The **VIKOR method** (VlseKriterijumska Optimizacija I Kompromisno Resenje), which translates as "Multi-Criteria Optimization and Compromise Solution," is a multi-criteria decision-making (MCDM) technique designed to rank and select from a set of alternatives in the presence of conflicting criteria. It helps to determine a compromise solution that provides the closest outcome to the ideal solution.

When using **triangular fuzzy numbers (TFNs)** in VIKOR, fuzzy set theory is applied to handle uncertainties or imprecise data. TFNs are useful because they represent imprecision in data through a fuzzy number described by a triplet (l, m, u), where:

- **l**: lower bound (the least possible value),
- **m**: the most likely value (the peak or the best estimate),
- **u**: upper bound (the greatest possible value).

This is useful in decision-making processes where exact values are hard to determine.

Steps to Apply the VIKOR Method with Triangular Fuzzy Numbers

The general procedure for applying the VIKOR method with triangular fuzzy numbers is as follows:

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1. Define the Decision Matrix Using Triangular Fuzzy Numbers

In the decision matrix, each alternative is evaluated under multiple criteria using triangular fuzzy numbers. Each criterion value for an alternative will be a TFN (l, m, u).

Criteria	Alternative 1	Alternative 2	...	Alternative n
C1	(l_{11}, m_{11}, u_{11})	(l_{12}, m_{12}, u_{12})	...	(l_{1n}, m_{1n}, u_{1n})
C2	(l_{21}, m_{21}, u_{21})	(l_{22}, m_{22}, u_{22})	...	(l_{2n}, m_{2n}, u_{2n})
...	...	...	...	...
Ck	(l_{k1}, m_{k1}, u_{k1})	(l_{k2}, m_{k2}, u_{k2})	...	(l_{kn}, m_{kn}, u_{kn})

Where:

- $C_1, C_2, \ldots, C_k$ are the criteria.
- $A_1, A_2, \ldots, A_n$ are the alternatives.
- (l_{ij}, m_{ij}, u_{ij}) is the fuzzy rating for alternative A_j under criterion C_i.

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2. Determine the Fuzzy Best and Fuzzy Worst Values for Each Criterion

For each criterion, determine the fuzzy best (ideal) and fuzzy worst (anti-ideal) values:

- **Fuzzy best value (A^*):** The maximum value of u_{ij} for each criterion.
- **Fuzzy worst value (A^-):** The minimum value of l_{ij} for each criterion.

Let $A^* = (l^*, m^*, u^*)$ be the ideal fuzzy solution and $A^- = (l^-, m^-, u^-)$ be the anti-ideal fuzzy solution.

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3. Calculate the Fuzzy Distance (L1 and L∞) for Each Alternative

The next step is to compute the fuzzy distance of each alternative from the fuzzy best and fuzzy worst. This involves calculating two measures:

- **L1 distance (group utility measure):** Measures the average distance from the ideal solution.
- **L∞ distance (individual regret measure):** Measures the maximum regret for each criterion.

For each alternative A_j, calculate the distances from the fuzzy best and fuzzy worst values.

1. **Group utility S_j:**

$$S_j = \sum_{i=1}^{k} w_i \cdot d(A_j, A^*)$$

where $d(A_j, A^*)$ is the distance between the triangular fuzzy number of A_j and the ideal solution and w_i is the weight of the criterion i.

2. **Individual regret R_j:**

$$R_j = \max_i \left(w_i \cdot d(A_j, A^*) \right)$$

where the distance is calculated using any appropriate distance measure for triangular fuzzy numbers.

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4. Compute the VIKOR Index for Each Alternative

The compromise ranking index Q_j for each alternative A_j is computed as:

$$Q_j = v \frac{S_j - S^*}{S^- - S^*} + (1 - v) \frac{R_j - R^*}{R^- - R^*}$$

Where:

- v is a weight representing the decision maker's preference for group utility (typically $v = 0.5$).
- S^* and S^- are the best and worst values for the utility measure.
- R^* and R^- are the best and worst values for the regret measure.

This formula combines the results of the group utility and individual regret to calculate a compromise solution.

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5. Rank the Alternatives Based on the VIKOR Index

Rank the alternatives based on the Q_j values in ascending order. The lower the value of Q_j, the better the rank of the alternative.

The alternative with the lowest Q_j is considered the best compromise solution. However, the following conditions must be met to confirm the compromise solution:

1. **Acceptable advantage condition**: The difference between the Q_j values of the first and second-ranked alternatives must be significant.
2. **Acceptable stability condition**: The alternative with the lowest Q_j must also have the best or second-best rank in terms of the S_j or R_j measures.

Find the rank of each supplier in the given dataset by VIKOR Method?

Criteria Suppliers	Service Quality (Sq)	Quality (q)	Price (p)	CO2 Emission (e)	Lead Time (l)
1	84	75	40	187	3
2	76	77	30	195	2
3	27	86	50	272	4
4	110	85	20	236	5
5	94	62	25	287	3

Solution. The **VIKOR** method is a multi-criteria decision-making tool. It focuses on ranking and selecting from a set of alternatives and determining a compromise solution. For a fuzzy approach, we use Triangular Fuzzy Numbers (TFNs), which help in representing uncertainty in decision-making by considering a range of values rather than fixed numbers. **We are taking a 5% deviation for TFNs**, which means that for each criterion, we will create fuzzy values.

Steps for applying the VIKOR method:

1. **Convert crisp data into TFNs (Triangular Fuzzy Numbers)**: For each criterion, convert the given crisp value into a TFN with a 5% deviation. This means:
   - **Lower Bound**: $x - 5\%$
   - **Middle (or Crisp) Value**: x
   - **Upper Bound**: $x + 5\%$

   Let's calculate the fuzzy numbers for each supplier and criterion.

2. **Determine the best f^* and worst f^- values**:
   - The best value is either the maximum or minimum depending on the criterion (maximization or minimization).
   - Similarly, determine the worst value for each criterion.
3. **Calculate the normalized fuzzy distance**: The normalized distance measures the closeness of each supplier to the best and worst values.

4. **Compute the utility and regret measures**.

5. **Calculate the Q value** for each supplier using the following formula:

$$Q_j = v\frac{S_j - S^*}{S^- - S^*} + (1 - v)\frac{R_j - R^*}{R^- - R^*}$$

   Where:

- S_j is the utility measure,
- R_j is the regret measure,
- v is the weight of the majority criterion (typically $v = 0.5$).

6. **Rank the suppliers** based on the Q-values.

Step 1: Convert Each Supplier's Data to Triangular Fuzzy Numbers (TFN)

The first step in the VIKOR method with fuzzy numbers is to convert each supplier's performance values for each criterion into **triangular fuzzy numbers (TFN)**.

A triangular fuzzy number (TFN) is represented as (l, m, u), where:

- l is the **lower bound** (the smallest plausible value),
- m is the **mean or most likely** value,
- u is the **upper bound** (the largest plausible value).

The deviation we use for the conversion to fuzzy numbers is given as **5%** of each criterion's value.

General Formula for TFN:

Given a crisp value x, the corresponding TFN (l, m, u) is:

- $l = x - 0.05 \times x = 0.95 \times x$,
- $m = x$ (the original value),
- $u = x + 0.05 \times x = 1.05 \times x$.

Now, we will convert the data for each criterion of each supplier into TFNs.

Supplier 1: Convert Crisp Values to TFN

Service Quality (Sq):

- Crisp value = **84**

$$l = 0.95 \times 84 = 79.8, \quad m = 84, \quad u = 1.05 \times 84 = 88.2$$

$$\text{TFN for Sq} = (79.8, 84, 88.2)$$

Quality (q):

- Crisp value = **75**

$$l = 0.95 \times 75 = 71.25, \quad m = 75, \quad u = 1.05 \times 75 = 78.75$$

$$\text{TFN for q} = (71.25, 75, 78.75)$$

Price (p):

- Crisp value = **40**

$$l = 0.95 \times 40 = 38, \quad m = 40, \quad u = 1.05 \times 40 = 42$$

$$\text{TFN for p} = (38,40,42)$$

CO2 Emission (e):

- Crisp value = **187**

$$l = 0.95 \times 187 = 177.65, \quad m = 187, \quad u = 1.05 \times 187 = 196.35$$

$$\text{TFN for e} = (177.65,187,196.35)$$

Lead Time (l):

- Crisp value = **3**

$$l = 0.95 \times 3 = 2.85, \quad m = 3, \quad u = 1.05 \times 3 = 3.15$$

$$\text{TFN for l} = (2.85,3,3.15)$$

Supplier 2: Convert Crisp Values to TFN

Service Quality (Sq):

- Crisp value = **76**

$$l = 0.95 \times 76 = 72.2, \quad m = 76, \quad u = 1.05 \times 76 = 79.8$$

$$\text{TFN for Sq} = (72.2,76,79.8)$$

Quality (q):

- Crisp value = **77**

$$l = 0.95 \times 77 = 73.15, \quad m = 77, \quad u = 1.05 \times 77 = 80.85$$

$$\text{TFN for q} = (73.15,77,80.85)$$

Price (p):

- Crisp value = **30**

$$l = 0.95 \times 30 = 28.5, \quad m = 30, \quad u = 1.05 \times 30 = 31.5$$

$$\text{TFN for p} = (28.5,30,31.5)$$

CO2 Emission (e):

- Crisp value = **195**

$$l = 0.95 \times 195 = 185.25, \quad m = 195, \quad u = 1.05 \times 195 = 204.75$$

$$\text{TFN for e} = (185.25, 195, 204.75)$$

Lead Time (l):

- Crisp value = **2**

$$l = 0.95 \times 2 = 1.9, \quad m = 2, \quad u = 1.05 \times 2 = 2.1$$

$$\text{TFN for l} = (1.9, 2, 2.1)$$

Supplier 3: Convert Crisp Values to TFN

Service Quality (Sq):

- Crisp value = **27**

$$l = 0.95 \times 27 = 25.65, \quad m = 27, \quad u = 1.05 \times 27 = 28.35$$

$$\text{TFN for Sq} = (25.65, 27, 28.35)$$

Quality (q):

- Crisp value = **86**

$$l = 0.95 \times 86 = 81.7, \quad m = 86, \quad u = 1.05 \times 86 = 90.3$$

$$\text{TFN for q} = (81.7, 86, 90.3)$$

Price (p):

- Crisp value = **50**

$$l = 0.95 \times 50 = 47.5, \quad m = 50, \quad u = 1.05 \times 50 = 52.5$$

$$\text{TFN for p} = (47.5, 50, 52.5)$$

CO2 Emission (e):

- Crisp value = **272**

$$l = 0.95 \times 272 = 258.4, \quad m = 272, \quad u = 1.05 \times 272 = 285.6$$

$$\text{TFN for e} = (258.4, 272, 285.6)$$

Lead Time (l):

- Crisp value = **4**

$$l = 0.95 \times 4 = 3.8, \quad m = 4, \quad u = 1.05 \times 4 = 4.2$$

$$\text{TFN for l} = (3.8, 4, 4.2)$$

Supplier 4: Convert Crisp Values to TFN

Service Quality (Sq):

- Crisp value = **110**

$$l = 0.95 \times 110 = 104.5, \quad m = 110, \quad u = 1.05 \times 110 = 115.5$$

$$\text{TFN for Sq} = (104.5, 110, 115.5)$$

Quality (q):

- Crisp value = **85**

$$l = 0.95 \times 85 = 80.75, \quad m = 85, \quad u = 1.05 \times 85 = 89.25$$

$$\text{TFN for q} = (80.75, 85, 89.25)$$

Price (p):

- Crisp value = **20**

$$l = 0.95 \times 20 = 19, \quad m = 20, \quad u = 1.05 \times 20 = 21$$

$$\text{TFN for p} = (19, 20, 21)$$

CO2 Emission (e):

- Crisp value = **236**

$$l = 0.95 \times 236 = 224.2, \quad m = 236, \quad u = 1.05 \times 236 = 247.8$$

$$\text{TFN for e} = (224.2, 236, 247.8)$$

Lead Time (l):

- Crisp value = **5**

$$l = 0.95 \times 5 = 4.75, \quad m = 5, \quad u = 1.05 \times 5 = 5.25$$

$$\text{TFN for l} = (4.75, 5, 5.25)$$

Supplier 5: Convert Crisp Values to TFN

Service Quality (Sq):

- Crisp value = **94**

$$l = 0.95 \times 94 = 89.3, \quad m = 94, \quad u = 1.05 \times 94 = 98.7$$

$$\text{TFN for Sq} = (89.3, 94, 98.7)$$

Quality (q):

- Crisp value = **62**

$$l = 0.95 \times 62 = 58.9, \quad m = 62, \quad u = 1.05 \times 62 = 65.1$$

$$\text{TFN for q} = (58.9,62,65.1)$$

***Price (p)*:**

- Crisp value = **25**

$$l = 0.95 \times 25 = 23.75, \quad m = 25, \quad u = 1.05 \times 25 = 26.25$$

$$\text{TFN for p} = (23.75,25,26.25)$$

***CO2 Emission (e)*:**

- Crisp value = **287**

$$l = 0.95 \times 287 = 272.65, \quad m = 287, \quad u = 1.05 \times 287 = 301.35$$

$$\text{TFN for e} = (272.65,287,301.35)$$

***Lead Time (l)*:**

- Crisp value = **3**

$$l = 0.95 \times 3 = 2.85, \quad m = 3, \quad u = 1.05 \times 3 = 3.15$$

$$\text{TFN for l} = (2.85,3,3.15)$$

Summary of TFNs for Each Supplier:

Supplier	Sq (Service Quality)	q (Quality)	p (Price)	e (CO2 Emission)	l (Lead Time)
1	(79.8, 84, 88.2)	(71.25, 75, 78.75)	(38, 40, 42)	(177.65, 187, 196.35)	(2.85, 3, 3.15)
2	(72.2, 76, 79.8)	(73.15, 77, 80.85)	(28.5, 30, 31.5)	(185.25, 195, 204.75)	(1.9, 2, 2.1)
3	(25.65, 27, 28.35)	(81.7, 86, 90.3)	(47.5, 50, 52.5)	(258.4, 272, 285.6)	(3.8, 4, 4.2)
4	(104.5, 110, 115.5)	(80.75, 85, 89.25)	(19, 20, 21)	(224.2, 236, 247.8)	(4.75, 5, 5.25)
5	(89.3, 94, 98.7)	(58.9, 62, 65.1)	(23.75, 25, 26.25)	(272.65, 287, 301.35)	(2.85, 3, 3.15)

This concludes the detailed calculations for Step 1, where the crisp values for each supplier and each criterion have been converted to triangular fuzzy numbers (TFN).

Step 2: Determine the best and worst values for each criterion

For each criterion:

- **Service Quality (Sq)**: Higher values are better (maximization).
- **Quality (q)**: Higher values are better (maximization).
- **Price (p)**: Lower values are better (minimization).
- **CO2 Emission (e)**: Lower values are better (minimization).
- **Lead Time (l)**: Lower values are better (minimization).

The best f^* and worst f^- fuzzy values for each criterion would be:

Criterion	Best (f*)	Worst (f-)
Service Quality	(104.5, 110, 115.5)	(25.65, 27, 28.35)
Quality	(81.7, 86, 90.3)	(58.9, 62, 65.1)
Price	(19, 20, 21)	(47.5, 50, 52.5)
CO2 Emission	(177.65, 187, 196.35)	(272.65, 287, 301.35)
Lead Time	(1.9, 2, 2.1)	(4.75, 5, 5.25)

Step 3: Normalize the Fuzzy Values for Each Criterion

We will now normalize the fuzzy values for each supplier using the formula:

$$N_{ij} = \frac{f_{ij}^* - f_{ij}}{f_{ij}^* - f_{ij}^-}$$

Where:

- f_{ij}^* is the best fuzzy value for criterion j,
- f_{ij} is the fuzzy value for supplier i,
- f_{ij}^- is the worst fuzzy value for criterion j.

For each supplier and criterion, we'll compute the normalized value using this formula. Here's the step-by-step breakdown for each criterion:

Service Quality (Sq)

Supplier	Fuzzy Value (f)	Normalized Value (N)
1	(79.8, 84, 88.2)	$\frac{(104.5,110,115.5)-(79.8,84,88.2)}{(104.5,110,115.5)-(25.65,27,28.35)}$ = (0.304, 0.316, 0.328)
2	(72.2, 76, 79.8)	$\frac{(104.5,110,115.5)-(72.2,76,79.8)}{(104.5,110,115.5)-(25.65,27,28.35)}$ = (0.385, 0.397, 0.409)
3	(25.65, 27, 28.35)	$\frac{(104.5,110,115.5)-(25.65,27,28.35)}{(104.5,110,115.5)-(25.65,27,28.35)}$ = (0, 0, 0)

Supplier	Fuzzy Value (f)	Normalized Value (N)
4	(104.5, 110, 115.5)	$\frac{(104.5,110,115.5)-(104.5,110,115.5)}{(104.5,110,115.5)-(25.65,27,28.35)} = (1, 1, 1)$
5	(89.3, 94, 98.7)	$\frac{(104.5,110,115.5)-(89.3,94,98.7)}{(104.5,110,115.5)-(25.65,27,28.35)} = (0.193, 0.205, 0.217)$

Quality (q)

Supplier	Fuzzy Value (f)	Normalized Value (N)
1	(71.25, 75, 78.75)	$\frac{(81.7,86,90.3)-(71.25,75,78.75)}{(81.7,86,90.3)-(58.9,62,65.1)} = (0.495, 0.5, 0.511)$
2	(73.15, 77, 80.85)	$\frac{(81.7,86,90.3)-(73.15,77,80.85)}{(81.7,86,90.3)-(58.9,62,65.1)} = (0.418, 0.429, 0.440)$
3	(81.7, 86, 90.3)	$\frac{(81.7,86,90.3)-(81.7,86,90.3)}{(81.7,86,90.3)-(58.9,62,65.1)} = (1, 1, 1)$
4	(80.75, 85, 89.25)	$\frac{(81.7,86,90.3)-(80.75,85,89.25)}{(81.7,86,90.3)-(58.9,62,65.1)} = (0.037, 0.036, 0.035)$
5	(58.9, 62, 65.1)	$\frac{(81.7,86,90.3)-(58.9,62,65.1)}{(81.7,86,90.3)-(58.9,62,65.1)} = (0, 0, 0)$

Price (p)

Supplier	Fuzzy Value (f)	Normalized Value (N)
1	(38, 40, 42)	$\frac{(19,20,21)-(38,40,42)}{(19,20,21)-(47.5,50,52.5)} = (0.541, 0.542, 0.543)$
2	(28.5, 30, 31.5)	$\frac{(19,20,21)-(28.5,30,31.5)}{(19,20,21)-(47.5,50,52.5)} = (0.738, 0.741, 0.745)$
3	(47.5, 50, 52.5)	$\frac{(19,20,21)-(47.5,50,52.5)}{(19,20,21)-(47.5,50,52.5)} = (0, 0, 0)$
4	(19, 20, 21)	$\frac{(19,20,21)-(19,20,21)}{(19,20,21)-(47.5,50,52.5)} = (1, 1, 1)$
5	(23.75, 25, 26.25)	$\frac{(19,20,21)-(23.75,25,26.25)}{(19,20,21)-(47.5,50,52.5)} = (0.849, 0.854, 0.860)$

CO2 Emission (e)

Supplier	Fuzzy Value (f)	Normalized Value (N)
1	(177.65, 187, 196.35)	$\frac{(177.65,187,196.35)-(177.65,187,196.35)}{(177.65,187,196.35)-(272.65,287,301.35)} = (1, 1, 1)$
2	(185.25, 195, 204.75)	$\frac{(177.65,187,196.35)-(185.25,195,204.75)}{(177.65,187,196.35)-(272.65,287,301.35)} = (0.896, 0.904, 0.912)$
3	(258.4, 272, 285.6)	$\frac{(177.65,187,196.35)-(258.4,272,285.6)}{(177.65,187,196.35)-(272.65,287,301.35)} = (0.163, 0.168, 0.174)$
4	(224.2, 236, 247.8)	$\frac{(177.65,187,196.35)-(224.2,236,247.8)}{(177.65,187,196.35)-(272.65,287,301.35)} = (0.548, 0.556,0.564$
5	| (272.65, 287, 301.35)	$\frac{(177.65,187,196.35)-(272.65,287,301.35)}{(177.65,187,196.35)-(272.65,287,301.35)} = (0, 0, 0)$

Lead Time (l)

Supplier	Fuzzy Value (f)	Normalized Value (N)
1	(2.85, 3, 3.15)	$\frac{(1.9,2,2.1)-(2.85,3,3.15)}{(1.9,2,2.1)-(4.75,5,5.25)}$ = (0.321, 0.326, 0.331)
2	(1.9, 2, 2.1)	$\frac{(1.9,2,2.1)-(1.9,2,2.1)}{(1.9,2,2.1)-(4.75,5,5.25)}$ = (1, 1, 1)
3	(3.8, 4, 4.2)	$\frac{(1.9,2,2.1)-(3.8,4,4.2)}{(1.9,2,2.1)-(4.75,5,5.25)}$ = (0.040, 0.041, 0.043)
4	(4.75, 5, 5.25)	$\frac{(1.9,2,2.1)-(4.75,5,5.25)}{(1.9,2,2.1)-(4.75,5,5.25)}$ = (0, 0, 0)
5	(2.85, 3, 3.15)	$\frac{(1.9,2,2.1)-(2.85,3,3.15)}{(1.9,2,2.1)-(4.75,5,5.25)}$ = (0.321, 0.326, 0.331)

Step 4: Calculate Utility (S_j) and Regret (R_j) Measures

For each supplier, we calculate the **Utility** (S_j) and **Regret** (R_j) measures:

- **Utility** (S_j) is the sum of the normalized values across all criteria.

$$S_j = \sum_{i=1}^{n} N_{ij}$$

- **Regret** (R_j) is the maximum normalized value across all criteria for a particular supplier.

$$R_j = \max_i N_{ij}$$

Let's compute the **Utility** (S_j) and **Regret** (R_j) for each supplier using the normalized values from Step 3.

Supplier 1:

- **Service Quality (Sq)**: $N_{11} = (0.304, 0.316, 0.328)$
- **Quality (q)**: $N_{12} = (0.495, 0.5, 0.511)$
- **Price (p)**: $N_{13} = (0.541, 0.542, 0.543)$
- **CO2 Emission (e)**: $N_{14} = (1, 1, 1)$
- **Lead Time (l)**: $N_{15} = (0.321, 0.326, 0.331)$

Utility S_1:

$$S_1 = 0.316 + 0.5 + 0.542 + 1 + 0.326 = 2.684$$

Regret R_1:

$$R_1 = \max(0.316, 0.5, 0.542, 1, 0.326) = 1$$

Supplier 2:

- **Service Quality (Sq)**: $N_{21} = (0.385, 0.397, 0.409)$
- **Quality (q)**: $N_{22} = (0.418, 0.429, 0.440)$
- **Price (p)**: $N_{23} = (0.738, 0.741, 0.745)$
- **CO2 Emission (e)**: $N_{24} = (0.896, 0.904, 0.912)$
- **Lead Time (l)**: $N_{25} = (1, 1, 1)$

Utility S_2:

$$S_2 = 0.397 + 0.429 + 0.741 + 0.904 + 1 = 3.471$$

Regret R_2:

$$R_2 = \max(0.397, 0.429, 0.741, 0.904, 1) = 1$$

Supplier 3:

- **Service Quality (Sq)**: $N_{31} = (0, 0, 0)$
- **Quality (q)**: $N_{32} = (1, 1, 1)$
- **Price (p)**: $N_{33} = (0, 0, 0)$
- **CO2 Emission (e)**: $N_{34} = (0.168, 0.174, 0.174)$
- **Lead Time (l)**: $N_{35} = (0.040, 0.041, 0.043)$

Utility S_3:

$$S_3 = 0 + 1 + 0 + 0.174 + 0.041 = 1.215$$

Regret R_3:

$$R_3 = \max(0,1,0,0.174,0.041) = 1$$

Supplier 4:

- **Service Quality (Sq)**: $N_{41} = (1,1,1)$
- **Quality (q)**: $N_{42} = (0.037,0.036,0.035)$
- **Price (p)**: $N_{43} = (1,1,1)$
- **CO2 Emission (e)**: $N_{44} = (0.556,0.556,0.564)$
- **Lead Time (l)**: $N_{45} = (0,0,0)$

Utility S_4:

$$S_4 = 1 + 0.036 + 1 + 0.556 + 0 = 2.592$$

Regret R_4:

$$R_4 = \max(1,0.036,1,0.556,0) = 1$$

Supplier 5:

- **Service Quality (Sq)**: $N_{51} = (0.193,0.205,0.217)$
- **Quality (q)**: $N_{52} = (0,0,0)$
- **Price (p)**: $N_{53} = (0.849,0.854,0.860)$
- **CO2 Emission (e)**: $N_{54} = (0,0,0)$
- **Lead Time (l)**: $N_{55} = (0.321,0.326,0.331)$

Utility S_5:

$$S_5 = 0.205 + 0 + 0.854 + 0 + 0.326 = 1.385$$

Regret R_5:

$$R_5 = \max(0.205,0,0.854,0,0.326) = 0.854$$

Summary of Utility (S_j) and Regret (R_j) Values:

Supplier	S_j	R_j
1	2.684	1
2	3.471	1
3	1.215	1
4	2.592	1
5	1.385	0.854

Step 5: Calculate Q_j Values

We will calculate the Q_j values for each supplier using the formula:

$$Q_j = v \cdot \frac{S_j - S^*}{S^- - S^*} + (1 - v) \cdot \frac{R_j - R^*}{R^- - R^*}$$

Where:

- $v = 0.5$ (weighting factor),
- S^* is the minimum S_j,
- S^- is the maximum S_j,
- R^* is the minimum R_j,
- R^- is the maximum R_j.

Step 5: Calculate Q_j Values and Determine Final Ranks

The formula for calculating Q_j is:

$$Q_j = v \cdot \frac{S_j - S^*}{S^- - S^*} + (1 - v) \cdot \frac{R_j - R^*}{R^- - R^*}$$

Where:

- $v = 0.5$ (weighting factor),
- $S^* = \min(S_j) = 1.215$ (minimum utility),
- $S^- = \max(S_j) = 3.471$ (maximum utility),
- $R^* = \min(R_j) = 0.854$ (minimum regret),
- $R^- = \max(R_j) = 1$ (maximum regret).

Now, let's calculate Q_j for each supplier.

Supplier 1:

$$Q_1 = 0.5 \cdot \frac{2.684 - 1.215}{3.471 - 1.215} + 0.5 \cdot \frac{1 - 0.854}{1 - 0.854}$$

$$Q_1 = 0.5 \cdot \frac{1.469}{2.256} + 0.5 \cdot \frac{0.146}{0.146}$$

$$Q_1 = 0.5 \cdot 0.651 + 0.5 \cdot 1 = 0.325 + 0.5 = 0.825$$

Supplier 2:

$$Q_2 = 0.5 \cdot \frac{3.471 - 1.215}{3.471 - 1.215} + 0.5 \cdot \frac{1 - 0.854}{1 - 0.854}$$

$$Q_2 = 0.5 \cdot \frac{2.256}{2.256} + 0.5 \cdot \frac{0.146}{0.146}$$

$$Q_2 = 0.5 \cdot 1 + 0.5 \cdot 1 = 1$$

Supplier 3:

$$Q_3 = 0.5 \cdot \frac{1.215 - 1.215}{3.471 - 1.215} + 0.5 \cdot \frac{1 - 0.854}{1 - 0.854}$$

$$Q_3 = 0.5 \cdot \frac{0}{2.256} + 0.5 \cdot \frac{0.146}{0.146}$$

$$Q_3 = 0 + 0.5 \cdot 1 = 0.5$$

Supplier 4:

$$Q_4 = 0.5 \cdot \frac{2.592 - 1.215}{3.471 - 1.215} + 0.5 \cdot \frac{1 - 0.854}{1 - 0.854}$$

$$Q_4 = 0.5 \cdot \frac{1.377}{2.256} + 0.5 \cdot \frac{0.146}{0.146}$$

$$Q_4 = 0.5 \cdot 0.610 + 0.5 \cdot 1 = 0.305 + 0.5 = 0.805$$

Supplier 5:

$$Q_5 = 0.5 \cdot \frac{1.385 - 1.215}{3.471 - 1.215} + 0.5 \cdot \frac{0.854 - 0.854}{1 - 0.854}$$

$$Q_5 = 0.5 \cdot \frac{0.17}{2.256} + 0.5 \cdot \frac{0}{0.146}$$

$$Q_5 = 0.5 \cdot 0.075 + 0 = 0.0375$$

Final Q_j Values:

Supplier	S_j	R_j	Q_j
1	2.684	1	0.825

Supplier	S_j	R_j	Q_j
2	3.471	1	1
3	1.215	1	0.5
4	2.592	1	0.805
5	1.385	0.854	0.0375

Final Ranks:

Based on the Q_j values, the suppliers are ranked as follows (lower Q_j is better):

Rank	Supplier	Q_j
1	Supplier 5	0.0375
2	Supplier 3	0.5
3	Supplier 4	0.805
4	Supplier 1	0.825
5	Supplier 2	1

Conclusion:

- **Supplier 5** is ranked as the best supplier.
- **Supplier 2** is ranked the lowest.