar{s}_{0.4969}, \quad \Gamma_{SF}(Z_{CIVT-3}) = \bar{s}_{0.1788}, \quad \Gamma_{SF}(Z_{CIVT-4}) = \bar{s}_{0.5652}, \quad \Gamma_{SF}(Z_{CIVT-5}) = \bar{s}_{0.3888}
\]

Some rules on the basis of the CIVQRO2-TLWG operator, we get:

\[
\Gamma_{SF}(Z_{CIVT-1}) = \bar{s}_{0.1516}, \quad \Gamma_{SF}(Z_{CIVT-2}) = \bar{s}_{0.4092}, \quad \Gamma_{SF}(Z_{CIVT-3}) = \bar{s}_{0.3453}, \quad \Gamma_{SF}(Z_{CIVT-4}) = \bar{s}_{0.2586}, \quad \Gamma_{SF}(Z_{CIVT-5}) = \bar{s}_{0.3763}
\]

With the help of the SF, the rankings of alternatives are achieved, such that

\[ Z_{CIVT-4} \geq Z_{CIVT-2} \geq Z_{CIVT-5} \geq Z_{CIVT-3} \geq Z_{CIVT-1} \]

\[ Z_{CIVT-2} \geq Z_{CIVT-5} \geq Z_{CIVT-3} \geq Z_{CIVT-4} \geq Z_{CIVT-1} \]

Therefore, \( Z_{CIVT-2}, Z_{CIVT-4} \), are the beneficial optimal for the CIVQRO2-TLWA operator and CIVQRO2-TLWG, respectively.

Additionally, if we choose the complex q-rung orthopair 2-tuple linguistic kind of information’s, which is discussed in the form of Table 5.

In the presence of the qualitative idea of CIVQRO2-TLWA and CIVQRO2-TLWG operators, we aggregate the single values into a collective one for \( q_{SC} = 4 \).

**Table 5.** Decision matrix in the form of CIVQRO2-TLNs.

| \( Z_{CSF-1} \) | \( L_{AT-1} \) | \( Z_{CSF-2} \) | \( L_{AT-2} \) | \( Z_{CSF-3} \) | \( L_{AT-3} \) | \( Z_{CSF-4} \) | \( L_{AT-4} \) | \( Z_{CSF-5} \) | \( L_{AT-5} \) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| \((\bar{s}_3, 0), (0.1, 0.9)e^{2\pi[0.11,0.21]}\) | \((\bar{s}_3, 0), (0.2, 0.9)e^{2\pi[0.21,0.41]}\) | \((\bar{s}_3, 0), (0.4, 0.9)e^{2\pi[0.41,0.51]}\) | \((\bar{s}_3, 0), (0.2, 0.3)e^{2\pi[0.21,0.31]}\) | \((\bar{s}_3, 0), (0.1, 0.2)e^{2\pi[0.11,0.21]}\) | \((\bar{s}_3, 0), (0.2, 0.9)e^{2\pi[0.21,0.41]}\) | \((\bar{s}_3, 0), (0.4, 0.9)e^{2\pi[0.41,0.51]}\) | \((\bar{s}_3, 0), (0.3, 0.6)e^{2\pi[0.31,0.41]}\) | \((\bar{s}_3, 0), (0.1, 0.9)e^{2\pi[0.11,0.21]}\) | \((\bar{s}_3, 0), (0.4, 0.5)e^{2\pi[0.41,0.51]}\) |
Table 6. Comparative analysis for Table 3.

| Methods      | AOs   | Score values                                      | Ranking values |
|--------------|-------|---------------------------------------------------|----------------|
| IM2-TLSs     | WA    | Failed                                            | Failed         |
|              | WG    | Failed                                            | Failed         |
| IVP2-TLSs    | WA    | Failed                                            | Failed         |
|              | WG    | Failed                                            | Failed         |
| IVQRO2-TLS   | WA    | Failed                                            | Failed         |
|              | WG    | Failed                                            | Failed         |
| CVI2-TLSs    | WA    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.036$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
|              | WG    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
| CVP2-TLSs    | WA    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
|              | WG    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
| Proposed     | WA    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
| work         | WG    | $\Gamma_S\left(Z_{\text{CIVT}-1}\right) = \$0.043$, $\Gamma_S\left(Z_{\text{CIVT}-2}\right) = \$0.107$, $\Gamma_S\left(Z_{\text{CIVT}-3}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-4}\right) = \$0.063$, $\Gamma_S\left(Z_{\text{CIVT}-5}\right) = \$0.063$ | $Z_{\text{CIVT}-1} \geq Z_{\text{CIVT}-2} \geq Z_{\text{CIVT}-3}$ |
\[ Z_{CIVT-1} = \left( \bar{s}_3, -0.32 \right), \left( [0.17, 0.91]e^{2\pi[0.18,0.32]}, [0.45, 0.55]e^{2\pi[0.46,0.56]} \right) \]

; \[ Z_{CIVT-2} = \left( \bar{s}_4, 0.02 \right), \left( [0.40, 0.93]e^{2\pi[0.41,0.54]}, [0.17, 0.28]e^{2\pi[0.18,0.29]} \right) \]

\[ Z_{CIVT-3} = \left( \bar{s}_3, -0.02 \right), \left( [0.28, 0.92]e^{2\pi[0.29,0.39]}, [0.41, 0.57]e^{2\pi[0.42,0.58]} \right) \]

\[ Z_{CIVT-4} = \left( \bar{s}_4, 0.19 \right), \left( [0.35, 0.9]e^{2\pi[0.351,0.47]}, [0.16, 0.34]e^{2\pi[0.17,0.346]} \right) \]

\[ Z_{CIVT-5} = \left( \bar{s}_4, -0.35 \right), \left( [0.32, 0.91]e^{2\pi[0.33,0.52]}, [0.21, 0.41]e^{2\pi[0.22,0.42]} \right) \]

and

\[ Z_{CIVT-1} = \left( \bar{s}_2, 0.1 \right), \left( [0.13, 0.9]e^{2\pi[0.131,0.291]}, [0.46, 0.56]e^{2\pi[0.461,0.561]} \right) \]

\[ Z_{CIVT-2} = \left( \bar{s}_4, -0.47 \right), \left( [0.39, 0.92]e^{2\pi[0.391,0.522]}, [0.231, 0.322]e^{2\pi[0.24,0.33]} \right) \]

\[ Z_{CIVT-3} = \left( \bar{s}_3, -0.19 \right), \left( [0.17, 0.90]e^{2\pi[0.18,0.31]}, [0.52, 0.43]e^{2\pi[0.521,0.44]} \right) \]

\[ Z_{CIVT-4} = \left( \bar{s}_4, -0.3 \right), \left( [0.23, 0.94]e^{2\pi[0.231,0.441]}, [0.24, 0.41]e^{2\pi[0.25,0.342]} \right) \]

\[ Z_{CIVT-5} = \left( \bar{s}_3, -0.18 \right), \left( [0.21, 0.907]e^{2\pi[0.21,0.48]}, [0.32, 0.48]e^{2\pi[0.33,0.49]} \right) \]

The score value is diagnosed with the help of SF (for CIVQRO2-TLWA operator), we have

\[ \Gamma_{SF}(Z_{CIVT-1}) = \tilde{s}_{0.3756}, \Gamma_{SF}(Z_{CIVT-2}) = \tilde{s}_{0.6793}, \Gamma_{SF}(Z_{CIVT-3}) = \tilde{s}_{0.3774}, \Gamma_{SF}(Z_{CIVT-4}) = \tilde{s}_{0.6794}, \Gamma_{SF}(Z_{CIVT-5}) = \tilde{s}_{0.5947} \]

And for the CIVQRO2-TLWG operator, we get:

\[ \Gamma_{SF}(Z_{CIVT-1}) = \tilde{s}_{0.2916}, \Gamma_{SF}(Z_{CIVT-2}) = \tilde{s}_{0.5892}, \Gamma_{SF}(Z_{CIVT-3}) = \tilde{s}_{0.5184}, \Gamma_{SF}(Z_{CIVT-4}) = \tilde{s}_{0.5182}, \Gamma_{SF}(Z_{CIVT-5}) = \tilde{s}_{0.4349} \]

Therefore, we can find the ranking lists for all alternatives, such that:

\[ Z_{CIVT-4} \geq Z_{CIVT-2} \geq Z_{CIVT-5} \geq Z_{CIVT-3} \geq Z_{CIVT-1} \]

\[ Z_{CIVT-2} \geq Z_{CIVT-4} \geq Z_{CIVT-3} \geq Z_{CIVT-5} \geq Z_{CIVT-1} \]
Obviously, $Z_{CIVT-2}$ is the beneficial optimal for the CIVQRO2-TLWA operator while $Z_{CIVT-4}$ for the CIVQRO2-TLWG method.

**Comparative analysis**

To evaluate the proficiency and capability of the invented works, we try to compare the invented works with some prevailing works in the presence of the data given in Table 3, Table 4, and Table 5. The CIVI2-TLS, CIVP2-TLS, q-rung orthopair 2-tuple linguistic set (IVQRO2-TLS) (Wang, Garg, and Li 2019) and their special cases are used to
Table 7. Comparative analysis for Table 4.

| Methods          | AOs | Score values | Ranking values |
|------------------|-----|--------------|----------------|
| IVI2-TLSs        | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| IVP2-TLSs        | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| IVRO2-TLSs       | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| CIVI2-TLSs       | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| CIVP2-TLSs       | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| CIVP2-TLSs       | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| CIVP2-TLSs       | WA  | Failed       | Failed         |
|                  | WG  | Failed       | Failed         |
| Proposed work    | WA  | $\gamma_s(Z_{CIVT-1}) = s0.1415, \gamma_s(Z_{CIVT-2}) = s0.5539, \gamma_s(Z_{CIVT-3}) = s0.3600, \gamma_s(Z_{CIVT-4}) = s0.4227$ | $Z_{CIVT-4} \geq Z_{CIVT-2} \geq Z_{CIVT-5}$ |
|                  |     | $\gamma_s(Z_{CIVT-1}) = s0.2222, \gamma_s(Z_{CIVT-2}) = s0.4737, \gamma_s(Z_{CIVT-3}) = s0.9880, \gamma_s(Z_{CIVT-4}) = s0.3802, \gamma_s(Z_{CIVT-5}) = s0.4511$ | $\geq Z_{CIVT-3} \geq Z_{CIVT-1}$ |
|                  |     | $\gamma_s(Z_{CIVT-1}) = s0.0288, \gamma_s(Z_{CIVT-2}) = s0.4969, \gamma_s(Z_{CIVT-3}) = s0.1788, \gamma_s(Z_{CIVT-4}) = s0.5653, \gamma_s(Z_{CIVT-5}) = s0.3388$ | $\geq Z_{CIVT-4} \geq Z_{CIVT-3}$ |
|                  |     | $\gamma_s(Z_{CIVT-1}) = s0.1516, \gamma_s(Z_{CIVT-2}) = s0.4002, \gamma_s(Z_{CIVT-3}) = s0.3453, \gamma_s(Z_{CIVT-4}) = s0.2586, \gamma_s(Z_{CIVT-5}) = s0.3763$ | $\geq Z_{CIVT-4} \geq Z_{CIVT-1}$ |
| Methods               | AOs | Score values  | Ranking values |
|-----------------------|-----|--------------|----------------|
| IVI2-TLSs             | WA  | Failed       | Failed         |
|                       | WG  | Failed       | Failed         |
| IVP2-TLSs             | WA  | Failed       | Failed         |
|                       | WG  | Failed       | Failed         |
| Wang, Garg, and Li (2019) | WA  | Failed       | Failed         |
|                       | WG  | Failed       | Failed         |
| CVI2-TLSs             | WA  | Failed       | Failed         |
|                       | WG  | Failed       | Failed         |
| CIVP2-TLSs            | WA  | Failed       | Failed         |
|                       | WG  | Failed       | Failed         |
| Proposed work         | WA  | $\Gamma_{SF} (Z_{CIVT-1}) = \tilde{s}_0.3756, \Gamma_{SF} (Z_{CIVT-2}) = \tilde{s}_0.6791$ | $Z_{CIVT-4} \geq Z_{CIVT-2} \geq Z_{CIVT-5}$ |
|                       |     | $\Gamma_{SF} (Z_{CIVT-3}) = \tilde{s}_0.3774, \Gamma_{SF} (Z_{CIVT-4}) = \tilde{s}_0.6794, \Gamma_{SF} (Z_{CIVT-5}) = \tilde{s}_0.5947$ | $\geq Z_{CIVT-3} \geq Z_{CIVT-1}$ |
|                       | WG  | $\Gamma_{SF} (Z_{CIVT-1}) = \tilde{s}_0.2916, \Gamma_{SF} (Z_{CIVT-2}) = \tilde{s}_0.5892$ | $Z_{CIVT-2} \geq Z_{CIVT-4} \geq Z_{CIVT-3}$ |
|                       |     | $\Gamma_{SF} (Z_{CIVT-3}) = \tilde{s}_0.5984, \Gamma_{SF} (Z_{CIVT-4}) = \tilde{s}_0.5882, \Gamma_{SF} (Z_{CIVT-5}) = \tilde{s}_0.4349$ | $\geq Z_{CIVT-5} \geq Z_{CIVT-1}$ |
calculated. Firstly, in the consideration of the data given in Table 3, the comparison of the invented and prevailing theories is diagnosed in Table 6.

Table 6 shows different ranking results different concepts used. The best alternatives are different from each other, which are follow as: $Z_{CIVT-1}, Z_{CIVT-2}$ and $Z_{CIVT-3}$. We can draw the graphical expression, which is utilized in the form of Figure 1, to express the family of alternatives with five different colors. In Figure 1, the X-axis represents the family of alternatives, and the Y-axis the score values. Thus, the decision-maker can easily examine the best alternative with the help of Figure 1. For simplicity, the different series have different values; thus, we easily obtained the result that which one is the best alternative.

In the consideration of the data given in Table 4, the comparison of the invented and prevailing theories is diagnosed in Table 7.

Table 7 also provides the different ranking results, which are in the form of $Z_{CIVT-2}, Z_{CIVT-3}$ and $Z_{CIVT-4}$. For simplicity, we can draw the graphical expression of the information in Table 7, which is utilized in the form of Figure 2.

In the consideration of the data given in Table 5, the comparison of the invented and prevailing theories are diagnosed in Table 8. Further, we can draw the graphical expression of Table 8, shown in Figure 3.

From above comparative analysis, we can see that the investigated operators based on CIVQRO2-TLS are extensively reliable and proficient to manage awkward and difficult information in realistic issues. Therefore, the explored approaches are more generalized than existing notions (Ali and Mahmood, 2020a; Akram and Naz 2019; Beg and Rashid 2016; Garg, Ali, and Mahmood 2020b; Herrera and Martinez 2001; Liu, Ali, and Mahmood 2019, 2020; Liu and Chen 2018).
Conclusion

The main contribution of this study is stated below: (1) We discussed the conception of the CIVQRO2-TLS and some of their important laws; (2) In the occurrence of the above theory, we discovered several aggregation methods for CIVQRO2-TLS, including the CIVQRO2-TLWA, CIVQRO2-TLOWA, CIVQRO2-TLHA, CIVQRO2-TLWG, CIVQRO2-TLOWG, and CIVQRO2-TLHG operators, and diagnosed their fundamental properties; (3) We demonstrated the beneficial features of the invented works, a MADM system is diagnosed and checked with the help of several examples; (4) In last, we elaborated on the advantages, comparative analysis, and graphical interpretation of the invented approaches.

There are also several limitations in the proposed methods. In many scenarios, the invented theory can’t be working effectively, such as for the situation $\mu^{*}_{qSC} + \phi^{*}_{qSC} + \eta^{*}_{qSC} \geq 1$, the CIVQRO2-TLS can’t handle such information. Moreover, the calculation of aggregation process is also cumbersome due to the complex data structure of CIVQRO2-TLS. In the upcoming time, we expose several new theories like the TOPSIS method for PFSs (Bakioglu and Atahan 2021), improved composite relation (Ejegwa 2020), divergence mean (Verma 2020), MABAC method (Verma 2021), matrix game (Verma and Aggarwal 2021), decision-making strategy (Ali, Mahmood, and Yang 2020; Aydemir and Gündüz 2020; Jan et al. 2019; Mahmood et al. 2021; Ullah et al. 2020a, 2018; Verma and Mergíó 2020, 2021; Zeng et al. 2020; 2022a; Zhang et al. 2012). Further, we will also try to invent some new theories, methods, and operators under the consideration of the above works are to enhance the quality of the diagnosed works.

Abbreviations

FS: Fuzzy set; IFS: Intuitionistic fuzzy set; PFS: Pythagorean fuzzy set; QROFS: q-rung orthopair fuzzy set; CFS: Complex fuzzy set; CIFS: Complex intuitionistic fuzzy set; CPFS: Complex Pythagorean fuzzy set; CQROFS: Complex q-rung orthopair fuzzy set; IVFS: Interval-valued fuzzy set; IVIFS: Interval-valued intuitionistic fuzzy set; IVPFS: Interval-valued Pythagorean fuzzy set; IVQROFS: Interval-valued q-rung orthopair fuzzy set; CIVIFS: Complex interval-valued intuitionistic fuzzy set; CIVPFs: Complex interval-valued Pythagorean fuzzy set; CIVQROFS: Complex interval-valued q-rung orthopair fuzzy set; CIVQRO2-TL: Complex interval-valued q-rung orthopair 2-tuple linguistic; CIVQRO2-TLS: Complex interval-valued q-rung orthopair 2-tuple linguistic set; CIVQRO2-TLWA: Complex interval-valued q-rung orthopair 2-tuple linguistic weighted averaging; CIVQRO2-TLOWA: Complex interval-valued q-rung orthopair 2-tuple linguistic weighted averaging;
q-rung orthopair 2-tuple linguistic ordered weighted averaging; CIVQRO2-TLHA: Complex interval-valued q-rung orthopair 2-tuple linguistic hybrid averaging; CIVQRO2-TLWG: Complex interval-valued q-rung orthopair 2-tuple linguistic weighted geometric; CIVQRO2-TLOWG: Complex interval-valued q-rung orthopair 2-tuple linguistic ordered weighted geometric; CIVQRO2-TLHG: Complex interval-valued q-rung orthopair 2-tuple linguistic hybrid geometric; MADM: Multi-attribute decision-making

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