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Sustainable Cost Management and Risk Evaluation in Prefabricated Infrastructure Projects under the Neutrosophic Bonferroni Mean Operator

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Abstract: The advent of prefabricated infrastructure has introduced a transformative shift in the construction sector, emphasizing speed, efficiency, and environmental consciousness. However, the economic and risk-related complexities tied to large-scale prefabrication demand a deeper exploration of sustainable cost management practices. This study aims to examine how systematic risk evaluation can be integrated into cost management frameworks to improve the financial and operational sustainability of prefabricated infrastructure projects. We use the multi-criteria decision-making (MCDM) approach to Sustainable Cost Management and Risk Evaluation in Prefabricated Infrastructure Projects. This study uses eight criteria and six alternatives to be evaluated. Three experts evaluate the criteria and alternatives. The RANCOM-ARTASI framework is used to compute the criteria weights and rank the alternatives.

Keywords: Bonferroni Mean Operator; Sustainability; Cost Management; Risk Evaluation; Prefabricated Infrastructure Projects.

1. Introduction

The construction industry is witnessing a paradigm shift as prefabricated infrastructure becomes an increasingly viable alternative to conventional on-site construction. Prefabrication offers numerous benefits, including reduced labor dependency, shortened project timelines, and enhanced construction quality. However, these advantages also come with new challenges in managing costs and risks throughout the project lifecycle. As global demands push for more resilient and sustainable infrastructure, managing cost risks in prefabrication projects has emerged as a critical research domain[1], [2]. Cost management in traditional construction largely focuses on budget control and financial tracking. In contrast, prefabricated systems require a more dynamic approach due to the involvement of off-site manufacturing, transportation logistics, and interdependent supply chains. These unique variables necessitate the development of tailored cost evaluation methods that can accommodate uncertainties in material procurement, labor deployment, and energy use in off-site facilities[3], [4]. Risk evaluation plays an equally pivotal role in the sustainability of prefabricated infrastructure. Unlike conventional methods, prefabrication is sensitive to disruptions in manufacturing or delivery. Delays or failures in these segments can result in cascading impacts on cost, quality, and project delivery. Therefore, integrating risk assessment models into the early stages of planning and budgeting is essential for preemptively identifying and mitigating potential threats[5], [6]. Sustainability cannot be overlooked when discussing cost and risk. The long-term environmental and economic implications of prefabricated infrastructure require the adoption of green building principles and life cycle thinking. Efficient material usage, waste minimization, and carbon footprint reduction must be factored into cost evaluations to ensure that projects align with broader sustainability goals. Technological innovations such as Building Information Modeling (BIM), IoT-based tracking, and AI-powered forecasting tools are reshaping how stakeholders manage cost and risk in prefab projects. These tools enhance transparency, provide real-time insights, and support data-driven decisions, allowing firms to anticipate problems before they escalate. The integration of such technologies must be analyzed for their contribution to cost efficiency and risk mitigation. The global shift toward sustainable infrastructure also brings new regulations and compliance frameworks that impact cost structures and risk profiles. Navigating these frameworks requires a comprehensive understanding of both domestic and international standards. As governments increase their emphasis on eco-friendly construction, compliance-related risks must be factored into economic planning for prefab initiatives[7], [8].

Neutosophic sets (NSs), which use the functions of truth, indeterminacy, and falsity to represent fuzzy information, were first proposed by Smarandache[9], [10]. Interestingly, the functions of truth and falsity do not affect the function of indeterminacy. However, because the values of the truth, indeterminacy, and falsity functions fall between]0−, 1+[, NSs are challenging to utilize in real-world scenarios. Thus, single-valued neutrosophic sets (SVNSs), where truth, indeterminacy, and falsity functions fall between zero and one, were introduced by Wang et al. [11]. SVNSs have now been investigated and expanded by fusing them with other hypotheses. One crucial tool for building MCDM techniques is the aggregation operator. Aggregation operators under various fuzzy environments, including single-valued neutrosophic settings, have been examined by many scholars. Most aggregation operators assume that the integrated pieces are independent of one another[11], [12].

2. Single valued neutrosophic (SVN) frank Bonferroni mean operator

This section shows some definitions of single valued neutrosophic (SVN) frank Bonferroni mean operator (SVNFBM)[13].

Let p, q>0 and $x_1 = (T_i, I_i, F_i)$ $is\ a\ SVN$

$$SVNFBM^{p,q}(x_1, x_2, \ldots, x_n) = \left(\frac{1}{n(n-1)} \cdot F \bigoplus_{i,j=1}^{n} \left((x_i)^{\wedge FP} \otimes F(x_j)^{\wedge FP}\right)\right)^{\wedge F\frac{1}{p+q}} \quad (1)$$

$$SVNFBM^{p,q}(x_1, x_2, \ldots, x_n) = \left(\frac{w_i w_j}{1-w_i} \cdot F \bigoplus_{i,j=1}^{n} \left((x_i)^{\wedge FP} \otimes F(x_j)^{\wedge FP}\right)\right)^{\wedge F\frac{1}{p+q}} \quad (2)$$

Where $w_i = \frac{H_i}{\sum_{t=1}^{n} H_i}, H_t = \prod_{k=1}^{t-1} sc(x_k)(t \geq 2), H_1 = 1$

$sc(x_k)$ is the score value

$$SVNFBM^{p,q}(x_1, x_2, \ldots, x_n)$$

$$= \left(\begin{array}{c} \log_\sigma \left(1 + (\sigma-1)\left(\frac{1 - \prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{T_{x_i}}-1\right)^p \left(\sigma^{T_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{T_{x_i}}-1\right)^p \left(\sigma^{T_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1 + (\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{T_{x_i}}-1\right)^p \left(\sigma^{T_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{T_{x_i}}-1\right)^p \left(\sigma^{T_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{\frac{1}{p+q}}\right), \\ 1 - \log_\sigma \left(1 + (\sigma-1)\left(\frac{1 - \prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{I_{x_i}}-1\right)^p \left(\sigma^{I_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{I_{x_i}}-1\right)^p \left(\sigma^{I_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1 + (\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{I_{x_i}}-1\right)^p \left(\sigma^{I_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{I_{x_i}}-1\right)^p \left(\sigma^{I_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{\frac{1}{p+q}}\right), \\ 1 - \log_\sigma \left(1 + (\sigma-1)\left(\frac{1 - \prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{F_{x_i}}-1\right)^p \left(\sigma^{F_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{F_{x_i}}-1\right)^p \left(\sigma^{F_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1 + (\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q} - \left(\sigma^{F_{x_i}}-1\right)^p \left(\sigma^{F_{x_j}}-1\right)^q}{(\sigma-1)^{p+q} - \left(\sigma^{F_{x_i}}-1\right)^p \left(\sigma^{F_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{\frac{1}{p+q}}\right) \end{array} \right) \quad (3)$$

$$\bigoplus_{i,j=1}^{n} F\left(\frac{w_i w_j}{1-w_i}\cdot F\left((x_i)^{\wedge FP} \otimes F\left(x_j\right)^{\wedge FP}\right)\right)$$

$$= \left(\begin{array}{c} 1-\log_\sigma\left(1+(\sigma-1)\left(\frac{1-\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{T_{x_i}}-1\right)^p\left(\sigma^{T_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{T_{x_i}}-1\right)^p\left(\sigma^{T_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1+(\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{T_{x_i}}-1\right)^p\left(\sigma^{T_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{T_{x_i}}-1\right)^p\left(\sigma^{T_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{1}\right), \\ \log_\sigma\left(1+(\sigma-1)\left(\frac{1-\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{I_{x_i}}-1\right)^p\left(\sigma^{I_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{I_{x_i}}-1\right)^p\left(\sigma^{I_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1+(\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{I_{x_i}}-1\right)^p\left(\sigma^{I_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{I_{x_i}}-1\right)^p\left(\sigma^{I_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{1}\right), \\ \log_\sigma\left(1+(\sigma-1)\left(\frac{1-\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{F_{x_i}}-1\right)^p\left(\sigma^{F_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{F_{x_i}}-1\right)^p\left(\sigma^{F_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}{1+(\sigma-1)\prod_{i,j=1}^{n}\left(\frac{(\sigma-1)^{p+q}-\left(\sigma^{F_{x_i}}-1\right)^p\left(\sigma^{F_{x_j}}-1\right)^q}{(\sigma-1)^{p+q}-\left(\sigma^{F_{x_i}}-1\right)^p\left(\sigma^{F_{x_j}}-1\right)^q}\right)^{\frac{w_i w_j}{1-w_i}}}\right)^{1}\right) \end{array} \right) \tag{4}$$

$$(x_1)^{\wedge FP} = \left(\begin{array}{c} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_1}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_1}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_1}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \end{array} \right) \tag{5}$$

$$(x_1)^{\wedge Fq} = \begin{pmatrix} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_1}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_1}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_1}}-1\right)^p}{(\sigma-1)^{q-1}}\right)\right), \end{pmatrix} \quad (6)$$

$$(x_2)^{\wedge FP} = \begin{pmatrix} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_2}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_2}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_2}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \end{pmatrix} \quad (7)$$

$$(x_2)^{\wedge Fq} = \begin{pmatrix} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_2}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_2}}-1\right)^p}{(\sigma-1)^{p-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_2}}-1\right)^p}{(\sigma-1)^{q-1}}\right)\right), \end{pmatrix} \quad (8)$$

$$(x_1)^{\wedge FP} \otimes (x_2)^{\wedge Fq} = \begin{pmatrix} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_1}}-1\right)^p\left(\sigma^{T_{x_2}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_1}}-1\right)^p\left(\sigma^{1-I_{x_2}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_1}}-1\right)^p\left(\sigma^{1-F_{x_2}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right) \end{pmatrix} \quad (9)$$

$$(x_2)^{\wedge FP} \otimes (x_1)^{\wedge Fq} = \begin{pmatrix} \log_\sigma\left(1+\left(\frac{\left(\sigma^{T_{x_2}}-1\right)^p\left(\sigma^{T_{x_1}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-I_{x_2}}-1\right)^p\left(\sigma^{1-I_{x_1}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right), \\ 1-\log_\sigma\left(1+\left(\frac{\left(\sigma^{1-F_{x_2}}-1\right)^p\left(\sigma^{1-F_{x_1}}-1\right)^q}{(\sigma-1)^{p+q-1}}\right)\right) \end{pmatrix} \quad (10)$$

We show the steps of the two methods as follows:

We show the steps of the RANCOM method such as:

Design the decision matrix. We use the single valued neutrosophic numbers (SVNNs) to evaluate the criteria and alternatives. The decision matrix is combined using the SVNFBM operator. The decision matrix is converted to the crisp values. We rank the criteria. Create a comparison matrix between the criteria such as:

$$y_{kj} = \begin{bmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{n1} & \cdots & y_{nn} \end{bmatrix} \quad (11)$$

$$y_{kj} = \begin{cases} 1, & if\ S(Y_j) < S(Y_k), \\ 0.5, & if\ S(Y_j) = S(Y_k), \\ 0, & if\ S(Y_j) > S(Y_k) \end{cases} \quad (12)$$

The total criteria weight is computed such as:

$$l_j = \sum_{k=1}^{n} y_{kj} \quad (13)$$

The weights of criteria are computed such as:

$$w_j = \frac{l_j}{\sum_{j=1}^{n} l_j} \quad (14)$$

After that, we show the steps of the ARTASI method such as:

Calculate the min and max values such as:

$$q_j^{max} = \max_{1 \le i \le m}\left(y_{ij}\right) + \left\{\max_{1 \le i \le m}\left(y_{ij}\right)\right\}^{\frac{1}{m}} \quad (15)$$

$$q_j^{min} = \min_{1 \le i \le m}\left(y_{ij}\right) + \left\{\min_{1 \le i \le m}\left(y_{ij}\right)\right\}^{\frac{1}{m}} \quad (16)$$

Normalize the decision matrix

$$u_{ij} = \frac{s^{(u)} - s^{(l)}}{q_j^{max} - q_j^{max}} r_{ij} + \frac{q_j^{max} s^{(u)} - q_j^{min} s^{(l)}}{q_j^{max} - q_j^{min}} \quad (17)$$

The values of $s^{(u)}$ *and* $s^{(l)}$ upper and lower numbers.

Alteration of the values, if the criterion is of the cost

$$c_{ij} = -u_{ij} + \max_{1 \le i \le m}(u_{ij}) + \min_{1 \le i \le m}(u_{ij}) \tag{18}$$

Obtain the usefulness of the alternatives

$$r_{ij}^{+} = \frac{c_{ij}}{\max_{1 \le i \le m}(c_{ij})} w_j s^{(u)} \tag{19}$$

$$r_{ij} = \frac{\min_{1 \le i \le m}(c_{ij})}{c_{ij}} w_j s^{(u)} \tag{20}$$

$$r_{ij}^{-} = -r_{ij} + \max_{1 \le i \le m}(r_{ij}) + \min_{1 \le i \le m}(r_{ij}) \tag{21}$$

Obtain the combined level of usefulness of alternatives

$$h_i^{+} = \sum_{j=1}^{n} r_{ij}^{+} \tag{22}$$

$$h_i^{-} = \sum_{j=1}^{n} r_{ij}^{-} \tag{23}$$

Obtain the ultimate utility functions

$$A_i = (h_i^{+} + h_i^{-})\{af(h_i^{+}) + (1 - a)f(h_i^{-})\} \tag{24}$$

$$f(A_i^{+}) = \frac{h_i^{+}}{h_i^{+} + h_i^{-}} \tag{25}$$

$$f(A_i^{-}) = \frac{h_i^{-}}{h_i^{+} + h_i^{-}} \tag{26}$$

Where a between 0 and 1.

3. Results and Discussion

This section shows the results of the proposed approach. Three experts are gathered eight criteria and six alternatives such as: Lifecycle Cost Efficiency, Resource Optimization and Waste Reduction, Risk of Supply Chain Disruption, Environmental Impact Mitigation, On-Site Assembly Time Reduction, Financial Flexibility and Investment Risk, Quality Control Consistency in Modular Components, Regulatory and Compliance Risk. The alternatives are: Centralized Manufacturing with Lean Construction Principles, Distributed Prefabrication with Local Supply Chains, Use of Recycled and Renewable Materials in Prefab Units, Implementation of Smart Cost Tracking and BIM Integration, Modular Prefab Units with On-Demand Logistics and Delivery, Hybrid Financing Models for Risk Diversification.

Three experts use the SVNNs to evaluate the criteria and alternatives as shown in Tables 1-3. These numbers are combined using the SVNFBM operator and converted to crisp values. We create the comparison matrix between the criteria using Eq. 11 and 12 as shown in Fig 1.

The total criteria weight is computed using eq. (13) as shown in Fig 2.

The weights of criteria are computed using eq. (14) as shown in Fig 3.

Table 1. The neutrosophic numbers.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.5,0.5,0.5)
A_2	(0.7,0.3,0.4)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.3,0.6,0.7)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.7,0.3,0.4)	(0.4,0.5,0.6)
A_3	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.3,0.6,0.7)
A_4	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.2,0.7,0.8)
A_5	(0.3,0.6,0.7)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.7,0.3,0.4)	(0.1,0.8,0.9)	(0.4,0.5,0.6)	(0.1,0.8,0.9)
A_6	(0.3,0.6,0.7)	(0.3,0.6,0.7)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.3,0.6,0.7)	(0.2,0.7,0.8)

Table 2. The second neutrosophic numbers.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.5,0.5,0.5)
A_2	(0.5,0.5,0.5)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.4,0.5,0.6)
A_3	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.3,0.6,0.7)
A_4	(0.7,0.3,0.4)	(0.5,0.5,0.5)	(0.6,0.4,0.5)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.2,0.7,0.8)
A_5	(0.1,0.8,0.9)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.3,0.6,0.7)
A_6	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.4,0.5,0.6)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.4,0.5,0.6)	(0.1,0.8,0.9)	(0.2,0.7,0.8)

Table 3. The third neutrosophic numbers.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	(0.7,0.3,0.4)	(0.6,0.4,0.5)	(0.5,0.5,0.5)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.5,0.5,0.5)
A_2	(0.1,0.8,0.9)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.3,0.6,0.7)	(0.4,0.5,0.6)	(0.5,0.5,0.5)	(0.7,0.3,0.4)	(0.4,0.5,0.6)
A_3	(0.2,0.7,0.8)	(0.7,0.3,0.4)	(0.4,0.5,0.6)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.6,0.4,0.5)	(0.1,0.8,0.9)	(0.3,0.6,0.7)
A_4	(0.3,0.6,0.7)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.7,0.3,0.4)	(0.2,0.7,0.8)	(0.2,0.7,0.8)
A_5	(0.4,0.5,0.6)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.1,0.8,0.9)	(0.7,0.3,0.4)	(0.3,0.6,0.7)	(0.1,0.8,0.9)
A_6	(0.5,0.5,0.5)	(0.3,0.6,0.7)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.2,0.7,0.8)	(0.1,0.8,0.9)	(0.4,0.5,0.6)	(0.2,0.7,0.8)

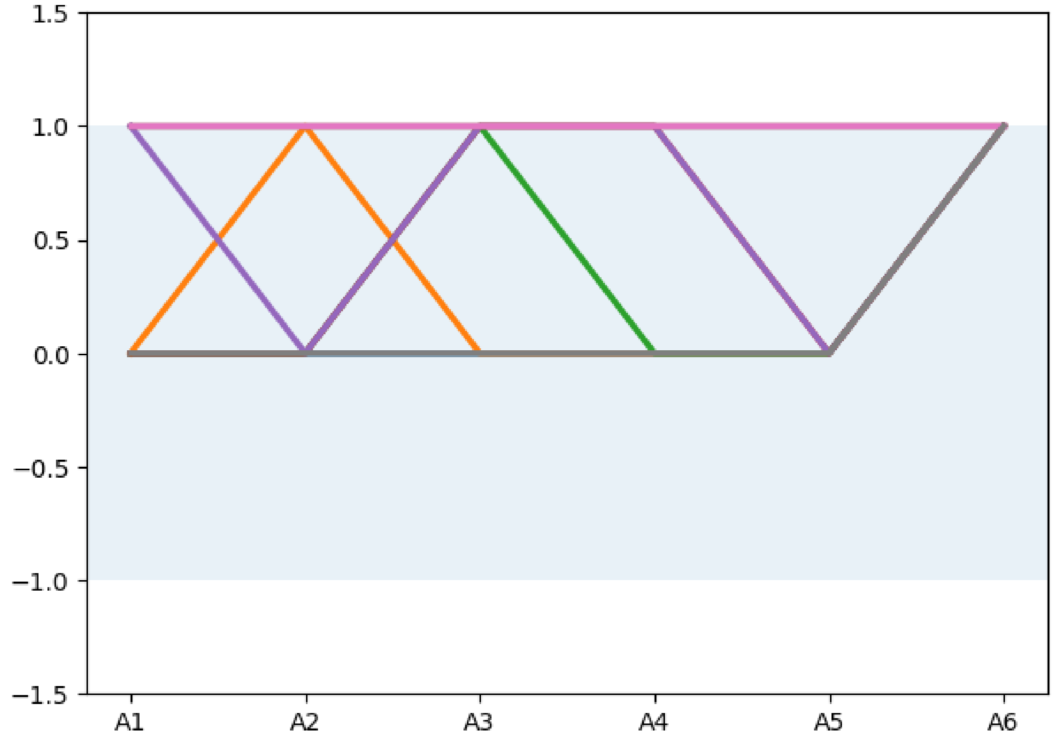

Fig 1-a. The comparison matrix.

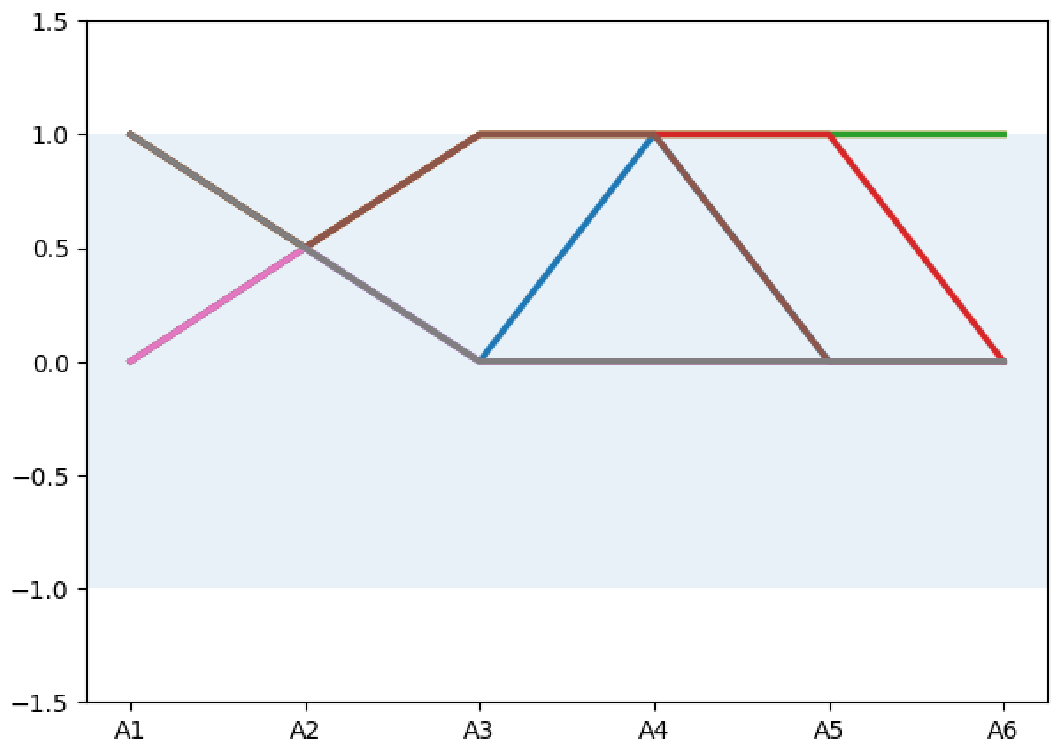

Fig 1-b. The comparison matrix.

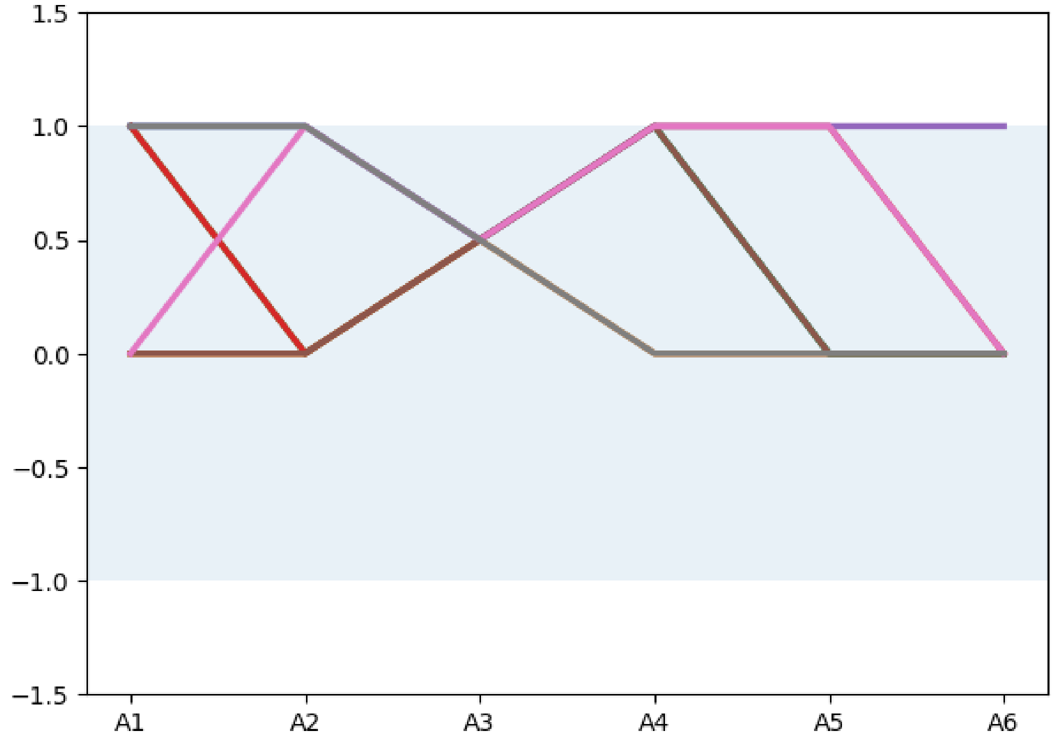

Fig 1-c. The comparison matrix.

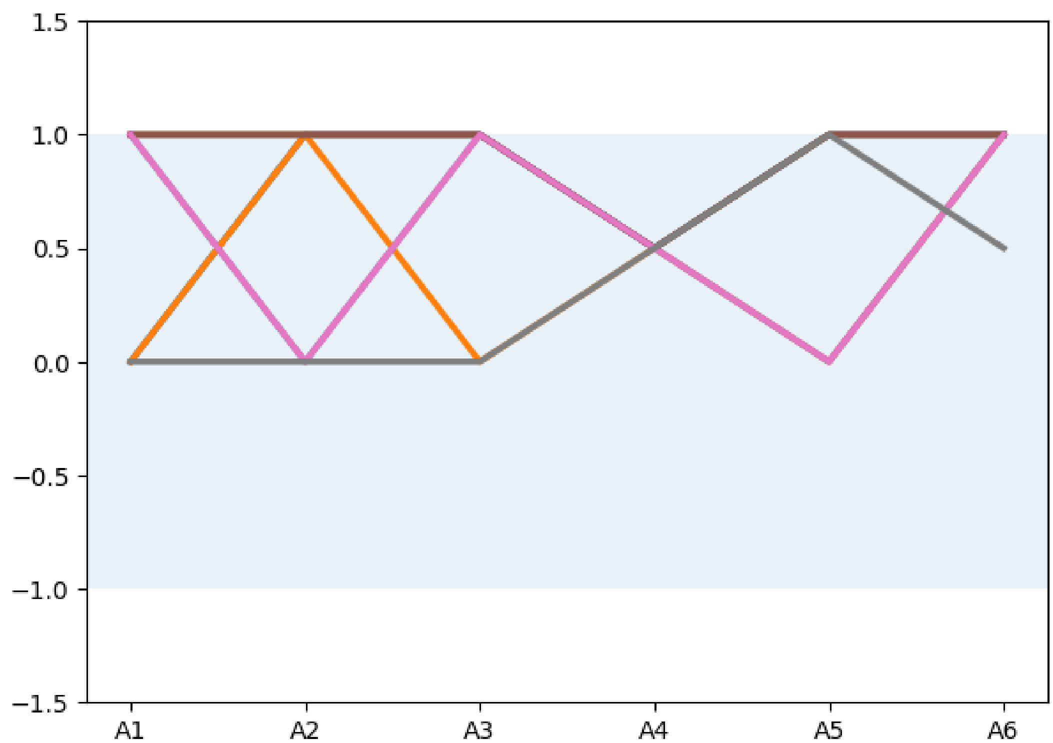

Fig 1-d. The comparison matrix.

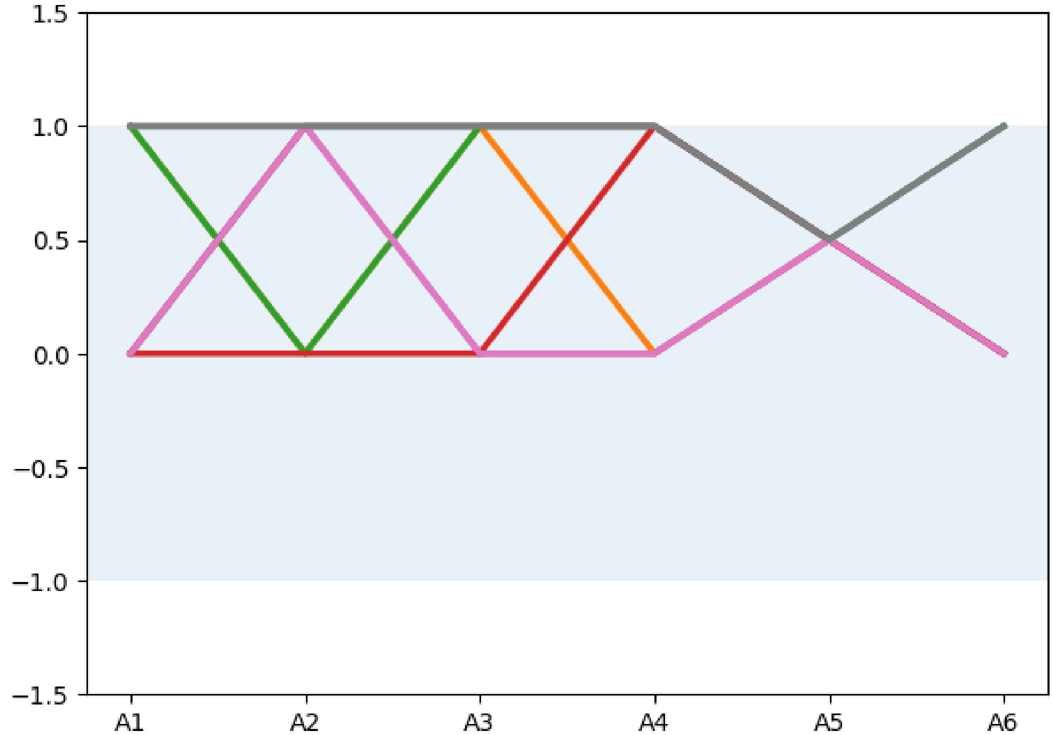

Fig 1-e. The comparison matrix.

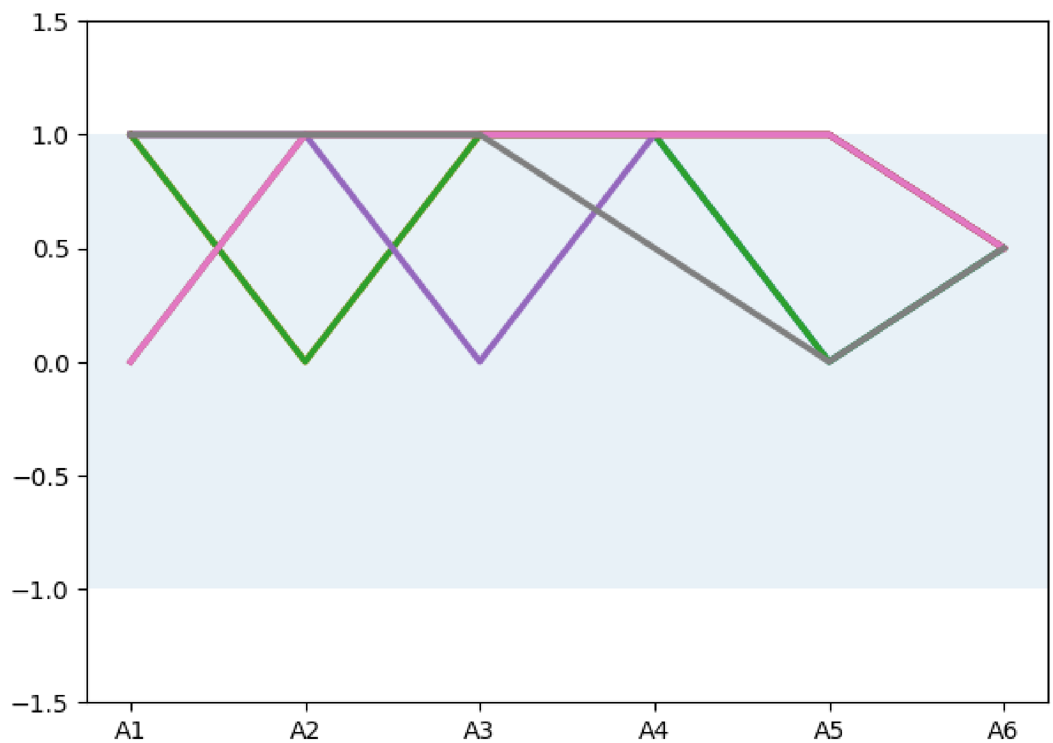

Fig 1-f. The comparison matrix.

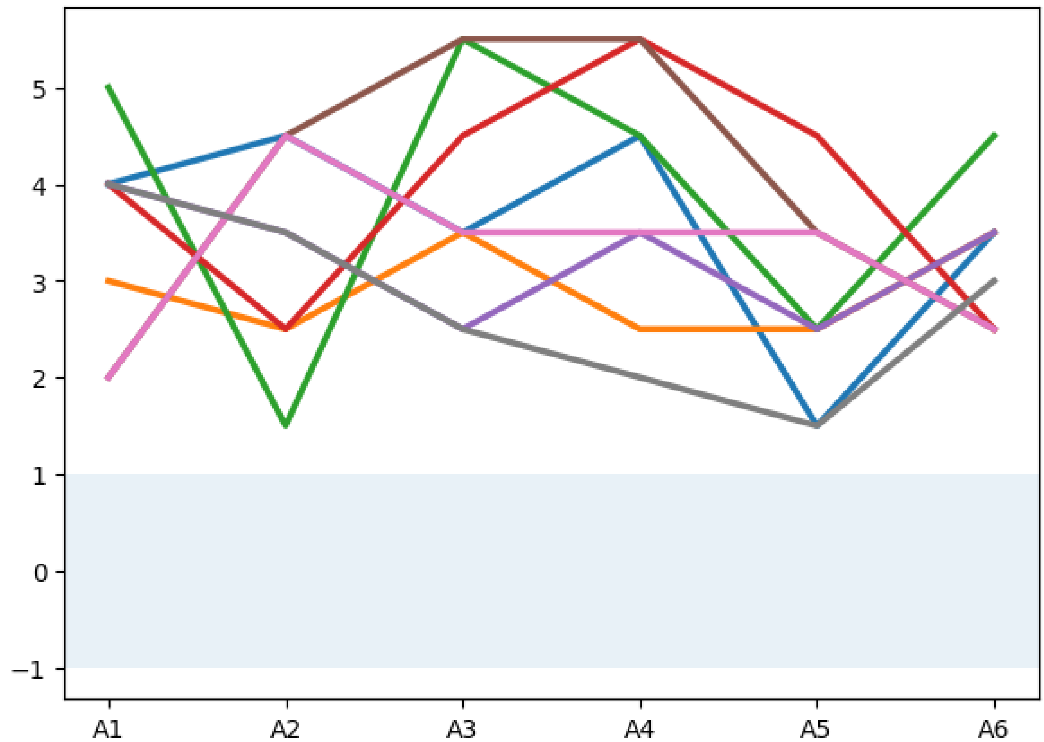

Fig 2. The total comparison matrix.

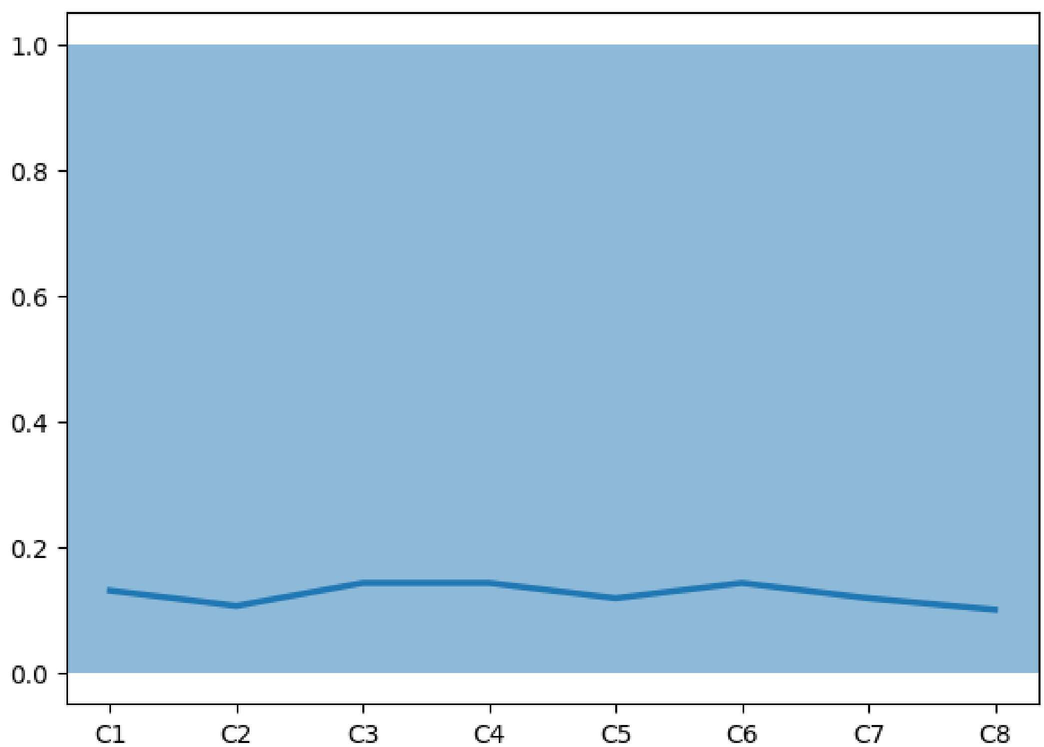

Fig 3. The criteria weights.

We calculate the min and max values using equation 15 and 16.

Normalize the decision matrix using equation 17 as shown in Fig 4.

Alteration of the values, if the criterion is of the cost using equation 18 as shown in Fig 5.

Obtain the usefulness of the alternatives using equations 19,20, and 21 as shown in Fig 6,7,8.

Obtain the combined level of usefulness of alternatives using equations 22 and 23.

Obtain the ultimate utility functions using equation 24-26. Then we rank the alternatives as shown in Fig 9.

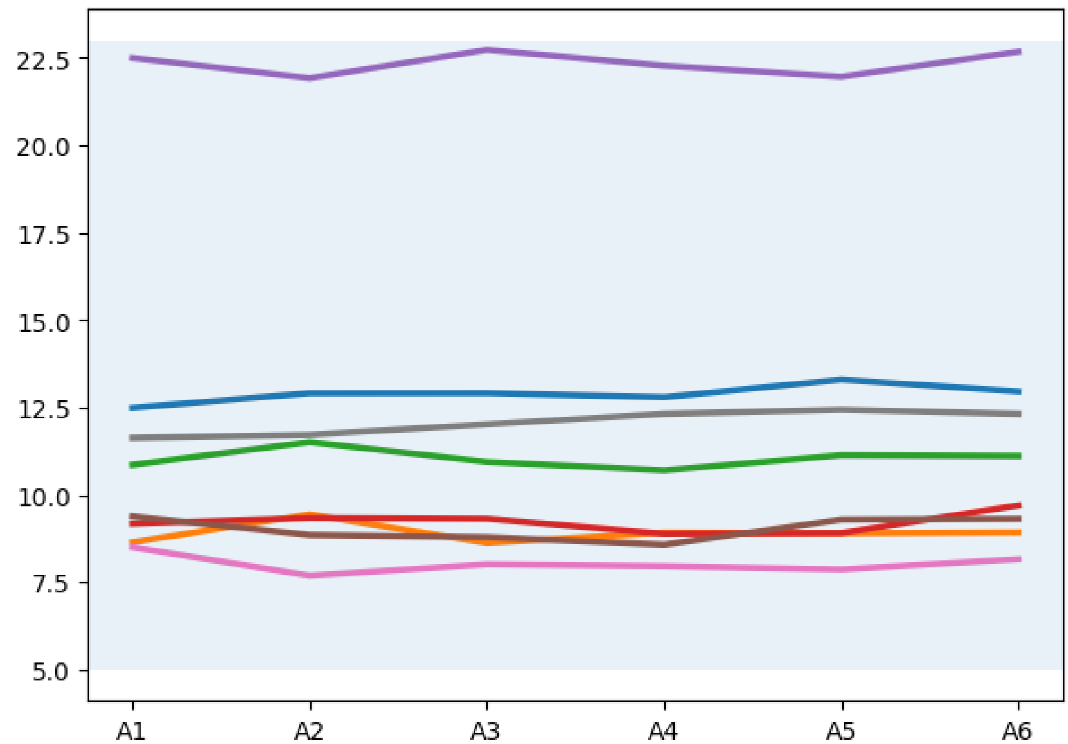

Fig 4. The normalized matrix.

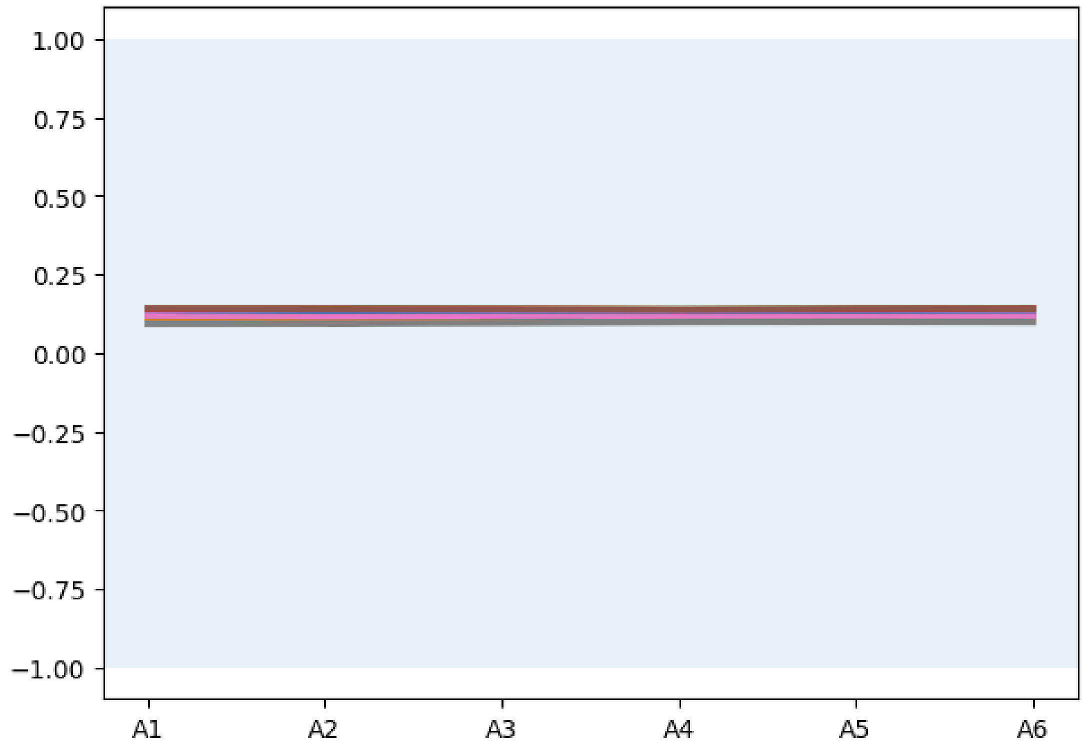

Fig 6. The values of r_{ij}^{+}.

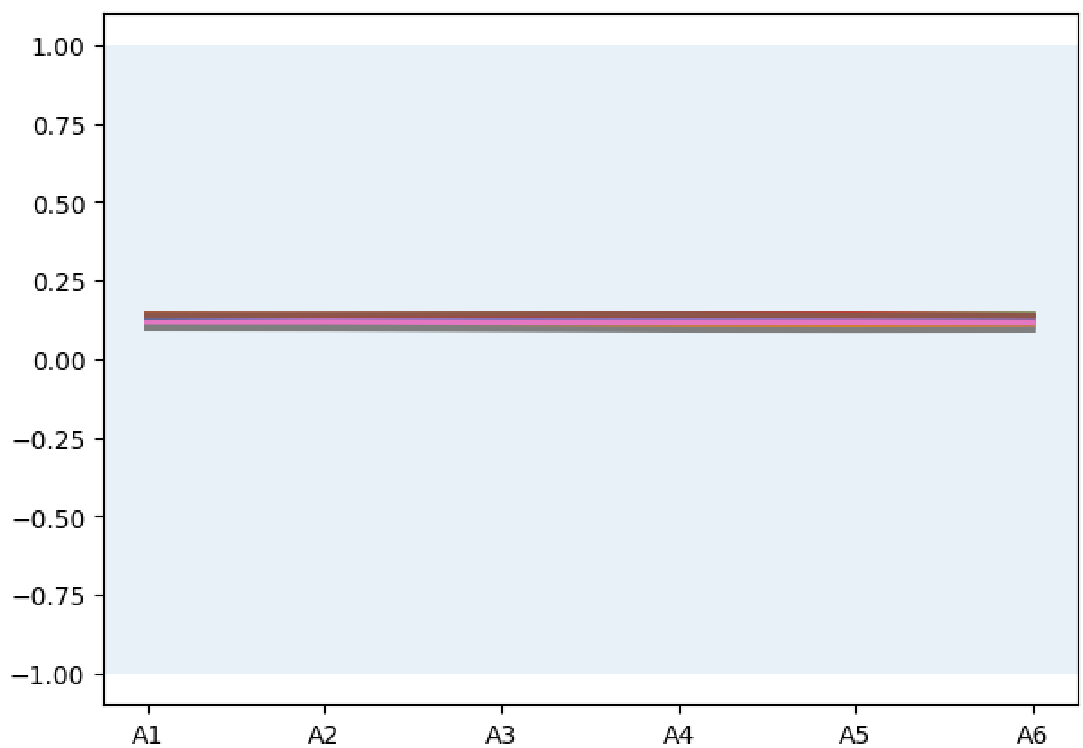

Fig 7. The values of r_{ij}.

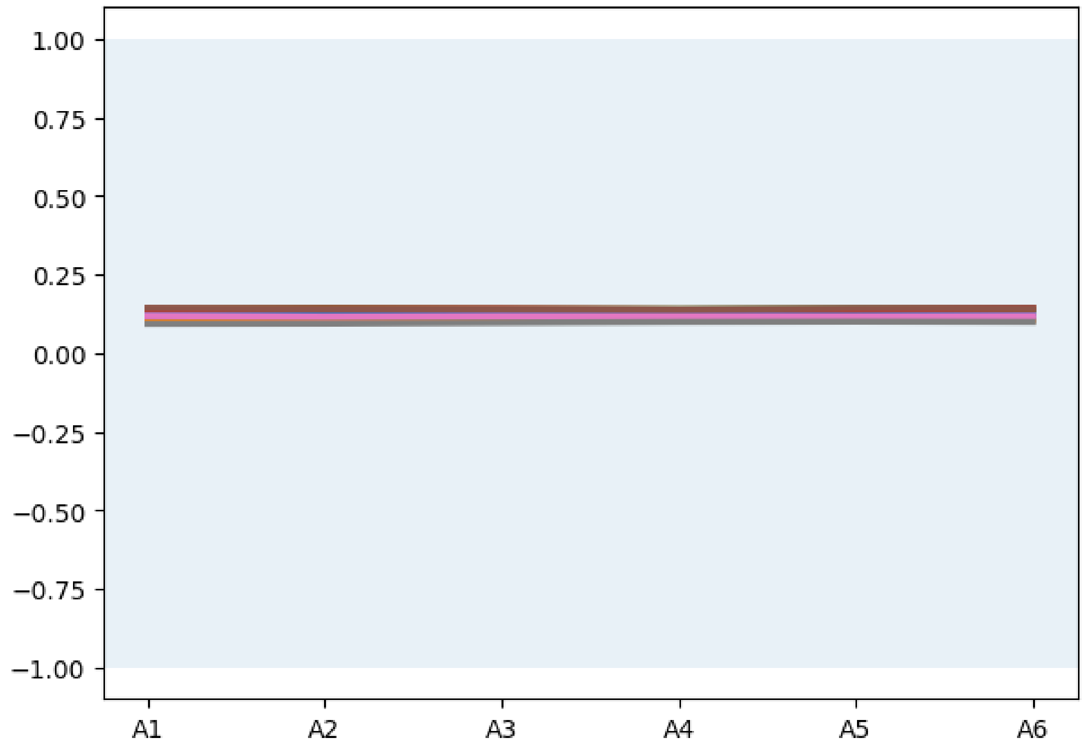

Fig 8. The values of r_{ij}^{-}.

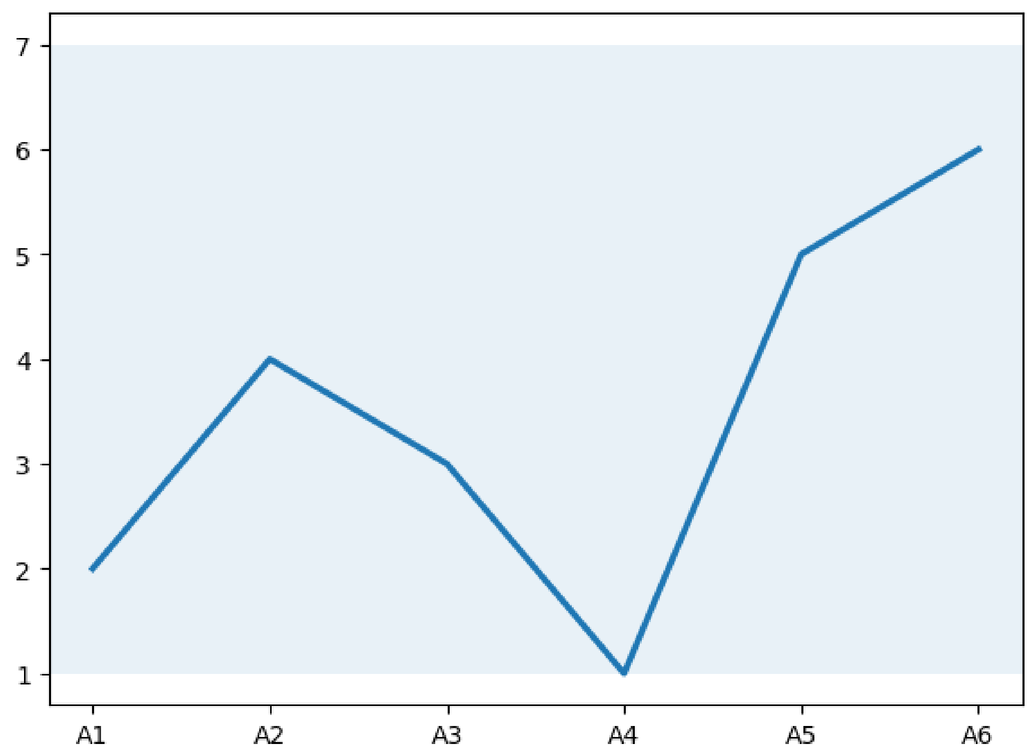

Fig 9. The rank of alternatives.

4. Conclusions

Sustainable management of costs and risks in prefabricated infrastructure projects is no longer optional, it is a strategic imperative. As the construction sector evolves toward automation and modularization, stakeholders must adapt by incorporating comprehensive cost-risk frameworks that reflect the nuances of prefabrication. This study underscores the need for integrated approaches that balance economic performance with long-term sustainability. This study used the MCDM approach to deal with different criteria and alternatives. Two MCDM methods are used in this study such as RANCOM method to compute the weights of criteria and ARTASI method to rank the alternatives. Eight criteria and six alternatives are used in this study. By embracing innovation, promoting regulatory compliance, and adopting lifecycle-based evaluations, project managers can significantly enhance the viability and resilience of prefabricated infrastructure in a rapidly changing global environment

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