NSS

Neutrosophic Sets and Systems, Vol. 79, 2025

University of New Mexico

Neutrosophic Decision Framework for Performance Analysis in Construction Project Management Using the EVAMIX Method

Jiao Wang[1,2]*

[1]Department of Construction Engineering, Guizhou Communications Polytechnic University, Guizhou, China

[2]School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia

*Corresponding author, E-mail: wangjiaoshirley@student.usm.my

Abstract: The performance evaluation of construction project management is the process of comprehensively assessing the effectiveness and efficiency of project management based on key indicators such as cost, schedule, quality, and safety. Through quantitative analysis and comprehensive evaluation, it identifies strengths and weaknesses in management, ensuring the achievement of project goals and providing references for future improvements. This evaluation not only helps optimize resource allocation but also enhances the overall level of project management, ensuring the project is completed on time, with quality, and efficiently. The performance evaluation of construction project management is multiple-attribute decision-making (MADM). Currently, the EVAMIX approach is employed to implement MADM. The type-2 neutrosophic sets (T2NSs) are administrated as an efficient approach for manipulating uncertain information during the performance evaluation of construction project management. In this paper, the type-2 neutrosophic number EVAMIX (T2NN-EVAMIX) approach is administrated for MADM. The average approach is to put forward weight information with T2NSs. Finally, a numerical example for performance evaluation of construction project management is administrated and some efficient comparisons are found to verify the T2NN-EVAMIX approach. The major contribution of this paper is administrated: (1) The average approach is utilized to manage the weight numbers based on T2NSs; (2) the T2NN-EVAMIX approach is administrated for MADM under T2NSs; (3) Finally, a numerical example for performance evaluation of construction project management is administrated and (4) some comparisons are administrated to show some advantages of T2NN-EVAMIX approach.

Keywords: Multiple attribute decision making (MADM); type-2 neutrosophic sets (T2NSs); T2NN-EVAMIX; performance evaluation of construction project management

1. Introduction

In recent years, rapid economic growth has fueled a continuous increase in railway transportation mileage and government investment in railway construction [1]. To achieve the desired outcomes of railway engineering projects, effective project management is crucial. It's a critical factor influencing the quality of railway infrastructure.

Railway engineering construction is a complex process influenced by various factors, including personnel, materials, equipment, technology, environment, and construction timelines.

Adverse conditions such as geographical constraints and weather patterns also pose significant challenges [2]. Implementing scientific and reasonable project management measures is essential to mitigate these challenges and enhance the quality of railway engineering projects.
Selecting the appropriate management model for specific railway projects requires careful comparison and analysis of existing project management methods to meet expected standards.
Railway construction offers substantial social and economic benefits, making it a key investment target for national and local governments [3]. Supported by national policies, railway construction has achieved remarkable progress. However, challenges persist:
The absence of a comprehensive theoretical system for railway project management contributes to inconsistencies in management capabilities, hindering overall effectiveness.
The mismatch between project management and construction needs: This disparity negatively impacts the quality of railway engineering projects and needs urgent attention from government departments and construction units.
The current investment management system needs better adaptability to accommodate diverse investment sources, channels, and methods. Some projects exhibit inappropriate management practices, and investment behaviors during construction are not accurately recognized as investment property rights [4, 5].
Factors such as the sense of responsibility among investors, slow improvement in management expertise, and the effectiveness of bidding management personnel and supervision engineers can negatively impact project quality [6, 7, 8].
Insufficient supervision and management can lead to projects failing to meet quality standards, hindering effectiveness [9, 10]. Furthermore, corruption, high investment costs, and low quality remain concerns in some railway engineering projects.

1.1 Addressing the Challenges

To enhance the quality and efficiency of railway engineering projects, several steps are crucial:
Develop a comprehensive theoretical framework: A robust theoretical system for railway project management will provide a standardized approach, improve consistency, and enhance effectiveness.
Align project management with construction requirements: Bridging the gap between management practices and construction needs is vital to ensure project quality and meet deadlines [11, 12].
Improve the investment management system: The system should be adapted to accommodate diverse investment patterns, ensure accurate recognition of investment property rights, and promote self-investment control, risk management, and sustainable development.
Strengthen oversight and accountability: Increased supervision and management are essential to ensure project quality, control costs, and prevent corruption.
By addressing these challenges, railway engineering projects can effectively contribute to improving China's railway transportation network and support economic growth.

1.2 Performance Evaluation

Performance evaluation of construction project management is a Multi-Attribute Decision Making (MADM) problem. The EVAMIX approach [15-17] is currently used to implement

MADM. Type-2 Neutrosophic Sets (T2NSs) [18] offer an efficient technique for handling fuzzy information in performance evaluation.

This study employs the T2NN-EVAMIX approach for MADM under T2NSs. The average approach is used to determine weight information with T2NSs. A numerical example for performance evaluation of construction project management is presented, and comparisons are made to validate the T2NN-EVAMIX approach.

1.3 Paper Organization

Section 2 introduces T2NSs.

Section 3 presents the MADM based on the T2NN-EVAMIX approach.

Section 4 outlines the development criteria.

Section 5 provides a numerical example of performance evaluation in construction project management.

Section 6 concludes the study.

2. Type-2 Neutrosophic Numbers Definitions

We define the operations of the Type-2 Neutrosophic numbers (T2NNs) [20,21] as:

Definition 2.1 T2NN can be defined as:

T2NN can be defined as

$Y = \{(x, A_Y(x), B_Y(x), C_Y(x)) | \, x \in X\};\ A_Y(x) = \left(A_{A_Y}(x), A_{B_Y}(x), A_{C_Y}(x)\right)$

$;B_Y(x) = \left(B_{A_Y}(x), B_{B_Y}(x), B_{C_Y}(x)\right);\ C_Y(x) = \left(C_{A_Y}(x), C_{B_Y}(x), C_{C_Y}(x)\right)$

$A_Y(x) = (\, A_Y^1(x), A_Y^2(x), A_Y^3(x));\ B_Y(x) = (\, B_Y^1(x), B_Y^2(x), B_Y^3(x));\ C_Y(x) = (\, C_Y^1(x), C_Y^2(x), C_Y^3(x))$

Where $A_Y(x), B_Y(x), C_Y(x) \to [0,1]$ and $0 \leq A_Y^1(x) + B_Y^1(x) + C_Y^1(x) \leq 3$

Definition 2.2. We can define two T2NNs as:

$$Y_1 = \left(\left(A_{A_{Y_1}}(x), A_{B_{I_{Y_1}}}(x), A_{C_{Y_1}}(x)\right), \left(B_{A_{Y_1}}(x), B_{B_{Y_1}}(x), B_{C_{Y_1}}(x)\right), \left(C_{A_{Y_1}}(x), C_{B_{Y_1}}(x), C_{C_{Y_1}}(x)\right)\right)$$

$$Y_2 = \left(\left(A_{A_{Y_2}}(x), A_{B_{Y_2}}(x), A_{C_{Y_2}}(x)\right), \left(B_{A_{Y_2}}(x), B_{B_{Y_2}}(x), B_{C_{Y_2}}(x)\right), \left(C_{A_{Y_2}}(x), C_{B_{Y_2}}(x), C_{C_{Y_2}}(x)\right)\right)$$

Definition 2.3. Some of two T2NNS as:

$$Y_1 \oplus Y_2 = \left\{ \begin{array}{c} \left(\begin{array}{c} A_{A_{Y_1}}(x) + A_{A_{Y_2}}(x) - A_{A_{Y_1}}(x) A_{A_{Y_2}}(x), \\ A_{B_{Y_1}}(x) + A_{B_{I_{Y_2}}}(x) - A_{B_{Y_1}}(x) A_{B_{Y_2}}(x), \\ A_{C_{Y_1}}(x) + A_{C_{Y_2}}(x) - A_{C_{Y_1}}(x) A_{C_{Y_2}}(x) \end{array} \right), \\ \left(B_{A_{Y_1}}(x) B_{A_{Y_2}}(x), B_{B_{Y_1}}(x) B_{B_{Y_2}}(x), B_{C_{Y_1}}(x) B_{C_{Y_2}}(x)\right), \\ \left(C_{A_{Y_1}}(x) C_{A_{Y_2}}(x), C_{B_{Y_1}}(x) C_{B_{Y_2}}(x), C_{C_{Y_1}}(x) C_{C_{Y_2}}(x)\right) \end{array} \right\} \quad (1)$$

Definition 2.4. Multiplication of two T2NNS as:

$$Y_1 \otimes Y_2 = \left\{ \begin{array}{c} \left(A_{A_{Y_1}}(x)A_{A_{Y_2}}(x), A_{B_{Y_1}}(x)A_{B_{Y_2}}(x), A_{C_{Y_1}}(x)A_{C_{Y_2}}(x)\right), \\ \left(\begin{array}{c} B_{A_{Y_1}}(x) + B_{A_{Y_2}}(x) - B_{A_{Y_1}}(x)B_{A_{Y_2}}(x), \\ B_{B_{Y_1}}(x) + B_{B_{Y_2}}(x) - B_{B_{Y_1}}(x)B_{B_{Y_2}}(x), \\ B_{C_{Y_1}}(x) + B_{C_{Y_{12}}}(x) - B_{C_{Y_1}}(x)B_{C_{Y_2}}(x) \end{array}\right), \\ \left(\begin{array}{c} C_{A_{Y_1}}(x) + C_{A_{Y_2}}(x) - C_{A_{Y_1}}(x)C_{A_{Y_2}}(x), \\ C_{B_{Y_1}}(x) + C_{B_{Y_2}}(x) - C_{B_{Y_1}}(x)C_{B_{Y_2}}(x), \\ C_{C_{Y_1}}(x) + C_{C_{Y_2}}(x) - C_{C_{Y_1}}(x)C_{C_{Y_2}}(x) \end{array}\right) \end{array} \right\} \quad (2)$$

Definition 2.5. Multiplication of constant by one T2NNS as:

$$\omega Y_1 = \left\{ \begin{array}{c} \left(\begin{array}{c} \left(1 - \left(1 - A_{A_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - A_{B_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - A_{C_{Y_1}}(x)\right)^{\omega}\right) \end{array}\right), \\ \left(\left(B_{A_{Y_1}}(x)\right)^{\omega}, \left(B_{B_{Y_1}}(x)\right)^{\omega}, \left(B_{C_{Y_1}}(x)\right)^{\omega}\right), \\ \left(\left(C_{A_{Y_1}}(x)\right)^{\omega}, \left(C_{B_{Y_1}}(x)\right)^{\omega}, \left(C_{C_{Y_1}}(x)\right)^{\omega}\right) \end{array} \right\} \quad (3)$$

Definition 2.6. Power of consent by one T2NNS as:

$$Y_1^{\omega} = \left\{ \begin{array}{c} \left(\left(\left(A_{A_{Y_1}}(x)\right)^{\omega}, \left(A_{B_{Y_1}}(x)\right)^{\omega}, \left(A_{C_{Y_1}}(x)\right)^{\omega}\right)\right), \\ \left(\left(\left(\begin{array}{c} \left(1 - \left(1 - B_{A_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - B_{B_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - B_{C_{Y_1}}(x)\right)^{\omega}\right) \end{array}\right)\right)\right), \\ \left(\left(\left(\begin{array}{c} \left(1 - \left(1 - C_{A_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - C_{B_{Y_1}}(x)\right)^{\omega}\right), \\ \left(1 - \left(1 - C_{C_{Y_1}}(x)\right)^{\omega}\right) \end{array}\right)\right)\right) \end{array} \right\} \quad (4)$$

Definition 2.7. The score function is:

$$S(Y_1) = \frac{1}{12} * \left(\begin{array}{c} 8 + \left(A_{A_{Y_1}}(x) + 2 * A_{B_{Y_1}}(x) + A_{C_{Y_1}}(x)\right) + \\ \left(B_{A_{Y_1}}(x) + 2 * B_{B_{Y_1}}(x) + B_{C_{Y_1}}(x)\right) + \\ \left(C_{A_{Y_1}}(x) + C_{B_{Y_1}}(x) + C_{C_{Y_1}}(x)\right) \end{array} \right) \quad (5)$$

3. T2NN- EVAMIX Approach

This section shows the steps of the T2NN- EVAMIX

Step 3.1. Evaluate the criteria and alternatives.

T2NN is used to evaluate the criteria and alternatives. Then we used the score function to obtain one value, then we aggregate these values into one matrix. Then we compute the criteria weights.

Step 3.2. Determine the superiority rate of alternatives.

The criteria are divided into quantitative and qualitative criteria. Then the superiority rate of alternatives is computed as:

$$u_{ii'} = \left[\sum_{j\in O}\left\{w_j \times sgn\left(t_{ij} - t_{i'j}\right)\right\}^c\right]^{1/c}; i, i' \in \{1, \dots, m\}, j = 1, \dots, n \quad (6)$$

$$n\left(t_{ij} - t_{i'j}\right) = \begin{Bmatrix} -1 & if t_{ij} < t_{i'j} \\ 0 & if t_{ij} = t_{i'j} \\ +1 & if t_{ij} > t_{i'j} \end{Bmatrix} \quad (7)$$

Step 3.3. Determine the differential matrix of ordinal criteria.

$$R_{ii'} = \frac{(u_{ii'} - \min u_{ii'})}{\max u_{ii'} - \min u_{ii'}} \quad (8)$$

Step 4.4. Determine the differential matrix of cardinal criteria.

$$F_{ii'} = \frac{(u_{ii'} - \min u_{ii'})}{\max u_{ii'} - \min u_{ii'}} \quad (9)$$

Step 5.5. Compute the total dominance

$$D_{ii'} = w_o R_{ii'} + w_c F_{ii'} \quad (10)$$

$$\text{Where } w_o = \sum_{j\in o} w_j \text{ and } w_o = \sum_{j\in c} w_j \quad (11)$$

$$N_i = \left[\sum_{i'} \frac{D_{i'i}}{D_{ii'}}\right]^{-1} \quad (12)$$

Step 3.6. Rank the alternatives.

4. Description of the Criteria

Below is a detailed list of 20 evaluation criteria for construction project management. Each criterion is marked as quantitative (Q) or qualitative (Ql) and ranked in order of importance, from highest to lowest.

1. Time Management (Q)

Ability to meet deadlines and complete milestones according to the project schedule.

2. Budget Adherence (Q)

The extent to which the project remains within the approved budget.

3. Quality of Work (Ql)

Compliance with design specifications and industry standards.

4. Risk Management (Ql)

Effectiveness in identifying, mitigating, and addressing risks throughout the project.

5. Safety Management (Ql)

Implementation of safety protocols and practices to ensure a secure working environment.

6. Stakeholder Satisfaction (Ql)

Degree of satisfaction among clients, contractors, and other stakeholders regarding project outcomes.

7. Resource Utilization Efficiency (Q)

Optimal use of manpower, materials, and machinery.

8. Communication Effectiveness (Ql)

Clarity, timeliness, and accuracy of information sharing between project teams and stakeholders.

9. Contract Management (Ql)

Adherence to contractual terms and conditions, including compliance with timelines and payment schedules.

10. Environmental Sustainability (Ql)

Integration of eco-friendly practices in construction, including waste reduction and energy efficiency.

11. Compliance with Regulations (Ql)

Adherence to local laws, codes, and regulatory requirements.

12. Innovation and Technology Integration (Ql)

Use of advanced tools and technology, such as Building Information Modeling (BIM) or project management software.

13. Supply Chain and Logistics Efficiency (Q)

Effectiveness in procurement, transportation, and delivery of materials to prevent delays.

14. Change Management (Ql)

Ability to handle changes in project scope or conditions without significantly affecting project goals.

15. Team Productivity (Q)

Assessment of workforce efficiency and output during project execution.

16. Cost-Effectiveness (Q)

Evaluates the balance between project expenditures and the value delivered.

17. Facility and Equipment Maintenance (Q)

Timely upkeep of machinery and equipment to prevent disruptions.

18. Feedback Mechanisms (Ql)

Systems in place to gather and act on feedback from stakeholders and teams.

19. Cultural and Workforce Inclusivity (Ql)

Measures to ensure diversity, equity, and inclusion in team composition and decision-making processes.

20. Post-Project Evaluation and Learning (Ql)

Review of project outcomes to identify successes, lessons learned, and areas for improvement.

Table 1. T2NN decision matrix.

	A_1	A_2	A_3	A_4	A_5
C_1	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_2	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_3	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_4	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_5	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_6	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_7	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))
C_8	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_9	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_{10}	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{11}	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{12}	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_{13}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{14}	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))
C_{15}	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_{16}	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_{17}	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{18}	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{19}	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_{20}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))

	A_1	A_2	A_3	A_4	A_5
C_1	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_2	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_3	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_4	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_5	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_6	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_7	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))
C_8	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_9	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_{10}	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{11}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{12}	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_{13}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{14}	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))
C_{15}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_{16}	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{17}	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{18}	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{19}	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_{20}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))

	A_1	A_2	A_3	A_4	A_5
C_1	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_2	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))
C_3	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_4	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_5	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))
C_6	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_7	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_8	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))
C_9	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{10}	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.35,0.35,0.10], (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{11}	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{12}	([0.60,0.45,0.50], (0.20,0.15,0.25), (0.10,0.25,0.15))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{13}	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{14}	([0.95,0.90,0.95], (0.10,0.10,0.05), (0.05,0.05,0.05))	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{15}	([0.20,0.20,0.10], (0.65,0.80,0.85), (0.45,0.80,0.70))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))	([0.50,0.30,0.50], (0.50,0.35,0.45), (0.45,0.30,0.60))	([0.70,0.75,0.80], (0.15,0.20,0.25), (0.10,0.15,0.20))	([0.40,0.45,0.50], (0.40,0.45,0.50), (0.35,0.40,0.45))

C_{16}	((0.35,0.35,0.10), (0.50,0.75,0.80), (0.50,0.75,0.65))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{17}	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))	((0.20,0.20,0.10), (0.65,0.80,0.85), (0.45,0.80,0.70))	((0.35,0.35,0.10), (0.50,0.75,0.80), (0.50,0.75,0.65))
C_{18}	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))	((0.20,0.20,0.10), (0.65,0.80,0.85), (0.45,0.80,0.70))
C_{19}	((0.60,0.45,0.50), (0.20,0.15,0.25), (0.10,0.25,0.15))	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))
C_{20}	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))	((0.40,0.45,0.50), (0.40,0.45,0.50), (0.35,0.40,0.45))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))	((0.70,0.75,0.80), (0.15,0.20,0.25), (0.10,0.15,0.20))	((0.50,0.30,0.50), (0.50,0.35,0.45), (0.45,0.30,0.60))

5. Application: Performance Evaluation of Construction Projects using the T2NN-EVAMIX Approach

This numerical example demonstrates the performance evaluation of five railway construction projects (A1 through A5) using the T2NN-EVAMIX approach. The evaluation considers multiple attributes (criteria) to determine the most favorable project.

Step 1: Evaluation and Weighting

Type-2 Neutrosophic Sets (T2NSs) were utilized to evaluate the projects against each criterion, as detailed in Table 1. A score function was applied to derive crisp values from the T2NSs, and these values were compiled into a decision matrix. Subsequently, the weights of each criterion were calculated as shown in Tabel 2.

Table .2 The crietria weights.

Synmbol	Weights	Rank
C_1	0.050170987	12
C_2	0.049797215	8
C_3	0.050038958	10
C_4	0.048900906	2
C_5	0.050749311	16
C_6	0.051887363	20
C_7	0.050747451	15
C_8	0.049706096	7
C_9	0.049213312	4
C_{10}	0.049581506	6
C_{11}	0.047491358	1
C_{12}	0.051085891	18
C_{13}	0.051106347	19
C_{14}	0.04930815	5
C_{15}	0.049853002	9
C_{16}	0.050068711	11
C_{17}	0.04896785	3
C_{18}	0.050170987	12
C_{19}	0.050957582	17
C_{20}	0.050197021	14

Step 2: Determining Superiority Rates

Pairwise comparisons of the five alternatives were conducted to determine the superiority rate of each alternative over the others. This involved assessing the performance of each alternative relative to the others for every criterion.

Step 3: Constructing the Differential Matrix for Ordinal Criteria

Ordinal criteria, which are qualitative and can be ranked but not precisely measured, were evaluated. A differential matrix was constructed to represent the performance differences between alternatives based on these ordinal criteria.

Step 4: Constructing the Differential Matrix for Cardinal Criteria

Cardinal criteria, which are quantitative and measurable, were analyzed. A differential matrix was created to illustrate the performance differences between alternatives based on these cardinal criteria.

Step 5: Computing Total Dominance

The information from the differential matrices of both ordinal and cardinal criteria was aggregated to compute the total dominance of each alternative. This measure reflects the overall performance superiority of an alternative considering all criteria.

Step 6: Ranking the Alternatives

Based on the calculated total dominance values, the alternatives were ranked in descending order of preference:

A4 > A3 > A1 > A2 > A5

5.1 Discussion of Results

The performance evaluation of construction project management is a systematic and comprehensive assessment of the key aspects of the management process within construction projects. Its primary purpose is to analyze and assess the effectiveness, efficiency, and outcomes of project management using scientific evaluation methods, ensuring that projects are completed on time, within budget, and meet quality standards, while also providing a basis for improving the management of future projects. Firstly, performance evaluation typically covers several core dimensions, including cost management, schedule control, quality assurance, safety management, and resource utilization. Cost management focuses on evaluating whether the project operates within the budget and whether resources are allocated and used efficiently. Schedule control assesses whether the project progresses as planned and if there are any delays or unreasonable timelines. In terms of quality assurance, the evaluation ensures that the project meets design standards and relevant regulations through inspections and acceptance testing. Safety management ensures that the construction process complies with safety regulations, minimizing the occurrence of accidents. Lastly, the assessment of resource utilization examines whether labor, materials, and financial resources are used efficiently and whether their utilization is maximized. Secondly, construction project management performance evaluation is not merely an assessment of the outcome but also serves as a tool for monitoring and providing feedback throughout the entire management process. By regularly tracking and evaluating the project, potential problems and deficiencies can be identified early, preventing them from accumulating and becoming more severe later in the project. For instance, by evaluating the schedule, adjustments can be made to the construction plan to ensure smooth progress; through cost control evaluation, the risk of budget overruns can be identified and corrective actions taken promptly. Moreover, performance evaluation is often based on quantitative indicators and standards, which can be developed from historical project data, market standards, or industry regulations. For example, cost variance, schedule completion rate, quality compliance rate, and safety incident rate are all important metrics for measuring project management performance. These quantitative indicators allow managers to objectively assess the project's actual situation and develop targeted improvement measures. Finally, the significance of performance evaluation in construction project management lies not only in controlling the current project but also in its guiding role for future projects. By evaluating existing projects, managers can accumulate valuable lessons and experiences that provide a reference for planning and executing future projects. Performance evaluation can also drive innovation in project management techniques, optimize management processes, and enhance the overall management capabilities of the team. In summary, the performance evaluation of construction project management is

a crucial tool for ensuring the successful implementation of projects. Through comprehensive analysis and assessment of the management process, it helps managers identify problems, optimize decision-making, and improve efficiency, thereby maximizing the project's economic and social benefits. However, the performance evaluation of construction project management is MADM.

5.2 Comparative analysis

Then, the T2NN-EVAMIX approach is compared, with the GRA approach [22], VIKOR approach[23], cross-entropy (CE) approach [24], and MABAC approach [19]. The order is administered in Table 3.

Table 3. The order

Approach	Order
MABAC approach	A4>A1>A3>A2>A5
VIKOR approach	A4>A3>A2>A1>A5
GRA approach	A4>A1>A3>A2>A5
CE approach	A4>A3>A2>A1>A5
Our approach	A4>A3>A1>A2>A5

Then, the order similarity coefficients between the GRA approach[22], VIKOR approach[23], cross-entropy (CE) approach [24], MABAC approach [19] and EVAMIX approach were administrated with WS coefficients [25, 26], the WS is administrated in Table 4.

Table 4. The WS coefficient

	Our approach	MABAC approach	VIKOR approach	GRA approach	CE approach
Coefficients	WS	0.9	0.9	0.9	0.9

The WS coefficient shows the order of the T2NN-EVAMIX approach are same as to order of the GRA approach[22], the VIKOR approach[23], the cross-entropy (CE) approach [24], the MABAC approach [19]; the WS coefficient shows the order of T2NN approach are slightly different to order of different approach. This verifies the T2NN-EVAMIX approach is effective. The advantages of the T2NN-EVAMIX approach are administrated by calculating the superiority rate from each alternative.

5. Conclusion

The performance evaluation of construction project management is a systematic and comprehensive assessment of the project management process. It aims to measure the actual effectiveness of management by analyzing multiple dimensions, such as cost control, schedule management, quality assurance, safety, and resource allocation. The evaluation not only focuses on whether the project is completed as planned but also examines the effectiveness of management strategies, the rationality of resource utilization, and the efficiency of team collaboration. Through quantitative indicators and standards, performance evaluation helps identify problems and shortcomings in project management, providing a basis for improving management methods and increasing efficiency. Additionally, it offers valuable insights and references for the planning and implementation of future projects. Ultimately, performance evaluation ensures that projects are completed on time, within budget, and to the desired quality, while also enhancing the management capabilities of the team and improving project operational efficiency. This maximizes both the economic and social benefits of the project. The performance evaluation of construction project management is MADM. Currently, the EVAMIX approach and average approach are employed to implement the MADM. The T2NSs are administrated as an efficient technique for manipulating the fuzzy information during the performance evaluation of construction project management. In this study, the T2NN-EVAMIX approach is administrated for MADM under T2NSs. The average approach is to put forward weight information with T2NSs. Finally, a numerical example for performance evaluation of construction project management is administrated and some efficient comparisons are found to verify the T2NN-EVAMIX approach. The major contribution of this paper is administrated: (1) The average approach is utilized to manage the weight numbers under T2NSs; (2) the T2NN-EVAMIX approach is administrated for MADM under T2NSs; (3) Finally, a numerical example for performance evaluation of construction project management is administrated and (4) some comparisons are administrated to show some advantages of T2NN-EVAMIX approach.

References

[1] S.Y. Hao, L.W. Guo, Application of a combined project financing model - TOBOT in China's railway construction, in: 12th International Conference on Management Science and Engineering, Harbin

Institute Technology Publishers, Incheon, SOUTH KOREA, 2005, pp. 2001-2005.

[2] L.X. Lou, Y.L. Yin, Ieee, Study on Cost Control of Railway Construction Project Based on Hall Three-Dimensional Structure, in: International Conference on Logistics Systems and Intelligent Management, Ieee, Harbin, PEOPLES R CHINA, 2010, pp. 1793-1797.

[3] M. Rosignoli, Industrialized Construction of Large-Scale High Speed Railway Projects: The Modena Bridges in Italy, Struct. Eng. Int., 21 (2011) 392-398.

[4] Y. Zhou, Y.S. Liu, N.G. Guo, A Few Thoughts about Promoting Railway Construction Informationization of Projects Management, in: International Conference on Future Management Science and Engineering (ICFMSE 2011), Information Engineering Research Inst, USA, Bali Island, INDONESIA, 2011, pp. 32-35.

[5] Y.C. Shiau, S.J. Song, W.C. Hsu, Case Study on Disaster Prevention and Rescue for Railway Construction Project, Disaster Adv., 5 (2012) 150-156.

[6] S. Uluöz, S. Düzbasan, M. Camcioglu, E. Yakit, Ankara-Istanbul Railway High-Speed Train Project, Construction of Viaduct V4 of 2400 Meters, in: 6th International Conference on Bridge Maintenance, Safety and Management (IABMAS), Crc Press-Taylor & Francis Group, Stresa, ITALY, 2012, pp. 490-497.

[7] C.L. Wu, D.P. Fang, N. Li, Roles of owners' leadership in construction safety: The case of high-speed railway construction projects in China, Int. J. Proj. Manag., 33 (2015) 1665-1679.

[8] Q. Li, R.K. Liu, Q.X. Sun, F.T. Wang, Research of Automatic Progress Report Generation for Railway Construction Projects in China, Adv. Mech. Eng., 7 (2015) 9.

[9] X.D. Zhao, J.Z. Lu, D.S. Zhang, D.E.P. Inc, LPS Application on Planning Management of Railway Construction Project, in: International Conference on Industrial Engineering and Management Science (ICIEMS), Destech Publications, Inc, Shanghai, PEOPLES R CHINA, 2013, pp. 292-296.

[10] Y.Z. Chang, Y. Yang, S.C. Dong, Comprehensive Sustainability Evaluation of High-Speed Railway (HSR) Construction Projects Based on Unascertained Measure and Analytic Hierarchy Process, Sustainability, 10 (2018) 19.

[11] D. Canca, J.L. Andrade-Pineda, A. De-Los-Santos, P.L. González-R, A quantitative approach for the long-term assessment of Railway Rapid Transit network construction or expansion projects, Eur. J. Oper. Res., 294 (2021) 604-621.

[12] S. Banerjee, P.K. Sikdar, Land Subsidence due to Leakage of Aquitard-aquifer Pore Water in an Under-construction Tunnel of East-West Metro Railway Project, Kolkata, J. Geol. Soc. India, 96 (2020) 467-474.

[13] M. Viturka, V. Paril, M. Farbiak, Evaluation of the usefulness and relevance criteria for high-speed railway route construction projects: case study of Czechia, Geografie, 127 (2022) 299-317.

[14] J.E. Nilsson, The Weak Spot of Infrastructure BCA: Cost Overruns in Seven Road and Railway Construction Projects, J. Benefit-Cost Anal., 13 (2022) 224-246.

[15] E. Chojnacka and D. Górecka, "Evaluating public benefit organizations in Poland with the EVAMIX method for mixed data," *Mult. Criteria Decis. Mak.*, no. 11, pp. 36–50, 2016.

[16] D. Yazır, B. Şahin, and T. L. Yip, "Selection of new design gas carriers by using fuzzy EVAMIX method," *Asian J. Shipp. Logist.*, vol. 37, no. 1, pp. 91–104, 2021.

[17] A. Alinezhad, J. Khalili, A. Alinezhad, and J. Khalili, "EVAMIX method," *New methods Appl. Mult. Attrib. Decis. Mak.*, pp. 59–65, 2019.

[18] M. Deveci, N. Erdogan, U. Cali, J. Stekli, and S. Zhong, "Type-2 neutrosophic number based multi-attributive border approximation area comparison (MABAC) approach for offshore wind farm site

selection in USA," *Eng. Appl. Artif. Intell.*, vol. 103, p. 104311, 2021.

[19] I. Irvanizam, N.N. Zi, R. Zuhra, A. Amrusi, H. Sofyan, An Extended MABAC Method Based on Triangular Fuzzy Neutrosophic Numbers for Multiple-Criteria Group Decision Making Problems, Axioms, 9 (2020) 18.

[20] U. Cali, M. Deveci, S. S. Saha, U. Halden, and F. Smarandache, "Prioritizing energy blockchain use cases using type-2 neutrosophic number-based EDAS," *IEEE Access*, vol. 10, pp. 34260–34276, 2022.

[21] M. Abdel-Basset, M. Saleh, A. Gamal, and F. Smarandache, "An approach of TOPSIS technique for developing supplier selection with group decision making under type-2 neutrosophic number," *Appl. Soft Comput.*, vol. 77, pp. 438–452, 2019.

[22] B. Xie, Modified GRA methodology for MADM under triangular fuzzy neutrosophic sets and applications to blended teaching effect evaluation of college English courses, Soft Computing, (2023) https://doi.org/10.1007/s00500-00023-08891-00506.

[23] J. Wang, G.W. Wei, M. Lu, An Extended VIKOR Method for Multiple Criteria Group Decision Making with Triangular Fuzzy Neutrosophic Numbers, Symmetry-Basel, 10 (2018) 15.

[24] L. Li, Cross-entropy method for efficiency evaluation of integrated development of agriculture and tourism to promote rural revitalization under the triangular fuzzy neutrosophic sets, Journal of Intelligent & Fuzzy Systems, 44 (2023) 6151-6161.

[25] W. Salabun, K. Urbaniak, A New Coefficient of Rankings Similarity in Decision-Making Problems, in: 20th Annual International Conference on Computational Science (ICCS), Springer International Publishing Ag, Amsterdam, NETHERLANDS, 2020, pp. 632-645.

[26] W. Sałabun, J. Wątróbski, A. Shekhovtsov, Are MCDA Methods Benchmarkable? A Comparative Study of TOPSIS, VIKOR, COPRAS, and PROMETHEE II Methods, Symmetry 12 (2020) 1549.

Received: Sep 21, 2024. Accepted: Dec 15, 2024