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Evaluating Construction Projects of Urban Road and Bridge Based on Environmental Sustainability with MCDM Methodology

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Abstract:

Evaluation construction projects of road and bridge has various criteria so, we used the concept of multi-criteria decision making (MCDM) methodology to deal with these criteria. The MOORA methodology is a MCDM methodology used to rank various projects. MOORA methodology is integrated under the Plithogenic set to deal with uncertainty data. The Plithogenic set is an extension of neutrosophic sets. Three experts are invited to evaluate the criteria and alternatives. This study gathered seven criteria and 13 alternatives. We compute the criteria weights and rank the alternatives. The results show the Environmental Impact Mitigation criterion has the highest weights and the Long-Term Environmental Monitoring criterion has the lowest weights.

Keywords: Decision Making; Environmental Sustainability; Construction Projects of Road and Bridge; MCDM Method; MOORA Method.

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1. Introduction

The lengthy and intricate process of every development project, from initial planning to the ultimate approval of the work, is well-established in the customs and practices of road design and construction, but the ex-post review procedure is little understood and frequently overlooked. It is now crucial to assess, upon completion, whether the infrastructure has achieved the goals for which it was first intended[1], [2].

To better guide the selection of measures to be recommended in the future and to address any objections that may be raised in the field by various actors, such as roadside residents, traders, and representatives of various associations and organizations, it is also crucial that this evaluation draw both positive and negative lessons from completed projects. Under some conditions, it would be possible to prevent undue delays in the development process by using clear communication to offer an impartial foundation for discussion regarding these objections[1], [3], [4].

Since assessing Construction Projects of Road and Bridge is a multi-criteria decision making (MCDM) problem, the evaluation metrics might serve as the criteria, and these sets of metrics could be used to choose the alternatives[5], [6].

One of the most accurate approaches to decision-making is MCDM, also known as Multi-Criteria Decision Analysis (MCDA), which has revolutionized the area. When Benjamin Franklin released his research on moral algebra notion, he created one of the earliest studies on multi-criteria decision-making. Since the 1950s, several theoretical and empirical researchers have studied MCDM techniques to investigate their mathematical modeling potential to offer a framework that can assist in organizing decision-making issues and producing preferences from options. MCDM encompasses a variety of approaches that vary from one another in many ways, which will be covered in the sections that follow[7], [8], [9].

When contradictory or non-contradictory multiple ancient entities are combined to create new entities, this process is known as plithogeny. Smarandache presented it in 2017 as a neutrosophical generalization. A plithogenic set is one whose elements are defined by the attribute values, and it is a generalization of crisp, fuzzy, intuitionistic fuzzy, and neutrosophic sets. Between vj and the dominant (most significant) attribute value vD, each attribute value has a contradiction degree value c(vj,vD). The degree of attribute disagreement helps the model produce more accurate findings. As generalizations of neutrosophic sets, logic, probability, and statistics, respectively, plithogeny yields the plithogenic set, logic, probability, and statistics that Smarandache also developed in 2017[10], [11], [12].

2. Plithogenic Set Characteristics

Plithogeny is the process by which contradictory (dissimilar) or non-contradictory combinations of several old entities arise, develop, germinate, and evolve into new entities. A plithogenic set (P, A, V, d, c) is a collection of items with values V = {v1, v2, …, vn}, for $n \geq 1$ and several attributes A = {α1, α2, …, αm}, $m \geq 1$. The value of each attribute, V, has two primary characteristics. The first is the element x's appurtenance degree function d(x,v), according to a set of specified condition. The second degree function that is achieved between each attribute value and the most significant (dominant) one is the contradiction (dissimilarity) degree function c(v,D)[11].

The primary component of the plithogenic aggregation procedures (union, intersection, complement, inclusion, and equality) that improve aggregation accuracy is the contradiction degree function.

Let A be a non-empty set of uni-dimensional attributes, such as A = {α1, α2, …, αm}, m ≥ 1, and let $\alpha \in$ A be an attribute whose value spectrum is the set S. S can be a finite discrete set, such as S = {s1, s2, …, sl}, 1 ≤ l <∞, or an infinitely countable set S = {s1, s2, …, s∞}, or an infinitely uncountable (continuum) set S =]a,b[, a < b, where]…[is any open, semi-open, or closed interval from the set of real numbers or from other general sets.

3. Proposed Model

In this study, we proposed a model to evaluate the Construction Projects of Road and Bridge Based on Environmental Sustainability based on combination of MCDM methodology and plithogenic aggregation operators. We aggregate the advantages of the MOORA method to evaluate the criteria and alternatives and the plithogenic sets. The aim of this model derives from the plithogenic sets due to this method ensure more accurate outcomes under uncertainty environments[13], [14], [15]. The steps of the proposed models are shown in Figure 1 and explained in detail in this part.

- Step 1: Decision makers and experts identify a set of criteria and alternatives. The most popular criteria and summarized in Table 1 are based on the opinions of experts and decision makers. These criteria can reflect the sustainability environmental factors.

Table 1. Popular environmental factors for this study.

Criteria	Name	Type
C_1	Debt Management and Leverage	Cost
C_2	Liquidity	Beneficial
C_3	Revenue Growth	Beneficial
C_4	Cash Flow Management	Beneficial
C_5	Profitability	Beneficial
C_6	Asset Efficiency	Beneficial
C_7	Market Valuation	Beneficial

Experts can compute the importance of criteria based on the linguistic terms.

- Step 2: We replace the linguistic terms with the plithogenic numbers. Then we combine these numbers using the plithogenic operators. This step can increase the accuracy of the outcomes.
- Step 3: Obtain crisp values from the aggregated plithogenic numbers.
- Step 4: Normalize crips values to compute the criteria weights
- Step 5: Build the decision matrix.
- Step 6: Normalize the decision matrix.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}; i = 1, \dots, m; j = 1, \dots n.$$

- Step 7: Compute the reference points for the positive and negative criteria.
- Step 8. Compute assessment values.

$$q_j = \sum_{j=1}^{g} r_{ij} w_j - \sum_{j=g+1}^{n} r_{ij} w_j$$

- Step 9. Final rank of alternatives

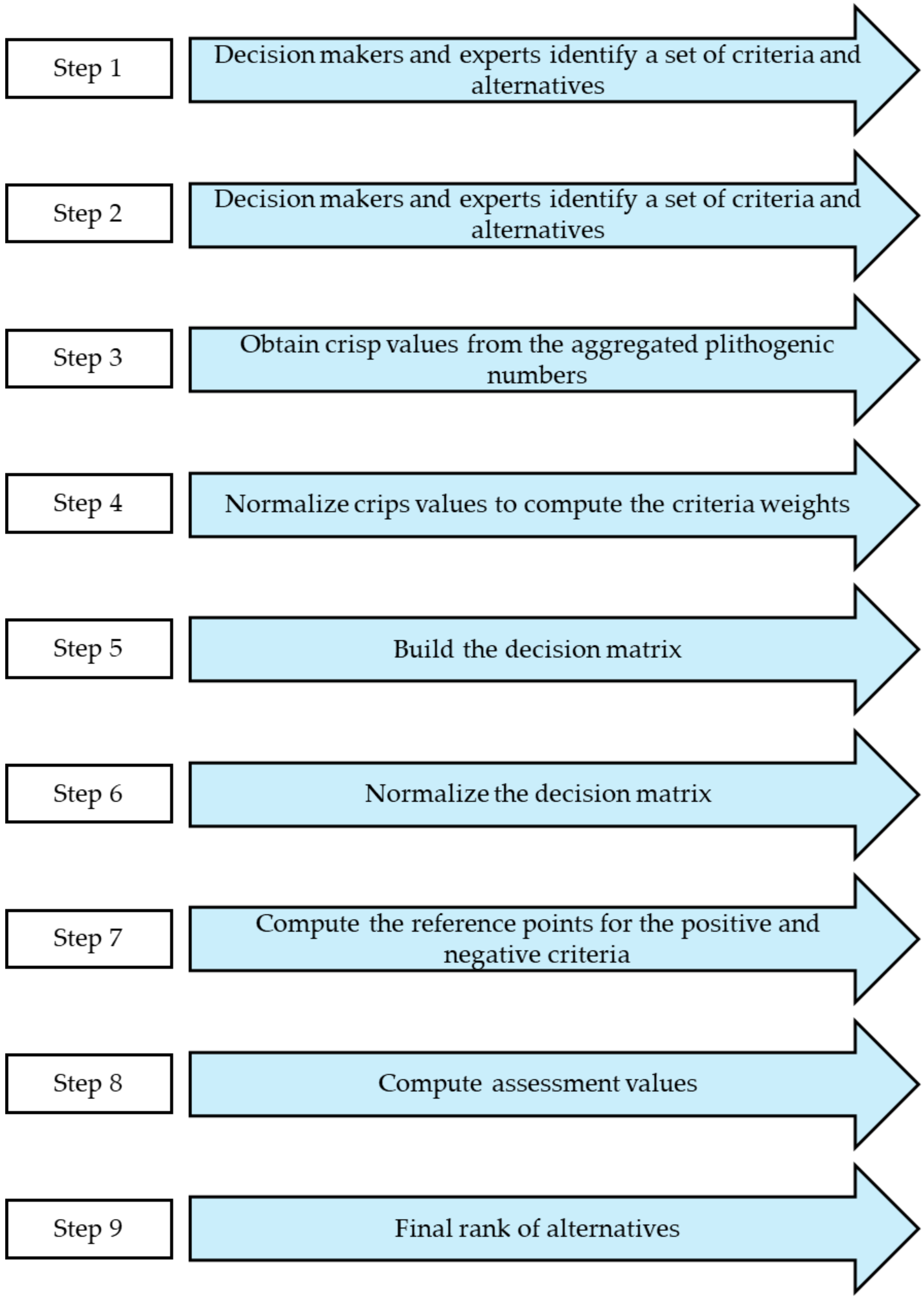

Figure 1. The steps of the MOORA method with plithogenic numbers.

4. Real World Case Study

In this study the proposed model has been applied in the application on China to evaluate the Construction Projects of Road and Bridge Based on Environmental Sustainability. In this application, three experts were assisted by their experience in solving such cases to assess the sustainability environment on construction projects. The main goal of this study to evaluate the Construction Projects of Road and Bridge Based on Environmental Sustainability. Firstly, three experts identified a group of seven criteria for environmental sustainability and threaten alternatives. Figure 2 shows the criteria and alternatives.

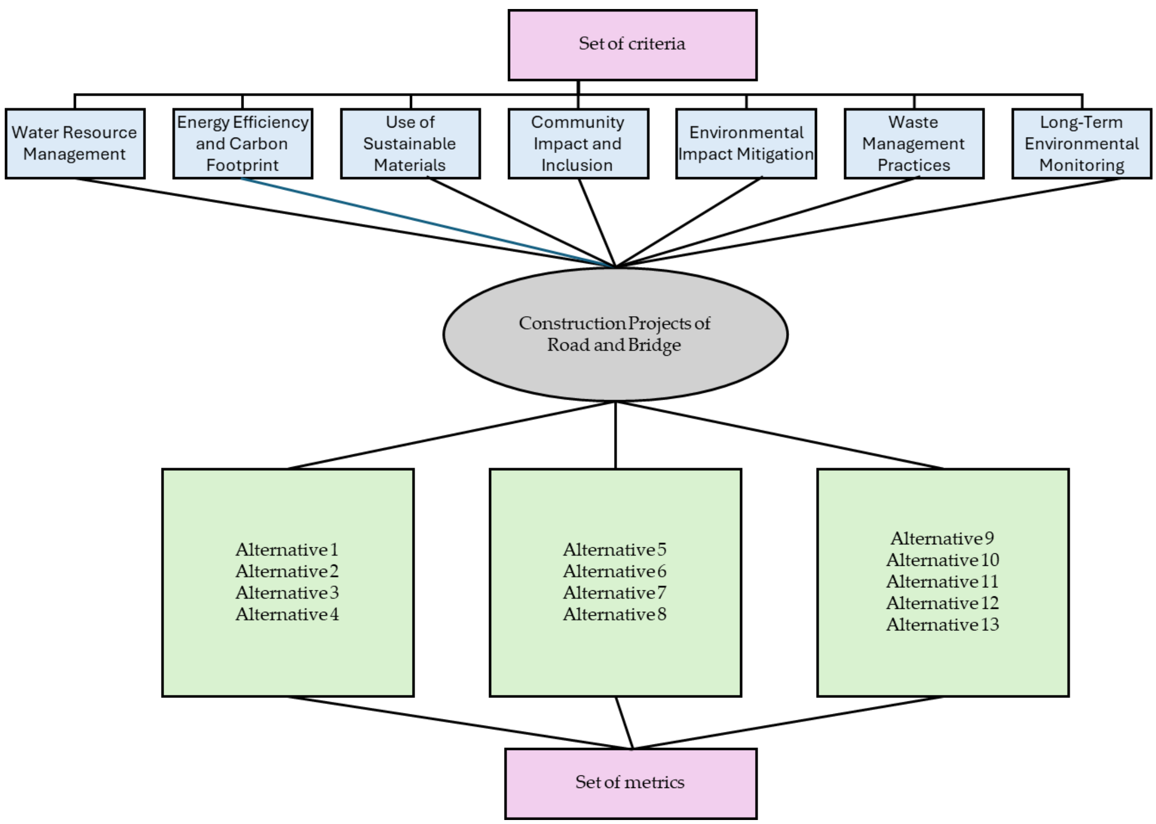

Figure 2. The Construction Projects of Road and Bridge criteria and alternatives.

The criteria by the experts based on linguistic terms are evaluated by using the plithogenic sets. Then we replace these terms by using the plithogenic numbers as shown in Table 2.

Table 2. The evaluation criteria by three experts.

D1	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)
A_2	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)
A_3	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)
A_4	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
A_5	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)
A_6	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)
A_7	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)
A_8	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)
A_9	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)
A_{10}	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_{11}	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.80, 0.10, 0.30)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)
A_{12}	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.95, 0.05, 0.05)	(0.65, 0.30, 0.45)
A_{13}	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
D2	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)
A_2	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)
A_3	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_4	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)
A_5	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)
A_6	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)
A_7	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)
A_8	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_9	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)
A_{10}	(0.95, 0.05, 0.05)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
A_{11}	(0.80, 0.10, 0.30)	(0.80, 0.10, 0.30)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)
A_{12}	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)
A_{13}	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
D3	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)
A_2	(0.50, 0.40, 0.60)	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)
A_3	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_4	(0.25, 0.60, 0.80)	(0.95, 0.05, 0.05)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)
A_5	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)
A_6	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)
A_7	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.65, 0.30, 0.45)	(0.25, 0.60, 0.80)	(0.50, 0.40, 0.60)	(0.40, 0.70, 0.50)
A_8	(0.10, 0.75, 0.85)	(0.65, 0.30, 0.45)	(0.50, 0.40, 0.60)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)
A_9	(0.95, 0.05, 0.05)	(0.50, 0.40, 0.60)	(0.65, 0.30, 0.45)	(0.40, 0.70, 0.50)	(0.40, 0.70, 0.50)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)
A_{10}	(0.95, 0.05, 0.05)	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.25, 0.60, 0.80)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)

A_{11}	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.40, 0.70, 0.50)
A_{12}	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.25, 0.60, 0.80)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.10, 0.75, 0.85)	(0.50, 0.40, 0.60)
A_{13}	(0.40, 0.70, 0.50)	(0.50, 0.40, 0.60)	(0.10, 0.75, 0.85)	(0.80, 0.10, 0.30)	(0.95, 0.05, 0.05)	(0.80, 0.10, 0.30)	(0.65, 0.30, 0.45)

We compute the criteria weights as in Table 3.

Table 3. The weights of criteria.

Criteria	Weights	Rank
C_1	0.143529	4
C_2	0.143656	5
C_3	0.149052	6
C_4	0.137201	2
C_5	0.150105	7
C_6	0.139396	3
C_7	0.137061	1

Then we applied the steps of the MOORA method to show the rank of alternatives. We normalize the criteria weights as shown in Table 4. Then we compute the weighted normalized decision matrix as in Table 5. Then we rank the alternatives as in Figure 3.

Table 4. The normalization matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.297576	0.141862	0.251397	0.278621	0.321986	0.394257	0.276094
A_2	0.277152	0.420262	0.361353	0.323071	0.26289	0.208337	0.383031
A_3	0.241771	0.17127	0.249973	0.302656	0.351958	0.140489	0.268299
A_4	0.11523	0.329344	0.139476	0.089226	0.330461	0.059481	0.154777
A_5	0.272568	0.344256	0.303448	0.117018	0.159696	0.369995	0.174983
A_6	0.255548	0.318321	0.319005	0.409629	0.288675	0.260581	0.276094
A_7	0.273399	0.193101	0.28292	0.329304	0.311507	0.361509	0.345575
A_8	0.27683	0.222213	0.303448	0.334258	0.211395	0.253223	0.253834
A_9	0.396402	0.242771	0.237843	0.195982	0.24486	0.14608	0.231631
A_{10}	0.420016	0.301452	0.272649	0.194321	0.159696	0.16515	0.174983
A_{11}	0.211777	0.273559	0.3006	0.173825	0.159696	0.260581	0.226256
A_{12}	0.222083	0.242771	0.258701	0.217104	0.288495	0.326064	0.361222
A_{13}	0.210249	0.274525	0.264805	0.404049	0.386501	0.394257	0.352807

Table 5. The weighted normalization matrix.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7
A_1	0.042711	0.020379	0.037471	0.038227	0.048332	0.054958	0.037842

A_2	0.039779	0.060373	0.053861	0.044326	0.039461	0.029041	0.052499
A_3	0.034701	0.024604	0.037259	0.041525	0.052831	0.019584	0.036773
A_4	0.016539	0.047312	0.020789	0.012242	0.049604	0.008291	0.021214
A_5	0.039121	0.049454	0.04523	0.016055	0.023971	0.051576	0.023983
A_6	0.036678	0.045729	0.047548	0.056202	0.043332	0.036324	0.037842
A_7	0.039241	0.02774	0.04217	0.045181	0.046759	0.050393	0.047365
A_8	0.039733	0.031922	0.04523	0.045861	0.031731	0.035298	0.034791
A_9	0.056895	0.034875	0.035451	0.026889	0.036755	0.020363	0.031748
A_{10}	0.060284	0.043305	0.040639	0.026661	0.023971	0.023021	0.023983
A_{11}	0.030396	0.039298	0.044805	0.023849	0.023971	0.036324	0.031011
A_{12}	0.031875	0.034875	0.03856	0.029787	0.043305	0.045452	0.04951
A_{13}	0.030177	0.039437	0.03947	0.055436	0.058016	0.054958	0.048356

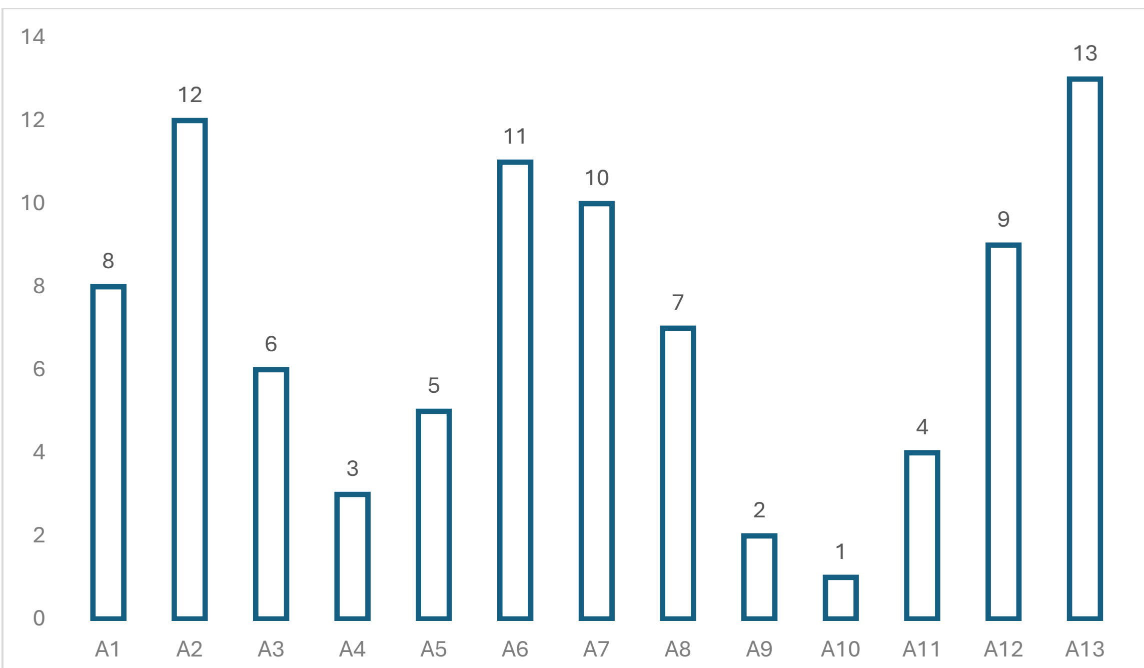

Figure 3. The rank of alternatives.

4. Results and Discussion

Based on the opinion of experts, the ranking of criteria Environmental Impact Mitigation, Use of Sustainable Materials, Energy Efficiency and Carbon Footprint, Water Resource Management, Waste Management Practices, Community Impact and Inclusion, Long-Term Environmental Monitoring. We show that Environmental Impact Mitigation has the highest weights, and Long-Term Environmental Monitoring has the lowest weights.

Three experts are evaluated the seven criteria and 13 alternatives. Based on these criteria weights, we applied the MOORA method to rank the alternatives. We show the alternative 13 has the highest rank and alternative 10 has the lowest rank.

5. Conclusions

This study proposed a MCDM methodology to evaluate the construction of projects or road and bridges. The MCDM methodology is integrated into Plithogenic sets to deal with uncertainty information. Three experts are invited to evaluate the criteria and alternatives. They used linguistic terms in their evaluation. Then we replaced their evaluation using the Plithogenic numbers. Then we combine these numbers into one matrix. Then we apply the MOORA method to rank the alternatives. The decision matrix is built between the criteria and alternatives. The criteria weights are computed by normalizing crisp values. The results show the alternative 13 has the highest rank and alternative 10 has the lowest rank.

References

[1] T. E. El-Diraby and J. T. O'Connor, "Model for evaluating bridge construction plans," *J. Constr. Eng. Manag.*, vol. 127, no. 5, pp. 399–405, 2001.

[2] E. K. Zavadskas, R. Liias, and Z. Turskis, "Multi-attribute decision-making methods for assessment of quality in bridges and road construction: State-of-the-art surveys," *Balt. J. road Bridg. Eng.*, vol. 3, no. 3, pp. 152–160, 2008.

[3] T. E. El-Diraby and J. T. O'Connor, "System for evaluating bridge construction plans," *Res. Rep*, 1999.

[4] S. Mortazavi, A. Kheyroddin, and H. Naderpour, "Risk evaluation and prioritization in bridge construction projects using system dynamics approach," *Pract. Period. Struct. Des. Constr.*, vol. 25, no. 3, p. 4020015, 2020.

[5] B. Uzun, I. Ozsahin, V. O. Agbor, and D. U. Ozsahin, "Theoretical aspects of multi-criteria decision-making (MCDM) methods," in *Applications of multi-criteria decision-making theories in healthcare and biomedical engineering*, Elsevier, 2021, pp. 3–40.

[6] T. Harputlugil, M. Prins, A. T. Gültekin, and Y. I. Topçu, "Conceptual framework for potential implementations of multi criteria decision making (MCDM) methods for design quality assessment," in *Management and Innovation for a Sustainable Built Environment MISBE 2011, Amsterdam, The Netherlands, June 20-23, 2011*, CIB,

Working Commissions W55, W65, W89, W112; ENHR and AESP, 2011.

[7] H. Taherdoost and M. Madanchian, "Multi-criteria decision making (MCDM) methods and concepts," *Encyclopedia*, vol. 3, no. 1, pp. 77–87, 2023.

[8] E. K. Zavadskas and Z. Turskis, "Multiple criteria decision making (MCDM) methods in economics: an overview," *Technol. Econ. Dev. Econ.*, vol. 17, no. 2, pp. 397–427, 2011.

[9] B. H. Massam, "Multi-criteria decision making (MCDM) techniques in planning," *Prog. Plann.*, vol. 30, pp. 1–84, 1988.

[10] N. Martin, F. Smarandache, and S. Sudha, "A novel method of decision making based on plithogenic contradictions," *Neutrosophic Syst. with Appl.*, vol. 10, pp. 12–24, 2023.

[11] M. Abdel-Basset, R. Mohamed, A. E.-N. H. Zaied, and F. Smarandache, "A hybrid plithogenic decision-making approach with quality function deployment for selecting supply chain sustainability metrics," *Symmetry (Basel).*, vol. 11, no. 7, p. 903, 2019.

[12] M. Abdel-Basset, M. El-Hoseny, A. Gamal, and F. Smarandache, "A novel model for evaluation Hospital medical care systems based on plithogenic sets," *Artif. Intell. Med.*, vol. 100, p. 101710, 2019.

[13] U. K. Mandal and B. Sarkar, "Selection of best intelligent manufacturing system (ims) under fuzzy moora conflicting mcdm environment," *Int. J. Emerg. Technol. Adv. Eng.*, vol. 2, no. 9, pp. 301–310, 2012.

[14] S. H. Rao, S. Kalvakolanu, and C. Chakraborty, "Integration of ARAS and MOORA MCDM techniques for measuring the performance of private sector banks in India," *Int. J. Uncertainty, Fuzziness Knowledge-Based Syst.*, vol. 29, no. Suppl 2, pp. 279–295, 2021.

[15] S. S. Raju, G. B. Murali, and P. K. Patnaik, "Ranking of Al-CSA composite by MCDM approach using AHP–TOPSIS and MOORA methods," *J. Reinf. Plast. Compos.*, vol. 39, no. 19–20, pp. 721–732, 2020.

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