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Fuzzy DEMATEL with Ranking Based on Degree of Optimism for Supplier Selection Criteria in Fertigation System

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ABSTRACT

Supplier selection is a critical factor in the success of fertigation systems, which integrate irrigation and fertilization to enhance agricultural productivity. This process's inherent uncertainty and complexity necessitate decision-making methodologies considering human judgment and risk preference factors. This study proposes the fuzzy DEMATEL method with a ranking based on the degree of optimism to evaluate and prioritise supplier selection criteria in fertigation systems. Six experts were involved in evaluating the influence of criteria such as price, quality, delivery, public procurement policy, technical, and managerial. The proposed method consists of 11 steps, including developing a fuzzy direct-relation matrix, average matrix, normalised fuzzy direct-relation matrix, fuzzy total relation matrix, and ranking based on left and right integral value. The left integral value represents the decision maker's perspective that is more inclined towards pessimism, while the right integral value represents the perspective that is more inclined towards optimism. The proposed method is implemented in the selection of supplier criteria in the fertigation system at one branch of RISDA (Rubber Industry Smallholders Development Authority) on the East Coast of Malaysia. The findings reveal that technical and quality criteria are paramount, though their relative importance shifts depending on the decision-maker’s degree of optimism. Specifically, technical criteria are prioritised by neutral and optimistic decision-makers, while quality criteria are regarded as most important by pessimistic decision-makers. Furthermore, the study identifies public procurement policy and technical criteria as part of the causal group, significantly influencing other criteria such as price, delivery, and managerial factors. The results align with previous research, confirming the consistency aspect of the fuzzy DEMATEL method with a degree of optimism-based ranking. This approach provides a comprehensive decision for agricultural decision-makers, facilitating more greater knowledge and balanced supplier selection decisions.

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1. INTRODUCTION

Fertigation systems, which integrate irrigation and fertilisation, are essential in contemporary agriculture for increasing crop yields and optimising resource use. According to Elasbah et al. (2019), an appropriate fertilisation plan consistent with current irrigation technology should be implemented to ensure the effectiveness of fertigation systems. Thus, selecting suppliers for fertigation systems is crucial as the criteria for evaluating are broad and complex, and the decision will impact the organisation's performance efficiency, sustainability, and cost.

Numerous studies have been developed to determine the selection of suppliers in the agricultural industry, including fertigation systems. Scott et al. (2015) offers an integrated strategy combining an optimization algorithm approach with the Analytic Hierarchy Process–Quality Function Deployment to identify suitable suppliers for the bioenergy business. According to the study, wood chip supply is the least preferred fuel source, whereas fuel derived from waste is the most preferred. In other studies, Ackerman et al. (2019) presents a genetic algorithm-based selection method for a multi-objective optimization strategy to select green suppliers for juice manufacturing in Mexico. Furthermore, Hadi et al. (2023) used an AHP method to choose cassava suppliers in Jember, Indonesia. The study ranked environment management as the best, while technical ability was the lowest.

Even though traditional quantification methods offer reliable solutions, they are not entirely effective in resolving human-centred issues as human factors are imprecise and ambiguous (Tsai et al., 2015). The fundamental concept of fuzzy set theory, as proposed by Zadeh (1965), is suitable for resolving real-world issues involving human judgment and complexity. Various studies have been carried out on supplier selection in agriculture using multicriteria decision making such as the Vikor method by Cheraghalipour et al. (2018), the fuzzy Logarithm Methodology of Additive Weights method by Puska et al. (2022), the Spherical Fuzzy Analytic Hierarchy Process by My et al. (2022), and Fuzzy Analytic Hierarchy Process and Complex Proportional Assessment of Alternatives by Thanh et al. (2022). These methods are applied to obtain the ranking of the weight of criteria and alternatives involved but do not look into the causal relationship between the criteria.

The DEMATEL technique is a multi-criteria decision-making method employed to evaluate the relationships between criteria (Si et al., 2018). This technique can consider the interrelationships between criteria and organise complex criteria into cause-and-effect groups. Fuzzy DEMATEL has been widely used as it can provide a model with a causal relationship between criteria in uncertain and complex environments. According to Mendes et al. (2014), the fuzzy DEMATEL is superior to other methods like fuzzy AHP, Topsis and Vikor since it considers the interrelationship between criteria via a causal diagram, which is not considered in those methods. Chang et al. (2011) was the first to utilise fuzzy DEMATEL to determine the electronic sector's significant element for supplier selection. The study demonstrates that the factors of technology ability, stable delivery of goods, lead time, and production capability are the causal criteria that impact the other criteria. Nasrullahi et al. (2021) utilised the fuzzy DEMATEL approach to determine the supplier selection criteria in the desalination supply chain and examine their relationships. The study identified management, financial status, and culture as the most influential criteria. In other studies, Kumar et al. (2023) employed the fuzzy DEMATEL methodology to examine the crucial performance indicator for India's agricultural cold supply chain, measured at both the local market and field level, with findings suggesting that the government should prioritise minimising waste. Mohd et al. (2020) considered six criteria for supplier selection in a fertigation system: price, quality, delivery, public procurement policy, technical, and managerial. When evaluating the supplier of the fertigation system, the farmer should compare the cost offered by the supplier and ensure that the price reflects the value of the system’s features and benefits.

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The aforementioned studies propose integrated models in uncertain environments that combine computational intelligence with decision-making techniques, but do not consider on decision-makers' degree of optimism. By integrating the level of optimism into the fuzzy DEMATEL approach, which incorporates the viewpoint of decision-makers, the fuzzy DEMATEL method can offer a more comprehensive assessment of the strength of criteria, leading to a better decision-making. Mohd et al. (2020) considered six criteria for supplier selection in a fertigation system: price, quality, delivery, public procurement policy, technical, and managerial. When evaluating the supplier of the fertigation system, the farmer should compare the cost offered by the supplier and ensure that the price reflects the value of the system's features and benefits. At the same time, the farmers should evaluate the supplier's delivery and installation capabilities, which can be crucial to the system's performance. The supplier selection process must also comply with the public procurement policy established in their organization. This might involve fairness and transparency in the competitive bidding process. Technical issues such as how well the supplier's system can integrate with the current fertigation system and how well the supplier performs in terms of management skills, including customer service and ongoing support, should also be considered. As a result, the study's findings show that the public procurement policy is the most influential criterion for supplier selection in the fertigation system.

This paper presents an enhanced approach that integrates fuzzy DEMATEL with ranking based on the degree of optimism to assess and prioritise supplier selection criteria in fertigation systems. The proposed method intends to enhance the efficiency of supplier selection in the context of fertigation systems by providing a more flexible decision-support tool. The paper's content is presented as follows: Section 2 provides an overview of the fundamental aspects of the concept employed in the suggested approach. Section 3 outlines the methodology, which involves integrating the degree of optimism into the fuzzy DEMATEL method. Section 4 provides a numerical example to illustrate the practical implementation of the suggested approach. Section 5 provides an analysis of the findings and their significance, while Section 6 represents the last section of the study.

2. PROPOSED METHODOLOGY

This section presents the proposed methodology for fuzzy Dematel method with ranking based on degree of optimism. Once the basic knowledge of fuzzy numbers is presented, the procedure of the proposed combine fuzzy Dematel and ranking based on the integral value is described.

2.1 Fuzzy Numbers

Some basic definitions of fuzzy numbers are reviewed in this sub-section. The ranking of fuzzy numbers based on the total integral value from Liou and Wang (1992) and the defuzzification method using centroid by Wang et al. (2006) are also presented.

Definition 2.1 (Cheng, 1998)

A fuzzy number T is a fuzzy set in the universe of discourse X that is both convex and normal, has bounded support, and all α-cuts of T are closed intervals of X.

Definition 2.2 (Cheng, 1998)

A trapezoidal fuzzy number, represented as $T = (t_1, t_2, t_3, t_4)$, has its membership function defined as follows:

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$$\mu_T(x)=\begin{cases}\dfrac{x-t_1}{t_2-t_1} & ,t_1\le x\le t_2\\ 1 & ,t_2\le x\le t_3\\ \dfrac{t_4-x}{t_4-t_3} & ,t_3\le x\le t_4\\ 0 & ,\text{otherwise}\end{cases}$$

For $t_2 = t_3$, T becomes a triangular fuzzy number represented as $T = (t_1, t_2, t_4)$, and has its membership function defined as follows:

$$\mu_T(x)=\begin{cases}\dfrac{x-t_1}{t_2-t_1} & ,t_1\le x\le t_2\\ \dfrac{t_4-x}{t_4-t_2} & ,t_2\le x\le t_4\\ 0 & ,\text{otherwise}\end{cases}$$

Definition 2.3 (Liou & Wang, 1992)

For a trapezoidal fuzzy number $T = (t_1, t_2, t_3, t_4)$, for $\beta\in[0,1]$ the total integral value is given in Eq. (1).

$$I_T^\beta=\frac{1}{2}\left[\beta\left(t_3+t_4\right)+\left(1-\beta\right)\left(t_1+t_2\right)\right], \tag{1}$$

The higher the value of I_T^β, the higher the rank of the fuzzy number.

Definition 2.4 (Wang et al, 2006)

For a trapezoidal fuzzy number $T = (t_1, t_2, t_3, t_4)$, the centroid point x can be expressed as indicated in Eq. (2).

$$x=\frac{\omega\left(\left((t_4)^2-2(t_3)^2+2(t_2)^2-(t_1)^2+t_4t_3-t_1t_2\right)+3\left((t_3)^2-(t_2)^2\right)\right)}{3\omega\left(t_4-t_3+t_2-t_1\right)+6\left(t_3-t_2\right)},\ \text{where } 0\le\omega\le 1 \tag{2}$$

2.2 Proposed Fuzzy Dematel with Ranking based on Degree of Optimism

This sub-section describes the procedure of the proposed fuzzy DEMATEL with a ranking based on the degree of optimism. The procedure consists of eleven (11) steps as follows:

Step 1: Define the evaluation criteria, B_1, B_2, … B_n, where B_i represents the i-th criteria and n is the total number of criteria.

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Step 2: Choose a group of K experts with knowledge and competence in evaluating the effect between criteria through pairwise comparison.

Step 3: Establish a fuzzy linguistic scale to address the uncertainty inherent in human judgement. The group decision-making process utilises a five-level linguistic concept called "influence". The scale consists of five levels of impact: no influence (NO), very low influence (VL), low influence (L), high influence (H), and very high influence (VH). Table 1 displays the fuzzy numbers for these linguistic terms.

Table 1. The fuzzy linguistic scale for experts' evaluation

Linguistic Terms	**Fuzzy numbers**
No influence (NO)	(0, 0, 0, 0.25)
Very low influence (VL)	(0, 0, 0.25, 0.5)
Low influence (L)	(0, 0.25, 0.5, 0.75)
High influence (H)	(0.25, 0.5, 0.75, 1)
Very high influence (VH)	(0.5, 0.75, 1, 1)

Step 4: Build a fuzzy direct-relation matrix where decision-makers gather judgements on a linguistic scale based on Table 1. The fuzzy initial direct-relation matrix S_k, which contains fuzzy numbers represented as $S_k = \left(s_{ijk}\right)_{n\times n} = \left(\left(a_{ijk}, b_{ijk}, c_{ijk}, d_{ijk}\right)\right)_{n\times n}$, can be expressed as indicated in Eq. (3), which s_{ijk} reflects the subjective assessment made by decision maker *k* regarding the degree of influence of element *i* on element *j*.

$$S_k = \left[s_{ijk}\right]_{n\times n} = \begin{bmatrix} 0 & s_{12k} & . & . & . & s_{1nk} \\ s_{21k} & 0 & . & . & . & s_{2nk} \\ . & . & . & & & . \\ . & . & & . & & . \\ . & . & & & . & . \\ s_{n1k} & s_{n2k} & . & . & . & 0 \end{bmatrix}_{n\times n} \tag{3}$$

Step 5: Aggregate the assessments of K decision-makers for each of the k experts. These form the average matrix, as indicated by Eq. (4).

$$S = \left(s_{ij}\right)_{n\times n} = \left(\frac{s_{ij1} \oplus s_{ij2} \oplus \ldots \oplus s_{ijK}}{K}\right)_{n\times n} \tag{4}$$

Step 6: Using Eq. (5), compute the normalised fuzzy direct-relation matrix as follows:

$$F = \left(f_{ij}\right)_{n\times n} = \begin{pmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{n1} & f_{n2} & \cdots & f_{nn} \end{pmatrix} \tag{5}$$

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where $f_{ij} = \frac{s_{ij}}{r} = \left(\frac{a_{ij}}{r}, \frac{b_{ij}}{r}, \frac{c_{ij}}{r}, \frac{d_{ij}}{r}\right)$; $r = \max_{1\le i\le n}\left(\Sigma_{j=1}^{n} d_{ij}\right)$ for all criteria of $i, j = 1, 2, ..., n$

Step 7: Let $F = \left(f_{ij}\right)_{ij} = \left(a'_{ij}, b'_{ij}, c'_{ij}, d'_{ij}\right)_{ij}$ and $F_a = \left(a'_{ij}\right)_{n\times n}$, $F_b = \left(b'_{ij}\right)_{n\times n}$, $F_c = \left(c'_{ij}\right)_{n\times n}$ and $F_d = \left(d'_{ij}\right)_{n\times n}$. The elements in these matrices are obtained from F as shown in Eq. (6):

$$F_a = \begin{pmatrix} 0 & a'_{12} & \cdots & a'_{1n} \\ a'_{21} & 0 & \cdots & a'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a'_{n1} & a'_{n2} & \cdots & 0 \end{pmatrix}; \quad F_b = \begin{pmatrix} 0 & b'_{12} & \cdots & b'_{1n} \\ b'_{21} & 0 & \cdots & b'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ b'_{n1} & b'_{n2} & \cdots & 0 \end{pmatrix};$$

$$F_c = \begin{pmatrix} 0 & c'_{12} & \cdots & c'_{1n} \\ c'_{21} & 0 & \cdots & c'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ c'_{n1} & c'_{n2} & \cdots & 0 \end{pmatrix}; \quad F_d = \begin{pmatrix} 0 & d'_{12} & \cdots & d'_{1n} \\ d'_{21} & 0 & \cdots & d'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ d'_{n1} & d'_{n2} & \cdots & 0 \end{pmatrix}; \quad (6)$$

Step 8: Using Eq. (7) and Eq. (8), construct the fuzzy total relation matrix $P = \lim_{k\to\infty}\left(F^1 + F^2 + \ldots + F^k\right)$ in which the matrix has trapezoidal fuzzy numbers.

$$P = \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{pmatrix} \quad (7)$$

$$p_{ij} = \left(P_a, P_b, P_c, P_d\right), \quad P_a = F_a\left(I - F_a\right)^{-1}, \; P_b = F_b\left(I - F_b\right)^{-1}, \; P_c = F_c\left(I - F_c\right)^{-1} \text{ and }$$
$$P_d = F_d\left(I - F_d\right)^{-1} \quad (8)$$

whereby I is the matrix identity n x n.

Compute the summation of rows (r_i) and columns (c_j) for each row i and column j from matrix $P = \left[p_{ij}\right]_{n\times n}$ respectively.

$$r_i = \Sigma_{1\le j\le n}^{n} s_{ij}, \forall i \quad (9)$$

$$c_j = \Sigma_{1\le i\le n}^{n} s_{ij}, \forall j \quad (10)$$

Step 9: Calculate the sum of r_i and c_j using the fuzzy arithmetic operation described in Eq. (11), and calculate the difference between r_i and c_j using the fuzzy arithmetic operation described in Eq. (12). The expressions $r_i + c_j$ and $r_i - c_j$ are in the form of trapezoidal fuzzy numbers. The sum of r_i and c_j represents the strength of each criterion. Meanwhile, $r_i - c_j$ denotes the group of criteria.

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For two trapezoidal fuzzy numbers, $A = (a_1, a_2, a_3, a_4)$ and $B = (b_1, b_2, b_3, b_4)$, the addition and subtraction operations are as in Eq. (11) and Eq. (12) relatively.

$$A \oplus B = \left(a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2\right) , \tag{11}$$

$$A - B = \left(a_1 - d_2, b_1 - c_2, c_1 - b_2, d_1 - a_2\right) \tag{12}$$

Step 10: Rank the $r_i + c_i$ using the integral value and degree of optimism approaches from Liou and Wang's (1992) study as indicated in Eq. (1). Calculate the total integral I_T^β for $r_i + c_i$ at $\beta = 0, 0.5$ and 1.

Step 11: Compute the defuzzification of $r_i - c_j$ using the centroid method in point-wise form, as proposed by Wang et al. (2006) in Eq. (2).

3. NUMERICAL EXAMPLE

This section applies the proposed fuzzy DEMATEL method in the selection of criteria for suppliers in the fertigation system. The selection process occurs at one branch of RISDA (Rubber Industry Smallholders Development Authority) located on the East Coast of Malaysia. The procedure for implementing the fuzzy DEMATEL with ranking based on the degree of optimism is illustrated in the subsequent steps.

Step 1: The six criteria for supplier selection in the fertigation system employed in this study were taken from Etraj and Jayaprakash (2017). The criteria include price (B_1), quality (B_2), delivery (B_3), public procurement policy (B_4), technical (B_5), and managerial (B_6).

Step 2: Six experts in the field of fertigation systems were engaged in the selection process. All experts possess over five years of expertise in managing the fertigation system.

Step 3: As stated in Table 1, the five fuzzy language terms used in this study were no influence (NO), very low influence (VL), low influence (L), high influence (H), and very high influence (VH).

Step 4: Table 2 displays the linguistic fuzzy scale direct-relation matrix S_1 for Expert 1 based on Table 1 and Eq. (3).

Table 2. The linguistic scale direct-relation matrix for Expert 1, S_1

	B_1	B_2	B_3	B_4	B_5	B_6
B_1	(0, 0, 0, 0)	(0.5, 0.75, 1.00, 1.00)	(0, 0.25, 0.50, 0.75)	(0, 0.25, 0.50, 0.75)	(0, 0, 0.25, 0.50)	(0, 0, 0.25, 0.50)
B_2	(0.25, 0.50, 0.75, 1.00)	(0, 0, 0, 0)	(0, 0, 0.25)	(0, 0, 0, 0.25)	(0, 0.25, 0.50)	(0, 0, 0.25, 0.50)
B_3	(0, 0.25, 0.50, 0.75)	(0, 0, 0.25, 0.50)	(0, 0, 0, 0)	(0, 0.25, 0.50, 0.75)	(0, 0.25, 0.50, 0.75)	(0.25, 0.50, 0.75, 1.00)
B_4	(0, 0.25, 0.50, 0.75)	(0, 0, 0.25, 0.50)	(0, 0.25, 0.50)	(0, 0, 0, 0)	(0.25, 0.50, 0.75, 1.00)	(0.50, 0.75, 1.00, 1.00)
B_5	(0, 0.25, 0.50, 0.75)	(0.50, 0.75, 1.00, 1.00)	(0.25, 0.50, 0.75, 1.00)	(0, 0, 0.25, 0.50)	(0, 0, 0, 0)	(0.50, 0.75, 1.00, 1.00)
B_6	(0, 0, 0.25, 0.50)	(0.25, 0.50, 0.75, 1.00)	(0.25, 0.50, 0.75, 1.00)	(0, 0, 0.25, 0.50)	(0.25, 0.50, 0.75, 1.00)	(0, 0, 0, 0)

Steps 5-6: Based on Eq. (4) and Eq. (5), and all experts' linguistic scale direct-relation matrix, the normalised fuzzy direct-relation matrix F is shown in Table 3.

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Table 3. The normalised fuzzy direct relation matrix F

	B_1	B_2	B_3	B_4	B_5	B_6
B_1	(0,0,0,0)	(0.33,0.58,0.83,1.0)	(0.08,0.29,0.54,0.79)	(0.17,0.42,0.67,0.88)	(0.17,0.33,0.54,0.75)	(0.08,0.29,0.54,0.75)
B_2	(0.33,0.5830.83,0.96)	(0,0,0,0)	(0.04,0.25,0.46,0.71)	(0.21,0.42,0.62,0.83)	(0.25,0.42,0.62,0.79)	(0.25,0.46,0.71,0.88)
B_3	(0,0.25,0.50,0.75)	(0.08,0.29,0.54,0.79)	(0,0,0,0)	(0,0.25,0.50,0.75)	(0.08,0.33,0.58,0.83)	(0.08,0.33,0.58,0.83)
B_4	(0.17,0.42,0.67,0.92)	(0.25,0.46,0.71,0.88)	(0.25,0.46,0.71,0.88)	(0,0,0,0)	(0.21,0.46,0.71,0.96)	(0.25,0.46,0.71,0.88)
B_5	(0.29,0.54,0.79,0.92)	(0.33,0.58,0.83,1.0)	(0.21,0.46,0.71,0.92)	(0.12,0.33,0.58,0.79)	(0,0,0,0)	(0.29,0.54,0.79,1.0)
B_6	(0.29,0.42,0.66,0.88)	(0.12,0.38,0.62,0.88)	(0.12,0.37,0.62,0.83)	(0,0.17,0.38,0.62)	(0.17,0.42,0.67,0.92)	(0,0,0,0)

Steps 7-9: Table 4 displays the values of $r_i + c_j$ and $r_i - c_j$ based on Eq. (6) to Eq. (12).

Table 4. The values of $ri + cj$ and $ri - cj$

	Sum of rows, r_i	Sum of columns, c_j	$r_i + c_j$	$r_i - c_j$
B_1	(0.228,0.737,2.212,11.262)	(0.292,0.837,2.421,11.845)	(0.520,1.574,4.632,23.107)	(-11.616,-1.684, 1.374, 10.971)
B_2	(0.293,0.808,2.290,11.269)	(0.299,0.863,2.467,12.130)	(0.592,1.671,4.756,23.399)	(-11.837,-1.659, 1.426, 10.970)
B_3	(0.069,0.566,1.943,10.787)	(0.186,0.695,2.140,11.146)	(0.255,1.261,4.083,21.934)	(-11.078,-1.574, 1.248, 10.601)
B_4	(0.296,0.846,2.437,12.034)	(0.138,0.615,1.974,10.602)	(0.434,1.461,4.411,22.635)	(-10.305,-1.128, 4.822, 11.895)
B_5	(0.329,0.915,2.557,12.279)	(0.235,0.744,2.201,11.429)	(0.563,1.659,4.757,23.708)	(-11.100,-1.285, 1.813, 12.045)
B_6	(0.189,0.669,2.096,11.158)	(0.254,0.787,2.331,11.638)	(0.443,1.456,4.427,22.797)	(-11.449,-1.662,1.309,10.904)

Step 10: Based on Eq. (1), the total integral and the ranking of $r_i + c_j$ is shown in Table 5, with $\beta = 0, 0.5, 1$ represent pessimistic, neutral and optimistic decision maker relatively.

Table 5. The ranking of $r_i + c_j$

	Pessimistic decision maker, $\beta = 0$	Ranking	Neutral decision maker, $\beta = 0.5$	Ranking	Optimistic decision maker, $\beta = 1$	Ranking
B_1	1.047	3	7.458	3	13.870	3
B_2	1.132	1	7.605	2	14.077	2
B_3	0.758	6	6.883	6	13.008	6
B_4	0.948	5	7.236	5	13.523	5
B_5	1.111	2	7.672	1	14.233	1
B_6	0.950	4	7.281	4	13.612	4

Step 11: From Eq. (2), the defuzzified value of r_i - c_j is shown in Table 6.

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Table 6. The defuzzified value of r_i - c_j

Criteria	Defuzzified value of $r_i - c_j$	Group
B₁	-0.260	Effect
B₂	-0.315	Effect
B₃	-0.210	Effect
B₄	0.628	Cause
B₅	0.395	Cause
B₆	-0.237	Effect

4. RESULT AND DISCUSSION

Based on Table 5, for an optimistic decision-maker $\beta = 1$, the ranking result is $B_5 \succ B_2 \succ B_1 \succ B_6 \succ B_4 \succ B_3$ which indicate that the technical criterion is ranked the highest, followed by quality, price, managerial factor, public procurement policy, and delivery. The neutral decision-maker $\beta = 0.5$ also has the same ranking as the optimistic decision-maker. However, for the pessimistic decision-maker $\beta = 0$, the ranking results differ slightly $B_2 \succ B_5 \succ B_1 \succ B_6 \succ B_4 \succ B_3$, that indicate quality is ranked the highest, followed by technical, while the remaining criteria have similar rankings. These results indicate that the technical criterion is the most important for both neutral and optimistic decision-makers, followed by quality.

Conversely, for pessimistic decision-makers, the quality criterion takes precedence, followed by technical. Thus, both technical and quality criteria are crucial in the selection of suppliers in fertigation systems. The ranking result for pessimistic decision-makers aligns with the study by Mohd et al. (2020), which utilised the CFC defuzzification approach. Meanwhile, the ranking results for optimistic and neutral decision-makers are consistent with the findings of Nassir et al. (2021) using the simplified centroid defuzzification method. The findings suggest that the supplier should allocate more resources to improve the quality and technical requirements.

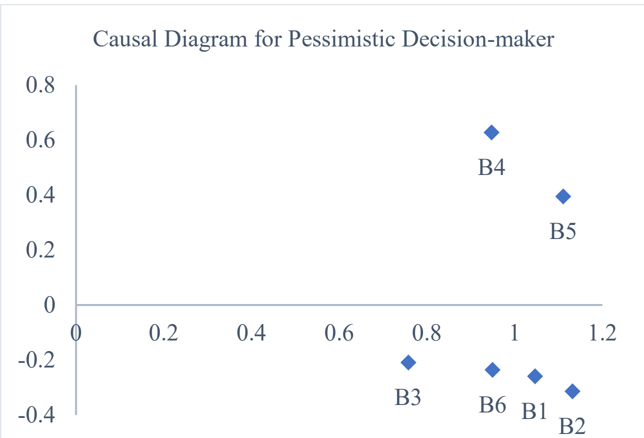

Fig. 1. The causal diagram for pessimistic decision-maker

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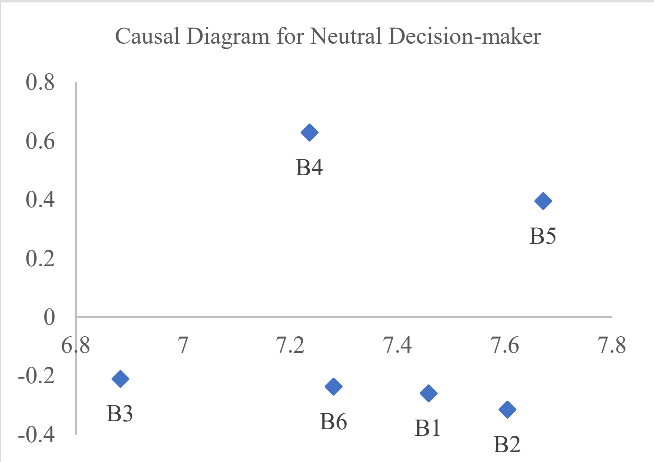

Fig. 2. The causal diagram for neutral decision-maker

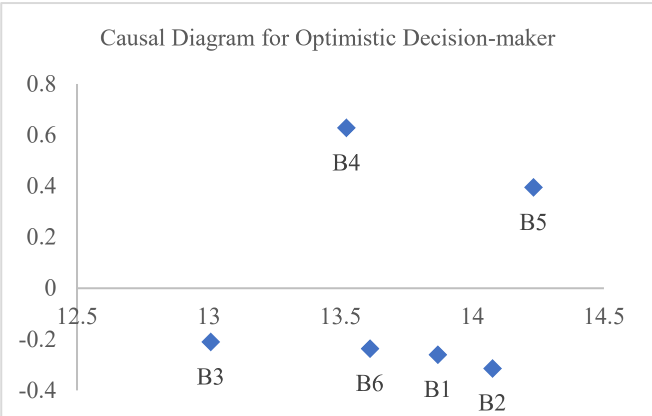

Fig. 3. The causal diagram for optimistic decision-maker

Based on Table 6 and the causal diagram in Figures 1, 2 and 3, for all types of decision-makers, pessimistic, neutral and optimistic, the criteria of quality (B_2), price (B_1), managerial (B_6), and delivery (B_3) are categorised as the effect group, and the technical (B_5) and public procurement policy (B_4) criteria are classified as the cause group. Consequently, it is recommended that the supplier prioritise the technical and public procurement policy criteria during the selection process. These results indicate that the technical and public procurement policies significantly impact other factors used in the fertigation system's supplier selection process for all types of decision-makers. Thus, the public procurement policy and technical requirements demand greater attention as any modifications to these two criteria may affect other criteria.

The other criteria, such as quality, price, managerial, and delivery, can be significantly improved by enhancing the cause group criteria, which are the technical and public procurement policy criteria.

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5. CONCLUSION

The fuzzy DEMATEL method has been widely used in solving multicriteria decision-making problems related to causal relationships among criteria in vague and uncertain environment. This study develops and applies a fuzzy DEMATEL with strength of criteria determined by the degree of optimism concept for supplier selection in the fertigation system. The choice of supplier has become more critical in enhancing the fertigation system's production and performance. Therefore, a high-quality fertigation system needs to have a carefully designed arrangement and an adequate selection of supplies and tools considering different perspectives. The study's findings indicate that the technical and public procurement policies are fall in the cause group and significantly impact other factors used in the fertigation system's supplier selection process for all types of decision-makers. Thus, the public procurement policy and technical requirements demand greater attention as any modifications to these two criteria may affect other criteria. This study also found that for neutral and optimistic decision-makers, the technical criterion is the most important factor, followed by quality, price, managerial factor, public procurement policy, and delivery. There is a slight difference for pessimistic decision-makers, where quality is ranked the highest, followed by technical, and the remaining criteria have similar rankings with neutral and optimistic decision-makers. These indicate that different decision-maker perspectives must be considered for a balanced selection process. This study systematically provides a reasonable solution for a decision problem under various mutual conflicts, whereby the determination of decision-makers degree of optimism has affected the strength of criteria. Thus, the proposed fuzzy DEMATEL method with ranking based on the degree of optimism not only gives knowledge on the criteria that need more attention but also provides a comprehensive and balanced selection process considering different decision-makers viewpoint such as pessimistic, neutral and optimistic.

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that there is no conflict of interest in conducting this research.

8. AUTHORS' CONTRIBUTIONS

Asyura Abd Nassir: Drafted introduction, data collection, literature review, data visualisation and editing.
Nazirah Ramli: Conceptualisation, methodology, formal analysis, writing-review, editing, and validation.
Roselah Osman: Literature review, interpretation of results, editing and validation.

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