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Enhanced framework for Effectiveness Evaluation of Teachers' Digital Leadership with Double-Valued Neutrosophic Number Distance Measures

Huisi Chen[1,2]*, Intan Marfarrina Binti Omar[2]

[1]South China Business College, Guangdong University of Foreign Studies, Guangzhou, 510545, Guangdong, P. R. China

[2]Education Department, University of Malaya, Kuala Lumpur, Malaysia (E-mail: imarfarrina@um.edu.my)

*Corresponding author, E-mail: 112006@gwng.edu.cn

Abstract: The evaluation of the effectiveness of teachers' digital leadership is significant in measuring their leadership abilities and influence in a digital teaching environment. Through assessment, we can understand the impact of teachers in areas such as technology integration, innovative teaching methods, and improving student engagement. This not only helps promote teachers' professional development but also provides a basis for educational institutions to optimize digital teaching strategies, ensuring students receive a higher quality learning experience and fostering sustainable development in educational digitalization. The effectiveness evaluation of teachers' digital leadership is regarded as the defined multiple-attribute decision-making (MADM). Recently, the EDAS method was utilized to cope with MADM. The double-valued neutrosophic sets (DVNSs) are utilized as a technique for characterizing fuzzy information during the effectiveness evaluation of teachers' digital leadership. In this study, double-valued neutrosophic number EDAS (DVNN-EDAS) technique is administrated for MADM in light with DVNN Euclidean distance (DVNNED). Finally, numerical example for effectiveness evaluation of teachers' digital leadership is put forward to show the DVNN- EDAS technique. The major contribution of this study is administrated: (1) DVNN-EDAS technique is administrated for MADM in light with DVNNED; (2) The objective weights are considered through average technique; (3) numerical example for effectiveness evaluation of teachers' digital leadership and some comparative analysis are administrated to verify the DVNN-EDAS technique.

Keywords: Multiple-attribute decision-making (MADM); double-valued neutrosophic sets (DVNSs); EDAS technique; teachers' digital leadership

1. Introduction

The concept of digital leadership has evolved across various fields over the past decade. Shu [1] first introduced the idea of "digital publishing leadership," a concept that emerged at the 2010 Frankfurt Book Fair and explored how the digital age, with its rapid technological advancements and diverse market demands, required publishers to innovate their management strategies. This early work laid the groundwork for understanding the need for leadership adaptation in digital environments. Yang [2] expanded on the application of digital leadership in higher education, particularly for presidents of private universities. In her study, she emphasized the necessity for university leaders to enhance decision-making and entrepreneurial abilities to meet the challenges posed by the digital era and highlighted that the rapid pace of technological and educational change required leaders to adopt flexible and innovative mindsets. Duan [3] then explored the core competencies required for leadership in the digital age, identifying four key abilities: mindful transformation, professional expertise, environmental awareness, and interactive resonance and proposed that leaders needed to continually update their knowledge and skills, distribute decision-making, and foster a culture of experimentation to thrive in a rapidly changing digital landscape. Building on this foundation, Xue [4] examined leadership in the context of the digital economy. He argued that managers in the digital economy must not only possess traditional leadership skills but also innovate on multiple levels to adapt to the fast-evolving business environment. In 2022, several studies focused on the role of digital leadership within educational institutions. Wang [5] emphasized the importance of teachers' digital leadership in universities, proposing a four-tiered framework that included technological application, teaching practice, professional development, and cultural construction and highlighted the need for comprehensive training and digital community building to enhance teachers' digital leadership abilities. Similarly, He and Ni [6] stressed the importance of improving university teachers' digital leadership by updating their digital knowledge, creating a conducive digital environment, and encouraging active participation in digital teaching practices. Additionally, Fan, Yu and Qiu [7] constructed a six-dimensional model of digital leadership for university teachers, focusing on areas such as digital insight and teaching organization. Their empirical study verified the model's effectiveness and proposed strategies for improving digital leadership in universities. In 2023, Fu [8] examined the development challenges of digital leadership in vocational colleges, proposing strategies such as enhancing digital literacy, promoting digital governance, and innovating evaluation models to improve leadership capabilities. Shan [9] further explored how university leaders could leverage digital leadership to drive institutional development, suggesting that data analysis could play a crucial role in formulating strategies. The most recent studies have focused on diverse applications of digital leadership. Wang and Liu [10] analyzed how the metaverse could influence digital leadership development, identifying potential conflicts in digital thinking, cognition, and skills within this virtual space. In the field of special education, Li and Yang [11] explored how digital leadership, mediated by organizational innovation and work engagement, positively affected teacher job satisfaction. Lastly, Mou and Fan [12] outlined a progressive framework for building digital leadership in government officials, emphasizing digital knowledge, communication, and service capabilities.

MADM is a decision-making method used to address problems that involve selecting from multiple options based on several evaluation criteria or attributes[13-16]. In complex decision-making scenarios, different alternatives are evaluated using independent attributes such as quality, cost, and efficiency. Since the importance of each attribute may vary, different weights are assigned accordingly[17, 18]. The goal of MADM is to determine the optimal solution or rank the alternatives by synthesizing the performance across all attributes. MADM methods are widely applied in various fields, such as management, engineering, and education. Common MADM techniques include AHP, TOPSIS, VIKOR, and EDAS, which effectively handle uncertainty and fuzziness in decision processes. Through systematic evaluation, MADM helps decision-makers make optimal choices or reasonable judgments under complex conditions. The effectiveness evaluation of teachers' digital leadership is regarded as a MADM problem. In recent years, EDAS [19] and entropy approach [20] have been widely used to address MADM challenges. Double-Valued Neutrosophic Sets (DVNS) [21] provide an effective technique for characterizing fuzzy information, making them suitable for handling uncertainty in the evaluation of teachers' digital leadership effectiveness. However, although EDAS [19] and the entropy approach [20] have been applied individually in the MADM domain, there has been little to no research integrating these methods under the DVNS framework. To fill this gap, this study proposes a new model based on DVNN-EDAS to address MADM within the context of DVNSs. The model is validated through a numerical example focused on the effectiveness evaluation of teachers' digital leadership, followed by a comparative analysis to further demonstrate its effectiveness.

The primary motivations and contributions of this study are summarized as follows:

(1) A novel MADM model based on the integration of EDAS method within the DVNS framework is proposed. This model leverages the strengths of both methods to effectively address uncertainty in multi-attribute decision-making.

(2) Objective attribute weights are determined using the average method, ensuring the scientific and reasonable distribution of weights, thereby enhancing the accuracy of the decision-making process.

(3) This paper introduces the DVNN-EDAS technique for the first time in the context of evaluating teachers' digital leadership effectiveness, offering an innovative solution to complex decision-making problems in this field.

(4) To validate the model's effectiveness, a specific numerical example is provided, along with a comparative analysis that demonstrates the superiority and application potential of the DVNN-EDAS model in handling MADM problems.

Through these contributions, this paper provides new technical support for the evaluation of teachers' digital leadership effectiveness and brings innovative solutions to the field of multi-attribute decision-making.

The structure of this study is outlined as follows: Sec. 2 introduces DVNSs, explaining their role in handling uncertainty in decision-making. Sec. 3 discusses the application of the DVNN-EDAS technique for MADM, detailing its methodology within the DVNS framework. In Sec. 4, a numerical example is presented to demonstrate the use of DVNN-EDAS in evaluating blended teaching quality, followed by a comparative analysis to assess the model's performance. The study concludes in Sec. 5, summarizing key findings and potential areas for future research.

2. Preliminaries

Kandasamy [21] administrated the DVNSs based on the neutrosophic sets[22-26].

Definition 1 [21]. The DVNSs RA in Θ is put forward:

$$A=\left\{\left(\theta,T_A\left(\theta\right),IT_A\left(\theta\right),IF_A\left(\theta\right),F_A\left(\theta\right)\right)\middle|\theta\in\Theta\right\}. \tag{1}$$

where $T_A\left(\theta\right)$ is truth-membership, $IT_A\left(\theta\right)$ is indeterminacy leaning towards $T_A\left(\theta\right)$, $IF_A\left(\theta\right)$ is indeterminacy leaning towards $F_A\left(\theta\right)$, $F_A\left(\theta\right)$ is falsity-membership, $T_A\left(\theta\right),IT_A\left(\theta\right),IF_A\left(\theta\right),F_A\left(\theta\right)\in\left[0,1\right]$, and

$$0\le T_A\left(\theta\right)+IT_A\left(\theta\right)+IF_A\left(\theta\right)+F_A\left(\theta\right)\le 4. \tag{2}$$

The DVNN is expressed as $RA=\left(T_A,T_A,IF_A,F_A\right)$, where $T_A,IT_A,IF_A,F_A\in\left[0,1\right]$, $0\le T_A+IT_A+IF_A+F_A\le 4$.

Definition 2[21]. Let $RA=\left(T_A,T_A,IF_A,F_A\right)$ be the DVNN, the score value is administrated:

$$SV\left(RA\right)=\frac{\left(2+T_A+IT_A-IF_A-F_A\right)}{4},\ SV\left(RA\right)\in\left[0,1\right]. \tag{3}$$

Definition 3[21]. Let $RA=\left(T_A,T_A,IF_A,F_A\right)$ be the DVNN, the accuracy value is administrated:

$$AV\left(RA\right)=\frac{\left(T_A+IT_A+IF_A+F_A\right)}{4},\ AV\left(RA\right)\in\left[0,1\right]. \tag{4}$$

The order for DVNNs is administrated.

Definition 4[21]. Let $RA=\left(T_A,T_A,IF_A,F_A\right)$ and $RB=\left(T_B,T_B,IF_B,F_B\right)$, $SV\left(RA\right)=\frac{\left(2+T_A+IT_A-IF_A-F_A\right)}{4}$, $SV\left(RB\right)=\frac{\left(2+T_B+IT_B-IF_B-F_B\right)}{4}$, $AV\left(RA\right)=\frac{\left(T_A+IT_A+IF_A+F_A\right)}{4}$, $AV\left(RB\right)=\frac{\left(T_B+IT_B+IF_B+F_B\right)}{4}$, if $SV\left(RA\right)<SV\left(RB\right)$, $RA<RB$; if $SV\left(RA\right)=SV\left(RB\right)$, (1)if $AV\left(RA\right)=AV\left(RB\right)$, $RA=RB$; (2) if $AV\left(RA\right)<AV\left(RB\right)$, $RA<RB$.

Definition 5[21]. Let $RA=\left(T_A,T_A,IF_A,F_A\right)$ and $RB=\left(RT_B,RT_B,RIF_B,RF_B\right)$ be two DVNNs, the operations are administrated:

(1) $RA \oplus RB = \left(T_A + T_B - T_A T_B, IT_A + IT_B - IT_A IT_B, IF_A IF_B, F_A F_B\right);$

(2) $RA \otimes RB = \left(T_A T_B, IT_A IT_B, IF_A + IF_B - IF_A IF_B, F_A + F_B - F_A F_B\right);$

(3) $\lambda RA = \left(1-\left(1-T_A\right)^{\lambda}, 1-\left(1-IT_A\right)^{\lambda}, \left(IF_A\right)^{\lambda}, \left(F_A\right)^{\lambda}\right), \lambda > 0;$

(4) $\left(RA\right)^{\lambda} = \left(\left(T_A\right)^{\lambda}, \left(IT_A\right)^{\lambda}, 1-\left(1-IF_A\right)^{\lambda}, 1-\left(1-F_A\right)^{\lambda}\right), \lambda > 0.$

Definition 6[21]. Let $RA = \left(T_A, T_A, IF_A, F_A\right)$ and $RB = \left(RT_B, RT_B, RIF_B, RF_B\right)$, the DVNN Euclidean distance (DVNNED) between $RA = \left(RT_A, RT_A, RIF_A, RF_A\right)$ and $RA = \left(RT_A, RT_A, RIF_A, RF_A\right)$ is:

$$DVNNHD\left(RA, RB\right) = \sqrt{\frac{1}{4}\left(\begin{array}{l}\left|RT_A - RT_B\right|^2 + \left|RIT_A - RIT_B\right|^2 \\ +\left|RIF_A - RIF_B\right|^2 + \left|RF_A - RF_B\right|^2\end{array}\right)} \tag{5}$$

3. DVNN- EDAS approach for MADM

The DVNN- EDAS technique is administrated for MADM. Let $RA = \left\{RA_1, RA_2, \cdots, RA_m\right\}$ be alternatives, $RG = \left\{RG_1, RG_2, \cdots, RG_n\right\}$ be attributes with weight rw, where $rw_j \in [0,1], \sum_{j=1}^{n} rw_j = 1$. Suppose that assessed information are DVNNs $RM = \left(RM_{ij}\right)_{m\times n} = \left(T_{ij}, IT_{ij}, IF_{ij}, F_{ij}\right)_{m\times n}$.

Then, DVNN- EDAS technique is put forward MADM (See Figure 1).

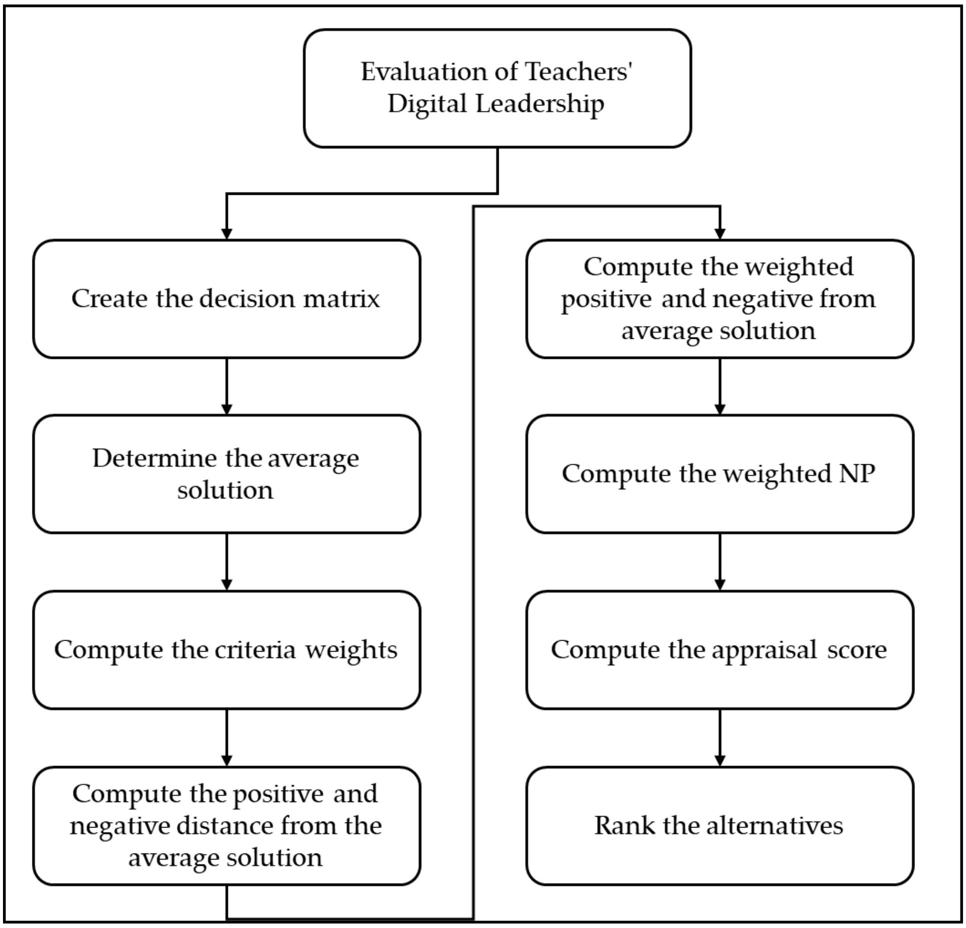

Figure 1. DVNN-EDAS technique for MADM in line with Euclidean distance and Logarithmic distance

Step 1. Create the decision matrix.

$$X = \begin{bmatrix} q_{11} & \cdots & q_{1n} \\ \vdots & \ddots & \vdots \\ q_{m1} & \cdots & q_{mn} \end{bmatrix} \quad (6)$$

Step 2. Determine the average solution.

$$R_j = \frac{\sum_{i=1}^{m} q_{ij}}{m} \quad (7)$$

Where $i = 1, \dots, m; j = 1, \dots, n$

Step 3. Compute the positive and negative distance from the average solution.

$$U_{ij} = \frac{\max\left(0, \left(q_{ij} - R_j\right)\right)}{R_j} \quad (8)$$

$$U_{ij} = \frac{\max\left(0, \left(R_j - q_{ij}\right)\right)}{R_j} \quad (9)$$

$$NU_{ij} = \frac{\max\left(0, \left(R_j - q_{ij}\right)\right)}{R_j} \quad (10)$$

$$NU_{ij} = \frac{\max\left(0, \left(q_{ij} - R_j\right)\right)}{R_j} \quad (11)$$

Step 4. Compute the weighted positive and negative from average solution.

$$P_i = \sum_{j=1}^{n} U_{ij} W_j \tag{12}$$

$$NP_i = \sum_{j=1}^{n} NU_{ij} W_j \tag{13}$$

Step 5. Compute the weighted NP.

$$D_i = \frac{P_i}{\max(P_i)} \tag{14}$$

$$ND_i = \frac{NP_i}{\max(NP_i)} \tag{15}$$

Step 6. Compute the appraisal score.

$$Z_i = 0.5 * (D_i + ND_i) \tag{6}$$

Step 7. Rank the alternatives.

4. Example study and comparative analysis

The evaluation of teachers' digital leadership effectiveness is a comprehensive assessment of their leadership abilities and impact on teaching in a digital education environment. As educational digitalization continues to advance, teachers are not only required to master digital technologies but also to possess the ability to lead and drive digital teaching reform. Digital leadership is reflected not only in teachers' use of technological tools but also in their performance in promoting teaching innovation, enhancing student engagement, and optimizing learning outcomes in a digital environment. Therefore, evaluating the effectiveness of teachers' digital leadership is of great importance. First, the evaluation helps educational institutions gain a comprehensive understanding of teachers' performance in the process of digital transformation, identifying their strengths and weaknesses. Through assessing their abilities in integrating digital resources, utilizing online teaching platforms, and making data-driven teaching decisions, educational administrators can provide targeted professional development opportunities, such as training or technical support, to enhance teachers' digital leadership. Second, the evaluation contributes to the improvement of teaching quality. In a digital teaching environment, teachers' leadership directly impacts classroom interaction, student learning experiences, and learning outcomes. By evaluating effectiveness, more effective teaching strategies can be identified, providing a basis for improving teaching methods. Finally, the evaluation of teachers' digital leadership effectiveness not only aids in individual teachers' professional development but also provides data to support educational policy-making and resource allocation. Overall, this evaluation process establishes a foundation for the sustainable development of educational digitalization and helps cultivate a high-quality teaching workforce that meets the demands of the digital age. The effectiveness evaluation of teachers’ digital leadership is MADM. Six possible local colleges and universities are assessed with 18 attributes as shown in Table 1.

Table 1. The criteria of this study.

	Criteria
C_1	Personalized Learning
C_2	Integration of Technology in Teaching
C_3	Digital Equity

C_4	Feedback and Assessment
C_5	Proficiency with Digital Tools
C_6	Cybersecurity Awareness
C_7	Ethical Use of Technology
C_8	Cultural Sensitivity
C_9	Innovative Teaching Practices
C_{10}	Content Creation and Sharing
C_{11}	Strategic Planning
C_{12}	Student Engagement
C_{13}	Data-Driven Decision Making
C_{14}	Continuous Learning
C_{15}	Mentorship and Support
C_{16}	Change Management
C_{17}	Development of Digital Skills
C_{18}	Improved Learning Outcomes
C_{19}	Collaboration and Teamwork

Step 1. Three experts evaluate the criteria and alternatives as shown in Tale 2.

Step 2. Eq. (7) was used to determine the average solution.

Step 3. Eqs. (8-11) were used to compute the positive and negative distance from the average solution as shown in Table 3.We compute the crietria weights as shown in Figure 2.

Step 4. Eqs. (13 and 13) were used to compute the positive and negative weighing from average solution as shown in Table 3.

Step 5. We compute the weighted NP.

Step 6. We compute the appraisal score.

Step 7. Rank the alternatives as shown in Figure 3.

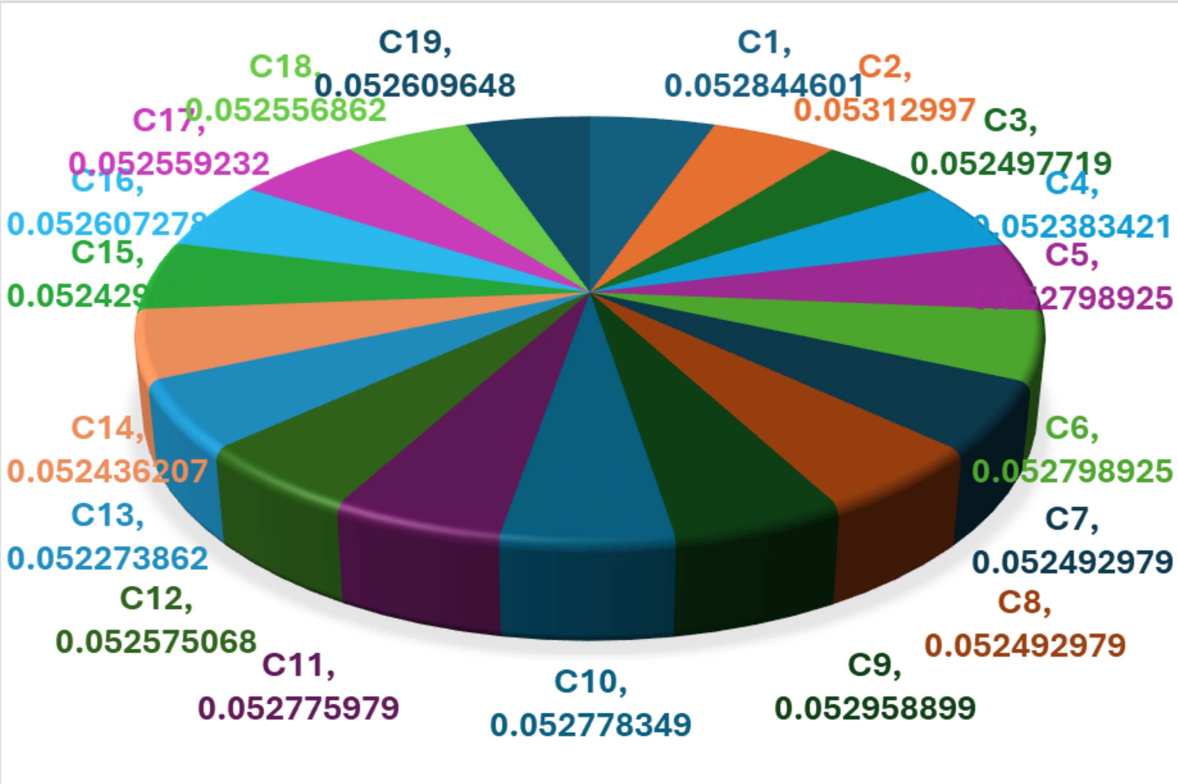

Figure 2. The criteria weights.

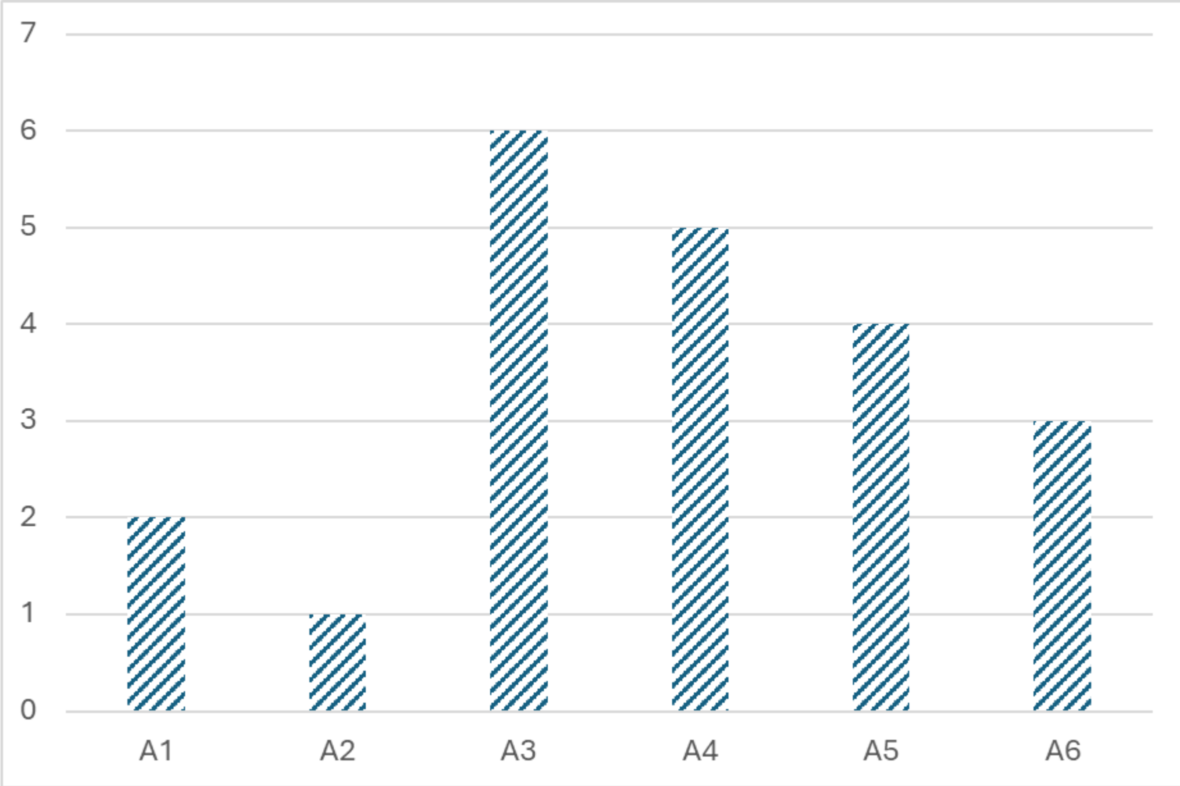

Figure 3. The order of alternatives.

Table 2. The opinions of three experts.

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	(0.9043, 0.0629, 0.0982, 0.0871)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)
C_2	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)
C_3	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)
C_4	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)
C_5	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)
C_6	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)
C_7	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)
C_8	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_9	(0.9043, 0.0629, 0.0982, 0.0871)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)
C_{10}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
C_{11}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{12}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{13}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)
C_{14}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
C_{15}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{16}	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{17}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{18}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)

C_{19}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
	A_1	A_2	A_3	A_4	A_5	A_6
C_1	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)
C_2	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.9043, 0.0629, 0.0982, 0.0871)
C_3	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_4	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)
C_5	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_6	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)
C_7	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)
C_8	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_9	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{10}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
C_{11}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{12}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{13}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{14}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
C_{15}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{16}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{17}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{18}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{19}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
	A_1	A_2	A_3	A_4	A_5	A_6
C_1	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)
C_2	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)
C_3	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.6741, 0.1869, 0.1396, 0.1027)
C_4	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)
C_5	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.8129, 0.1148, 0.0913, 0.0567)
C_6	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)
C_7	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_8	(0.6741, 0.1869, 0.1396, 0.1027)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_9	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)
C_{10}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{11}	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{12}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{13}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{14}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)
C_{15}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{16}	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)
C_{17}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)
C_{18}	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.6741, 0.1869, 0.1396, 0.1027)	(0.8129, 0.1148, 0.0913, 0.0567)
C_{19}	(0.6741, 0.1869, 0.1396, 0.1027)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.7032, 0.2107, 0.1268, 0.1091)	(0.9043, 0.0629, 0.0982, 0.0871)	(0.8129, 0.1148, 0.0913, 0.0567)	(0.7032, 0.2107, 0.1268, 0.1091)

Table 2. The average solution.

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	0.008087	0	0	0	0.021678	0.00842
C_2	0.000834	0.002672	0.007176	0	0	0
C_3	0.000565	0	0.007176	0.029782	0	0.00869
C_4	0	0	0.014477	0.028968	0.00869	0
C_5	0	0.002137	0.014748	0	0	0
C_6	0.019988	0.015313	0	0	0.00842	0.021678
C_7	0.008087	0	0	0	0.021678	0.00842
C_8	0.000834	0.002672	0.007176	0	0	0
C_9	0.000565	0	0.007176	0.029782	0	0.00869
C_{10}	0	0	0.014477	0.028968	0.00869	0
C_{11}	0	0.002137	0.014748	0	0	0
C_{12}	0.019988	0.015313	0	0	0.00842	0.021678
C_{13}	0.008087	0	0	0	0.021678	0.00842
C_{14}	0.000834	0.002672	0.007176	0	0	0
C_{15}	0.000565	0	0.007176	0.029782	0	0.00869
C_{16}	0	0	0.014477	0.028968	0.00869	0
C_{17}	0	0.002137	0.014748	0	0	0
C_{18}	0.019988	0.015313	0	0	0.00842	0.021678
C_{19}	0.008087	0	0	0	0.021678	0.00842

Table 3. The weighted average solution.

	A_1	A_2	A_3	A_4	A_5	A_6
C_1	0.000427	0	0	0	0.001145	0.000445
C_2	4.41E-05	0.000142	0.000377	0	0	0
C_3	2.98E-05	0	0.000377	0.00156	0	0.000459
C_4	0	0	0.00076	0.001517	0.000459	0
C_5	0	0.000114	0.000774	0	0	0
C_6	0.001056	0.000814	0	0	0.000445	0.001145
C_7	0.000427	0	0	0	0.001145	0.000445
C_8	4.41E-05	0.000142	0.000377	0	0	0
C_9	2.98E-05	0	0.000377	0.00156	0	0.000459
C_{10}	0	0	0.00076	0.001517	0.000459	0
C_{11}	0	0.000114	0.000774	0	0	0
C_{12}	0.001056	0.000814	0	0	0.000445	0.001145
C_{13}	0.000427	0	0	0	0.001145	0.000445
C_{14}	4.41E-05	0.000142	0.000377	0	0	0
C_{15}	2.98E-05	0	0.000377	0.00156	0	0.000459
C_{16}	0	0	0.00076	0.001517	0.000459	0
C_{17}	0	0.000114	0.000774	0	0	0

C_{18}	0.001056	0.000814	0	0	0.000445	0.001145
C_{19}	0.000427	0	0	0	0.001145	0.000445

Sensitivity analysis

We change the criteria weights by 20 cases to show the rank of alternatives as shown in Figure 4. We change the criteria weights by 0.07 weights and other criteria have the same weights. Then we applied the DVNN-EDAS method under the different weights. Figure 5 shows the rank of alternatives under the different weights. We show the alternative 3 is the best and alternative 2 is the worst.

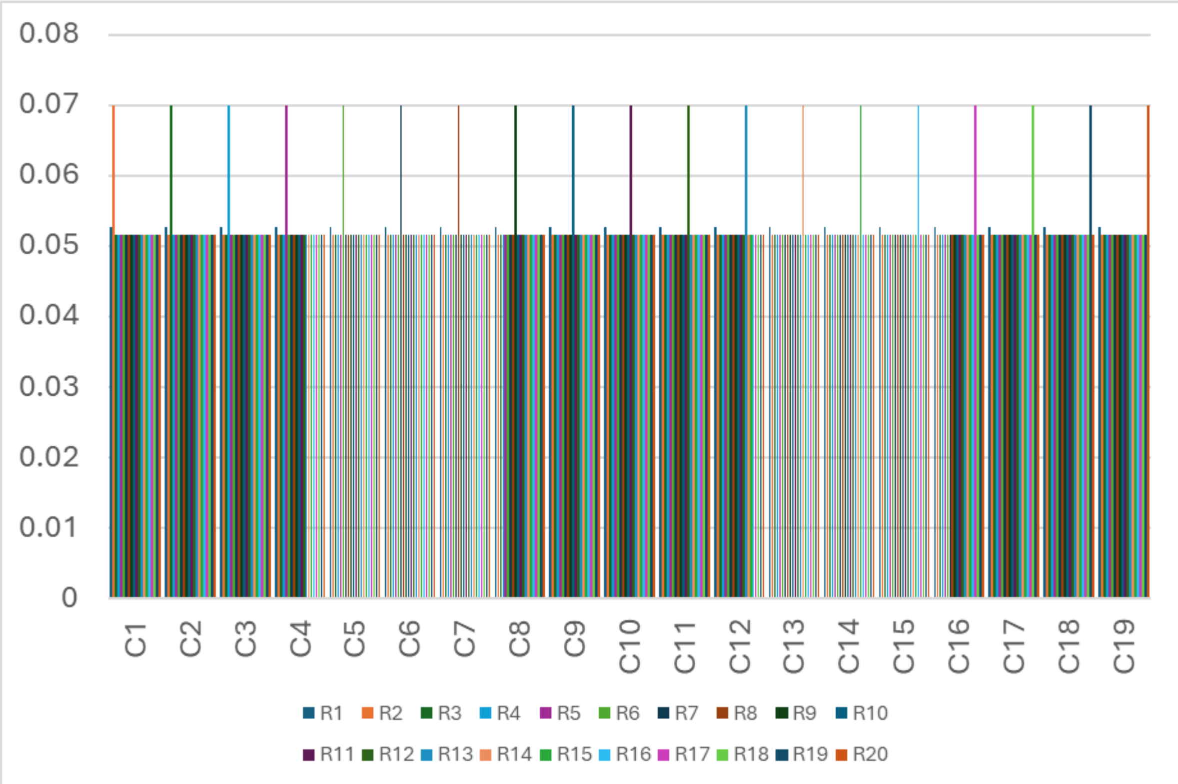

Figure 4. The different weights of criteria

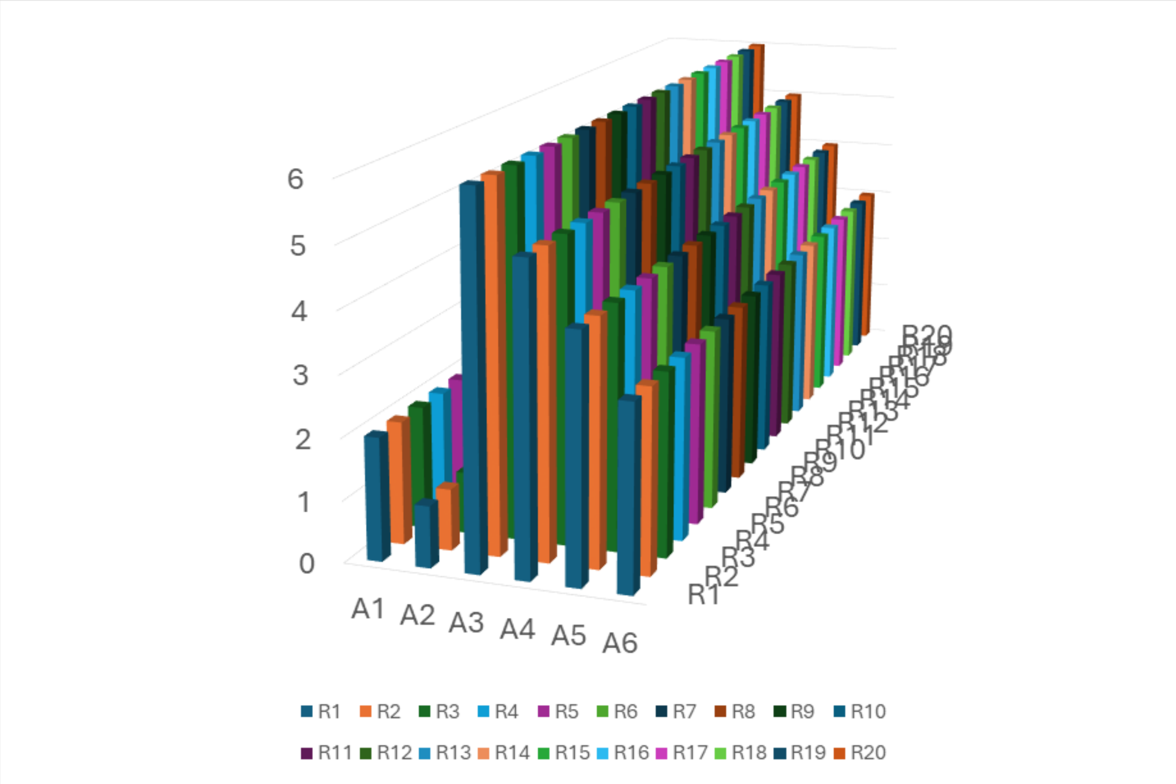

Figure 5. The different rank of alternatives.

5. Conclusion

The evaluation of teachers' digital leadership effectiveness aims to comprehensively assess their leadership abilities and impact on education quality in a digital teaching environment. This evaluation not only focuses on teachers' skills in utilizing technological tools and integrating digital resources but also examines their performance in fostering teaching innovation, enhancing student engagement, and improving classroom interaction. Regular assessments enable educational institutions to identify teachers' strengths and weaknesses in the process of digital transformation, offering targeted training and resource support. Furthermore, the evaluation results provide valuable data for school administrators to optimize teaching strategies, advancing the progress of educational digitization and improving overall teaching quality. Ultimately, this evaluation helps develop a team of teachers with strong digital leadership, ensuring students receive a higher-quality learning experience in an ever-evolving digital age. The effectiveness evaluation of teachers' digital leadership is regarded as MADM. In this study, the DVNN-EDAS technique is applied to MADM using DVNNED. A numerical example evaluating the effectiveness of teachers' digital leadership is provided to demonstrate the DVNN-EDAS method. The key contributions of this research are as follows: (1) the DVNN-EDAS technique is utilized for MADM in conjunction with DVNNED; (2) objective weights are determined through the average method; and (3) a numerical example along with comparative analysis is conducted to validate the DVNN-EDAS technique.

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