A Novel Method Using Spherical Bipolar Fuzzy Sets with the DEMATEL Approach for Analyzing Cause and Effect in Small and Micro Enterprises

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***Abstract*—In this paper, we introduce a new method for analyzing cause and effect criteria utilizing the Spherical Bipolar Fuzzy Sets and the DEMATEL (SBFS-DEMATEL) method. This approach merges the principles of Spherical Bipolar Fuzzy Sets with the methodologies of fuzzy decision-making trial and evaluation laboratories (fuzzy DEMATEL). We aim to construct a cause-effect diagram for subcontractor selection, employing an enhanced SBFS-DEMATEL method. We detail the operational concepts applicable to Spherical Bipolar Fuzzy Sets to establish cause and effect criteria using the fuzzy DEMATEL approach. Key elements integrated into the SBFS-DEMATEL include the memberships of SBFSs, the relative weights of experts, and a transformation equation. The use of linguistic variables within SBFSs aims to encompass a broad spectrum of uncertain and fuzzy information, addressing the positive and negative decisions made by decision-makers. Additionally, we demonstrate the application of our proposed method through case studies involving small and micro enterprises.**

***Index Terms*—Spherical fuzzy set, Spherical bipolar fuzzy set, Fuzzy DEMATEL, Cause–effect diagram.**

I. Introduction

THE fuzzy DEMATEL method incorporates fuzzy sets (FS) to identify causes within DEMATEL elements. This approach, a component of multi-criteria decision-making (MCDM), evaluates causes, factors, or criteria elements using data that may not be stable, reflecting the inherent ambiguity in fuzzy sets as initially proposed by Zadeh in 1965 [1]. Researchers have adapted and refined DEMATEL methods to suit specific scenarios, developing various fuzzy DEMATEL processes and incorporating different set elements to broaden the method's applications. For instance, in 2019, Lazim Abdullah and Pinxin Goh [2] demonstrated the use of fuzzy DEMATEL with Pythagorean fuzzy sets for decision-making. In 2020, Sait Gül [3] introduced a spherical fuzzy extension of DEMATEL (SF-DEMATEL), enhancing the method's capability in MCDM contexts. Further, in 2021, Lazim Abdullah et al. [4] advanced intuitionistic fuzzy decision-making for subcontractor selection, proposing that the intuitionistic fuzzy DEMATEL (IF-DEMATEL) could provide a novel approach for tackling MCDM challenges by utilizing intuitionistic fuzzy sets (IFSs) for linguistic evaluations. In 2019, Lazim Abdullah and Norsyahida Zulkifli [5] introduced a new DEMATEL method based on interval type-2 fuzzy sets for developing causal relationships between knowledge management criteria. The fuzzy DEMATEL method has been applied across various fields, including a 2020 study by Merdivinci, F., and Karakaş, H. [6], which analyzed factors affecting health tourism performance using the fuzzy DEMATEL method. In their work, Filipe, J. A., and Genç, T. [7] explored modeling an idle building case using SWOT analysis and fuzzy DEMATEL in a study entitled Modelling an Idle Building Case Through SWOT Analysis and Fuzzy DEMATEL: A Study on Anti-Commons. They employed these methodologies to analyze the complexities of unused buildings. In 2024, Juan Yang et al. [8] presented an analysis to assess and prioritize drivers and strategies for transitioning to green energy in China for sustainable development. Their study utilized the Analytic Hierarchy Process (AHP) and the fuzzy DEMATEL method to address decision-making dilemmas associated with this strategic shift.

Adapting sets with unique characteristics has proven beneficial in refining the fuzzy DEMATEL model. One particular challenge in decision-making and cause-and-effect analysis is the presence of negative considerations, which can influence decision-making processes and cause analyses through linguistic evaluations. This issue has sparked interest in developing algorithms incorporating negative considerations, such as the negative fuzzy DEMATEL algorithm. The development of bipolar-valued fuzzy sets has led to spherical fuzzy sets (SFSs), which integrate the properties of Pythagorean fuzzy sets (PFS) and neutrosophic sets to provide a broader preference domain. This allows experts to express their hesitations more comprehensively. A distinctive feature of SFSs is that the squared sum of membership, nonmembership, and hesitancy degrees falls between 0 and 1, with each degree independently defined within the interval [0,1] [9], [10], [11], [12]. In 2019, Prince, R., and Mohana, K. [13] explored the concept of spherical bipolar fuzzy sets and their application in multi-criteria decision-making

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problems, assessing the value of alternatives. This research underpinned the structured integration of spherical bipolar fuzzy sets into the fuzzy DEMATEL framework.

This paper presents a new spherical bipolar fuzzy set in the DEMATEL method, the spherical bipolar fuzzy DEMATEL (SBFS-DEMATEL), to analyze the cause and effect criteria and develop a cause-effect diagram. The outline of the paper is as follows: First, we describe the bipolar fuzzy set, spherical fuzzy set, and spherical bipolar fuzzy set. Second, we show the design of the algorithms applied to the SBFS-DEMATEL method. Finally, we illustrate our proposed methods with examples of analysis of small and micro enterprises' cause-effect criteria with a diagram.

II. Preliminaries

This section introduces Spherical Fuzzy Sets (SFS), detailing their definition, significance, innovation, and a graphical comparison with Spherical Bipolar Fuzzy Sets (SBFS). SFSs play a vital role in scenarios where opinions are not limited to simple binary choices but also include options like abstention or refusal. For example, in decision-making, an individual's opinion about a candidate can range from yes to abstain to no or even refusal. Similarly, in voting contexts, voters can be categorized into four types: those who vote in favor, those who vote against, those who refuse to vote, and those who abstain. Zadeh's seminal work on fuzzy sets in 1965 [1] established the foundational concepts, defining a fuzzy set ω within a non-empty set F as a function mapping F to the closed interval $[0, 1]$, that is, $\omega : F \to [0, 1]$.

Definition 2.1. *[14] A* bipolar fuzzy set *(shortly, BF set) A on X is an object having the form*

$$A := \{\langle x, \omega_A^+(x), \omega_A^-(x)\rangle \mid x \in X\},$$

where $\omega_A^+ : X \to [0, 1]$ *and* $\omega_A^- : X \to [-1, 0]$.

Definition 2.2. *[14] Let* $A = \langle \omega_A^+, \omega_A^-\rangle$ *and* $B = \langle \omega_B^+, \omega_B^-\rangle$ *be two bipolar valued fuzzy sets. Then, their union, intersection, and complement are well-defined as follows:*

- $\omega_{A\cup B}^+(x) = max\{\omega_A^+(x), \omega_B^+(x)\} = \omega_A^+(x) \vee \omega_B^+(x)$
- $\omega_{A\cup B}^-(x) = min\{\omega_A^-(x), \omega_B^-(x)\} = \omega_A^-(x) \wedge \omega_B^-(x)$
- $\omega_{A\cap B}^+(x) = min\{\omega_A^+(x), \omega_B^+(x)\} = \omega_A^+(x) \wedge \omega_B^+(x)$
- $\omega_{A\cap B}^-(x) = max\{\omega_A^-(x), \omega_B^-(x)\} = \omega_A^-(x) \vee \omega_B^-(x)$
- $\omega_{\overline{A}}^+(x) = 1 - \omega_A^+(x)$ *and* $\omega_{\overline{A}}^-(x) = -1 - \omega_A^-(x)$

for all $x \in X$

For simplicity, we use the symbol $A = \langle \omega_A^+, \omega_A^-\rangle$ for the BF set.

Definition 2.3. *[9] Let T be a non-empty set on G. A spherical fuzzy set (SFS) A is given by,*

$$A := \{\langle u, \mu_A(u), \nu_A(u), \pi_A(u)\rangle | u \in G\},$$

where $\mu_A : T \to [0, 1], \nu_A : T \to [0, 1]$ *and* $\pi_A : T \to [0, 1]$ *represent the degree of membership, nonmembership, and hesitancy of the object* $u \in T$ *to the set SFS subset to the condition* $0 \leq (\mu_A(u))^2 + (\nu_A(u))^2 + (\pi_A(u))^2 \leq 1$ *for all* $u \in T$.

For the sake of simplicity, an SFS is denoted as $A = \langle \mu_A, \nu_A, \pi_A\rangle$ for the SFS. The basic operators of Spherical Fuzzy Sets are as follows:

Definition 2.4. *Let* $A = \langle \mu_A, \nu_A, \pi_A\rangle$ *and* $B = \langle \mu_B, \nu_B, \pi_B\rangle$ *be two SFSs. Then*

- *The union of two SFS A and B is defined as*

$$\begin{aligned} A \sqcup B &= \langle \mu_{A\cup B}, \nu_{A\cup B}, \pi_{A\cup B}\rangle \\ &= \{\langle x, \mu_{A\cup B}(x), \nu_{A\cup B}(x), \pi_{A\cup B}(x)\rangle : x \in X\} \end{aligned}$$

  where, $\mu_{A\cup B}(x) = \max\{\mu_A(x), \mu_B(x)\}$, $\nu_{A\cup B}(x) = \min\{\nu_A(x), \nu_B(x)\}$ *and* $\pi_{A\cup B}(x) = \min\{(1 - ((\max\{\mu_A(x), \mu_B(x)\})^2 + (\min\{\nu_A(x), \nu_B(x)\})^2))^{1/2}, \max\{\pi_A(x), \pi_B(x)\}\}$, $\forall x \in X$.
- *The intersection of two SFS A and B is defined as*

$$\begin{aligned} A \sqcap B &= \langle \mu_{A\cap B}, \nu_{A\cap B}, \pi_{A\cap B}\rangle \\ &= \{\langle x, \mu_{A\cap B}(x), \nu_{A\cap B}(x), \pi_{A\cap B}(x)\rangle : x \in X\} \end{aligned}$$

  where, $\mu_{A\cap B}(x) = \min\{\mu_A(x), \mu_B(x)\}$, $\nu_{A\cap B}(x) = \max\{\nu_A(x), \nu_B(x)\}$ *and* $\pi_{A\cap B}(x) = \max\{(1 - ((\min\{\mu_A(x), \mu_B(x)\})^2 + (\max\{\nu_A(x), \nu_B(x)\})^2))^{1/2}, \min\{\pi_A(x), \pi_B(x)\}\}$, $\forall x \in X$.
- *The complement of two SBFS A is defined as*

$$\begin{aligned} \overline{A} &= \langle \mu_{\overline{A}}, \nu_{\overline{A}}, \pi_{\overline{A}}\rangle \\ &= \{\langle x, \mu_{\overline{A}}(x), \nu_{\overline{A}}(x), \pi_{\overline{A}}(x)\rangle : x \in X\}, \end{aligned}$$

  where, $\mu_{\overline{A}} = 1 - \mu_{\overline{A}}$, $\nu_{\overline{A}} = 1 - \nu_{\overline{A}}$ *and* $\pi_{\overline{A}} = 1 - \pi_{\overline{A}}$, $\forall x \in X$.
- *The addition of two SFS A and B is defined as*

$$\begin{aligned} A \oplus B &= \langle \mu_{A\oplus B}, \nu_{A\oplus B}, \pi_{A\oplus B}\rangle \\ &= \{\langle x, \mu_{A\oplus B}(x), \nu_{A\oplus B}(x), \pi_{A\oplus B}(x)\rangle : x \in X\} \end{aligned}$$

  where, $\mu_{A\oplus B}(x) = ((\mu_A(x))^2 + (\mu_B(x))^2 - (\mu_A(x))^2(\mu_A(x))^2)^{1/2}$, $\nu_{A\oplus B}(x) = \nu_A\nu_B$ *and* $\pi_{A\oplus B}(x) = ((1 - (\mu_B(x))^2)\pi_A + (1 - (\mu_A(x))^2)\pi_B - (\pi_A)^2(\pi_B)^2))^{1/2}$, $\forall x \in X$.
- *The multipication of two SFS A and B is defined as*

$$\begin{aligned} A \otimes B &= \langle \mu_{A\otimes B}, \nu_{A\otimes B}, \pi_{A\otimes B}\rangle \\ &= \{\langle x, \mu_{A\otimes B}(x), \nu_{A\otimes B}(x), \pi_{A\otimes B}(x)\rangle : x \in X\} \end{aligned}$$

  where, $\mu_{A\otimes B}(x) = \mu_A(x)\mu_B(x)$, $\nu_{A\otimes B}(x) = ((\nu_A(x))^2 + (\nu_B(x))^2 - (\nu_A(x))^2(\nu_A(x))^2)^{1/2}$ *and* $\pi_{A\otimes B}(x) = ((1 - (\nu_B(x))^2)\pi_A + (1 - (\nu_A(x))^2)\pi_B - (\pi_A)^2(\pi_B)^2)^{1/2}$, $\forall x \in X$.
- *The multiplication by scalar ($\lambda > 0$) of SFS A is defined as*

$$\begin{aligned} \lambda A &= \langle \lambda\mu_A, \lambda\nu_A, \lambda\pi_A\rangle \\ &= \{\langle x, \lambda\mu_A(x), \lambda\nu_A(x), \lambda\pi_A(x)\rangle : x \in X\} \end{aligned}$$

  where, $\lambda\mu_A(x) = (1-(1-(\mu_A(x))^2)^\lambda)^{1/2}$, $\lambda\nu_A(x) = (\nu_A(x))^\lambda$ *and* $\lambda\pi_A(x) = ((1 - (\mu_A(x))^2)^\lambda - (1 - (\mu_A(x))^2 - (\pi_A(x))^2)^\lambda)^{1/2}$, $\forall x \in X$.
- *The power of SFS A ($\lambda > 0$) is defined as*

$$\begin{aligned} A^\lambda &= \langle (\mu_A)^\lambda, (\nu_A)^\lambda, (\pi_A)^\lambda\rangle \\ &= \{\langle x, (\mu_A(x))^\lambda, (\nu_A(x))^\lambda, (\pi_A)(x)^\lambda\rangle : x \in X\} \end{aligned}$$

  where, $(\mu_A)^\lambda = (\mu_A(x))^\lambda$, $(\nu_A(x))^\lambda = (1 - (1 - (\nu_A(x))^2)^\lambda)^{1/2}$ *and* $(\pi_A(x))^\lambda = ((1 - (\nu_A(x))^2)^\lambda - (1 - (\nu_A(x))^2 - (\pi_A(x))^2)^\lambda)^{1/2}$, $\forall x \in X$.

Definition 2.5. *[15] Let* $A = \langle \mu_A, \nu_A, \pi_A \rangle$ *be an SFS defined at the beginning of this section. Then, the score value of* A *is defined as*

$$SC(A) = (\mu_A)^2 - (\pi_A)^2$$

and $SC(A) \in [-1, 1]$.

The accuracy value of A *is defined as* AC

$$AC(A) = (\mu_A)^2 + (\nu_A)^2 + (\pi_A)^2$$

and $AC(A) \in [0, 1]$.

Definition 2.6. *Let* T *be a non-empty set on* G. *A spherical bipolar fuzzy set (SBFS)* A *is given by,* $A := \{\langle u, \mu_A^+(u), \nu_A^+(u), \pi_A^+(u), \mu_A^-(u), \nu_A^-(u), \pi_A^-(u)\rangle | u \in G\}$, *where* $\mu_A^+ : T \to [0,1], \nu_A^+ : T \to [0,1]$, $\pi_A^+ : T \to [0,1]$, $\mu_A^- : T \to [-1,0], \nu_A^- : T \to [-1,0]$, $\pi_A^- : T \to [-1,0]$ *and* $0 \leq (\mu_A^+(u))^2 + (\nu_A^+(u))^2 + (\pi_A^+(u))^2 \leq 1$, $-1 \leq -(\mu_A^-(u))^2 + (\nu_A^-(u))^2 + (\pi_A^-(u))^2 \leq 0$ *for all* $u \in T$.

For each, the numbers $\mu_A^+(u), \nu_A^+(u), \pi_A^+(u)$ are the positive degree of membership, non-membership, and the hesitancy of u to SBFS A, and $\mu_A^-(u), \nu_A^-(u), \pi_A^-(u)$ are the negative degree of membership, non-membership, and the hesitancy of u to SBFS A. For the sake of simplicity, a SBFS is denoted as $A = \langle \mu_A^+, \nu_A^+, \pi_A^+, \mu_A^-, \nu_A^-, \pi_A^- \rangle$ for the SBFS. In 2020, Princy, R., and Mohana, K. [13] gave basic operators of SBFS as fowllows:

Definition 2.7. *Let* $A = \langle \mu_A^+, \nu_A^+, \pi_A^+, \mu_A^-, \nu_A^-, \pi_A^- \rangle$ *and* $B = \langle \mu_B^+, \nu_B^+, \pi_B^+, \mu_B^-, \nu_B^-, \pi_B^- \rangle$ *be two SBFSs. Then*

- *The union of two SBFS* A *and* B *is defined as*

$$\begin{aligned} A \sqcup B =& \langle \mu^+_{A\cup B}, \nu^+_{A\cup B}, \pi^+_{A\cup B}, \mu^-_{A\cup B}, \nu^-_{A\cup B}, \pi^-_{A\cup B} \rangle \\ =& \{\langle x, \mu^+_{A\cup B}(x), \nu^+_{A\cup B}(x), \pi^+_{A\cup B}(x), \\ & \mu^-_{A\cup B}(x), \nu^-_{A\cup B}(x), \pi^-_{A\cup B}(x)\rangle : x \in X\}, \end{aligned}$$

where $\mu^+_{A\cup B}(x) = \max\{\mu_A^+(x), \mu_B^+(x)\}$, $\nu^+_{A\cup B}(x) = \min\{\nu_A^+(x), \nu_B^+(x)\}$, $\pi^+_{A\cup B}(x) = \min\{(1 - ((\max\{\mu_A^+(x), \mu_B^+(x)\})^2 + (\min\{\nu_A^+(x), \nu_B^+(x)\})^2))^{1/2}, \max\{\pi_A^+(x), \pi_B^+(x)\}\}$ $\mu^-_{A\cup B}(x) = \min\{\mu_A^-(x), \mu_B^-(x)\}$, $\nu^-_{A\cup B}(x) = \max\{\nu_A^-(x), \nu_B^-(x)\}$ *and* $\pi^-_{A\cup B}(x) = \max\{(1 - ((\min\{\mu_A^-(x), \mu_B^-(x)\})^2 + (\max\{\nu_A^-(x), \nu_B^-(x)\})^2))^{1/2}, \min\{\pi_A^-(x), \pi_B^-(x)\}\}$, $\forall x \in X$.

- *The intersection of two SBFS* A *and* B *is defined as*

$$\begin{aligned} A \sqcap B =& \langle \mu^+_{A\cap B}, \nu^+_{A\cap B}, \pi^+_{A\cap B}, \mu^-_{A\cap B}, \nu^-_{A\cap B}, \pi^-_{A\cap B} \rangle \\ =& \{\langle x, \mu^+_{A\cap B}(x), \nu^+_{A\cap B}(x), \pi^+_{A\cap B}(x), \\ & \mu^-_{A\cap B}(x), \nu^-_{A\cap B}(x), \pi^-_{A\cap B}(x)\rangle : x \in X\}, \end{aligned}$$

where $\mu^+_{A\cap B}(x) = \min\{\mu_A^+(x), \mu_B^+(x)\}$, $\nu^+_{A\cap B}(x) = \max\{\nu_A^+(x), \nu_B^+(x)\}$, $\pi^+_{A\cap B}(x) = \max\{(1 - ((\min\{\mu_A^+(x), \mu_B^+(x)\})^2 + (\max\{\nu_A^+(x), \nu_B^+(x)\})^2))^{1/2}, \min\{\pi_A^+(x), \pi_B^+(x)\}\}$, $\mu^-_{A\cap B}(x) = \max\{\mu_A^-(x), \mu_B^-(x)\}$, $\nu^-_{A\cap B}(x) = \min\{\nu_A^-(x), \nu_B^-(x)\}$ *and* $\pi^-_{A\cap B}(x) = \min\{(1 - ((\max\{\mu_A^-(x), \mu_B^-(x)\})^2 + (\min\{\nu_A^-(x), \nu_B^-(x)\})^2))^{1/2}, \max\{\pi_A^-(x), \pi_B^-(x)\}\}$, $\forall x \in X$.

- *The complement of two SBFS* A *is defined as*

$$\begin{aligned} \overline{A} =& \langle \mu^+_{\overline{A}}, \nu^+_{\overline{A}}, \pi^+_{\overline{A}}, \mu^-_{\overline{A}}, \nu^-_{\overline{A}}, \pi^-_{\overline{A}} \rangle \\ =& \{\langle x, \mu^+_{\overline{A}}(x), \nu^+_{\overline{A}}(x), \pi^+_{\overline{A}}(x), \mu^-_{\overline{A}}(x), \nu^-_{\overline{A}}(x), \pi^-_{\overline{A}}(x)\rangle \\ & : x \in X\}, \end{aligned}$$

where $\mu^+_{\overline{A}} = 1 - \mu^+_{A}$, $\nu^+_{\overline{A}} = 1 - \nu^+_{A}$, $\pi^+_{\overline{A}} = 1 - \pi^+_{A}$, $\mu^-_{\overline{A}} = -1 - \mu^-_{A}$, $\nu^-_{\overline{A}} = -1 - \nu^-_{A}$ *and* $\pi^-_{\overline{A}} = -1 - \pi^-_{A}$, $\forall x \in X$.

- *The addition of two SBFS* A *and* B *is defined as*

$$\begin{aligned} A \oplus B =& \langle \mu^+_{A\oplus B}, \nu^+_{A\oplus B}, \pi^+_{A\oplus B}, \mu^-_{A\oplus B}, \nu^-_{A\oplus B}, \pi^-_{A\oplus B} \rangle \\ =& \{\langle x, \mu^+_{A\oplus B}(x), \nu^+_{A\oplus B}(x), \pi^+_{A\oplus B}(x), \\ & \mu^-_{A\oplus B}(x), \nu^-_{A\oplus B}(x), \pi^-_{A\oplus B}(x)\rangle : x \in X\}, \end{aligned}$$

where $\mu^+_{A\oplus B}(x) = ((\mu_A^+(x))^2 + (\mu_B^+(x))^2 - (\mu_A^+(x))^2(\mu_A^+(x))^2)^{1/2}$, $\nu^+_{A\oplus B}(x) = \nu_A^+\nu_B^+$, $\pi^+_{A\oplus B}(x) = ((1 - (\mu_B^+(x))^2)\pi_A^+ + (1 - (\mu_A^+(x))^2)\pi_B^+ - (\pi_A^+)^2(\pi_B^+)^2))^{1/2}$, $\mu^-_{A\oplus B}(x) = \mu_A^-\mu_B^-$, $\nu^-_{A\oplus B}(x) = ((\nu_A^-(x))^2 + (\nu_B^-(x))^2 - (\nu_A^-(x))^2(\nu_A^-(x))^2)^{1/2}$ *and* $\pi^-_{A\oplus B}(x) = ((1 - (\nu_B^-(x))^2)\pi_A^- + (1 - (\nu_A^-(x))^2)\pi_B^- - (\pi_A^-)^2(\pi_B^-)^2)^{1/2}$, $\forall x \in X$.

- *The multipication of two SBFS* A *and* B *is defined as*

$$\begin{aligned} A \otimes B =& \langle \mu^+_{A\otimes B}, \nu^+_{A\otimes B}, \pi^+_{A\otimes B}, \mu^-_{A\otimes B}, \nu^-_{A\otimes B}, \pi^-_{A\otimes B} \rangle \\ =& \{\langle x, \mu^+_{A\otimes B}(x), \nu^+_{A\otimes B}(x), \pi^+_{A\otimes B}(x), \\ & \mu^-_{A\otimes B}(x), \nu^-_{A\otimes B}(x), \pi^-_{A\otimes B}(x)\rangle : x \in X\}, \end{aligned}$$

where $\mu^+_{A\otimes B}(x) = \mu_A^+(x)\mu_B^+(x)$, $\nu^+_{A\otimes B}(x) = ((\nu_A^+(x))^2 + (\nu_B^+(x))^2 - (\nu_A^+(x))^2(\nu_A^+(x))^2)^{1/2}$, $\pi^+_{A\otimes B}(x) = ((1 - (\nu_B^+(x))^2)\pi_A^+ + (1 - (\nu_A^+(x))^2)\pi_B^+ - (\pi_A^+)^2(\pi_B^+)^2)^{1/2}$, $\mu^-_{A\otimes B}(x) = ((\mu_A^+(x))^2 + (\mu_B^+(x))^2 - (\mu_A^+(x))^2(\mu_A^+(x))^2)^{1/2}$, $\nu^-_{A\otimes B}(x) = \nu_A^+(x)\nu_B^+(x)$ *and* $\pi^-_{A\otimes B}(x) = ((1 - (\mu_B^+(x))^2)\pi_A^+ + (1 - (\mu_A^+(x))^2)\pi_B^+ - (\pi_A^+)^2(\pi_B^+)^2)^{1/2}$, $\forall x \in X$.

- *The multiplication by scalar* ($\lambda > 0$) *of SBFS* A *is defined as*

$$\begin{aligned} \lambda A =& \langle \lambda\mu_A^+, \lambda\nu_A^+, \lambda\pi_A^+, \lambda\mu_A^-, \lambda\nu_A^-, \lambda\pi_A^- \rangle \\ =& \{\langle x, \lambda\mu_A^+(x), \lambda\nu_A^+(x), \lambda\pi_A^+(x), \\ & \lambda\mu_A^-(x), \lambda\nu_A^-(x), \lambda\pi_A^-(x)\rangle : x \in X\}, \end{aligned}$$

where $\lambda\mu_A^+(x) = (1 - (1 - (\mu_A^+(x))^2)^\lambda)^{1/2}$, $\lambda\nu_A^+(x) = (\nu_A^+(x))^\lambda$, $\lambda\pi_A^+(x) = ((1 - (\mu_A^+(x))^2)^\lambda - (1 - (\mu_A^+(x))^2 - (\pi_A^+(x))^2)^\lambda)^{1/2}$, $\lambda\mu_A^-(x) = (-\mu_A^+(x))^{-\lambda}$, $\lambda\nu_A^-(x) = -(1 - (1 - (\nu_A^+(x))^2)^\lambda)^{1/2}$ *and* $\lambda\pi_A^-(x) = -((1 - (\nu_A^+(x))^2)^\lambda - (1 - (\nu_A^+(x))^2 - (\pi_A^+(x))^2)^\lambda)^{1/2}$, $\forall x \in X$

- *The power of SBFS* A ($\lambda > 0$) *is defined as*

$$\begin{aligned} A^\lambda =& \langle (\mu_A^+)^\lambda, (\nu_A^+)^\lambda, (\pi_A^+)^\lambda, (\mu_A^-)^\lambda, (\nu_A^-)^\lambda, (\pi_A^-)^\lambda \rangle \\ =& \{\langle x, (\mu_A^+(x))^\lambda, (\nu_A^+(x))^\lambda, (\pi_A^+)(x)^\lambda, \\ & (\mu_A^-(x))^\lambda, (\nu_A^-(x))^\lambda, (\pi_A^-)(x)^\lambda\rangle : x \in X\}, \end{aligned}$$

where $(\mu_A^+)^\lambda = (\mu_A(x))^\lambda$, $(\nu_A^+(x))^\lambda = (1 - (1 - (\nu_A(x))^2)^\lambda)^{1/2}$ *and* $(\pi_A^+(x))^\lambda = ((1 - (\nu_A(x))^2)^\lambda - (1 - (\nu_A(x))^2 - (\pi_A(x))^2)^\lambda)^{1/2}$, $(\mu_A^-)^\lambda = -(1 - (1 - (\mu_A^-(x))^2)^\lambda)^{1/2}$, $(\nu_A^-(x))^\lambda = -(\nu_A^-(x))^{-\lambda}$ *and* $(\pi_A^-(x))^\lambda = -((1 - (\mu_A^-(x))^2)^\lambda - (1 - (\mu_A^-(x))^2 - (\pi_A^-(x))^2)^\lambda)^{1/2}$, $\forall x \in X$.

Theorem 2.8. *For these SBFSs,* $A = \langle \mu_A^+, \nu_A^+, \pi_A^+, \mu_A^-, \nu_A^-, \pi_A^- \rangle$ *and* $B = \langle \mu_B^+, \nu_B^+, \pi_B^+, \mu_B^-, \nu_B^-, \pi_B^- \rangle$ *, the following are valid under the condition* $\lambda, \lambda_1, \lambda_2 > 0$*.*

- $A \oplus B = B \oplus A$
- $A \otimes B = B \otimes A$
- $\lambda(A \oplus B) = \lambda A \oplus \lambda B$
- $\lambda_1 A \oplus \lambda_2 A = (\lambda_1 + \lambda_2) A$
- $(A \otimes B)^\lambda = A^\lambda \otimes B^\lambda$
- $A^{\lambda_1} \otimes A^{\lambda_2} = A^{\lambda_1 + \lambda_2}$

Proof: Straightforward. ∎

Definition 2.9. *Spherical Bipolar Weighted Arithmetic Mean (SBWAM) for* $w = w_1, w_2, w_3, ..., w_n$ *where* $w_i \in [0,1]$ *and* $\sum_{i=1}^{n} w_i = 1$*, SBWGM is defined as,*

$$SBWAM_w(A_1, A_2, ..., A_n) = w_1 A_1 \oplus w_2 A_2 \oplus ... \oplus w_n A_n$$
$$= \Big\langle [1 - \prod_{i=1}^{n}(1 - (\mu_{A_i}^+)^2)^{w_i})]^{1/2}, \prod_{i=1}^{n}(\nu_{A_i}^+)^{w_i},$$
$$[\prod_{i=1}^{n}(1 - (\mu_{A_i}^+)^2)^{w_i} - \prod_{i=1}^{n}(1 - (\mu_{A_i}^+)^2 - (\pi_{A_i}^+)^2)^{w_i}]^{1/2},$$
$$-\prod_{i=1}^{n}((\mu_{A_i}^-)^2)^{w_i}, -(1 - \prod_{i=1}^{n}(1 - (\nu_{A_i}^-)^2)^{w_i})^{1/2},$$
$$-[\prod_{i=1}^{n}(1 - (\nu_{A_i}^-)^2)^{w_i} - \prod_{i=1}^{n}(1 - (\nu_{A_i}^-)^2 - (\pi_{A_i}^-)^2)^{w_i}]^{1/2} \Big\rangle.$$

Definition 2.10. *Spherical Bipolar Weighted Geometric Mean (SBWGM) for* $w = w_1, w_2, w_3..., w_n$*,* $w_i \in [0,1]$ *and* $\sum_{i=1}^{n} w_i = 1$*, SBWGM is defined as,*

$$SBWGM_w(A_1, ..., A_n) = (A_1)^{w_1} \oplus ... \oplus (A_n)^{w_n}$$
$$= \Big\langle \prod_{i=1}^{n}(\mu_{A_i}^+)^{w_i}, [1 - \prod_{i=1}^{n}(1 - (\nu_{A_i}^+)^2)^{w_i}]^{1/2},$$
$$[\prod_{i=1}^{n}(1 - (\nu_{A_i}^+)^2)^{w_i} - \prod_{i=1}^{n}(1 - (\nu_{A_i}^+)^2 - (\pi_{A_i}^+)^2)^{w_i}]^{1/2},$$
$$-(1 - \prod_{i=1}^{n}(1 - (\mu_{A_i}^-)^2)^{w_i})^{1/2}, \prod_{i=1}^{n}(-(\nu_{A_i}^-)^2)^{w_i},$$
$$-[\prod_{i=1}^{n}(1 - (\mu_{A_i}^-)^2)^{w_i} - \prod_{i=1}^{n}(1 - (\mu_{A_i}^-)^2 - (\pi_{A_i}^-)^2)^{w_i}]^{1/2} \Big\rangle.$$

Definition 2.11. *[13] The score function and accuracy function of sorting SBFS* $A = \langle \mu_A^+, \nu_A^+, \pi_A^+, \mu_A^-, \nu_A^-, \pi_A^- \rangle$ *are defined by,*

- *Score(A)=*$\frac{1}{2}[(\mu_A^+ - \pi_A^+)^2 - (\nu_A^+ - \pi_A^+)^2 + (\mu_A^- - \pi_A^-)^2 - (\nu_A^- - \pi_A^-)^2]$
- *Accuracy(A)=*$\frac{1}{2}[(\mu_A^+)^2 + (\nu_A^+)^2 + (\pi_A^+)^2 + (\mu_A^-)^2 + (\nu_A^-)^2 + (\pi_A^-)^2]$

III. Spherical Bipolar Fuzzy DEMATEL

Traditional DEMATEL does not account for expert hesitancy and negative considerations of a problem. To solve this problem, the literature has introduced the spherical bipolar fuzzy DEMATEL (SBFS-DEMATEL). The flowchart of the proposed method is shown in Figure 1. The following section presents an illustrative example to showcase the method's practical application.

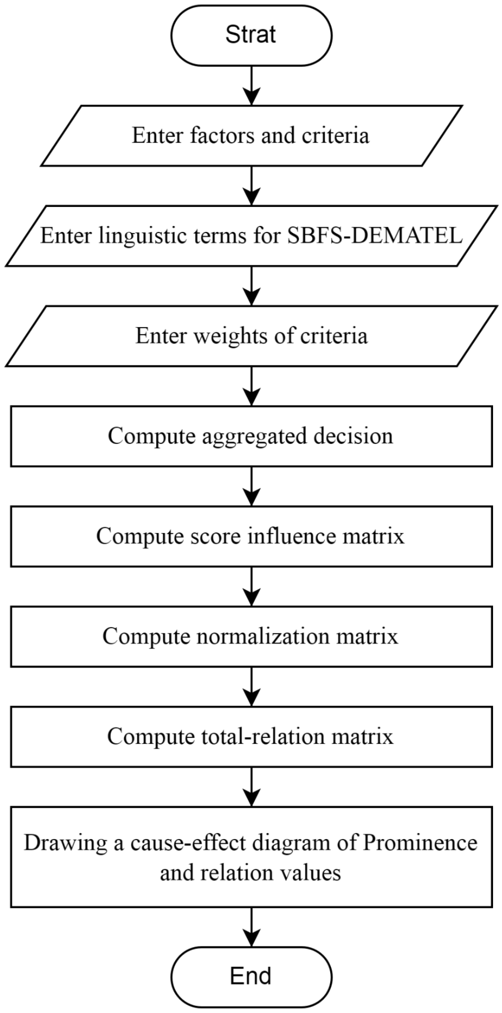

Fig. 1. Flowchart of SBFS-DEMATEL.

Step 1: Identifying attributes and selecting decision-makers.

This step involves the identification of the DMs (D^k), objective, main, and/or criteria (C_i), where $k = 1, 2, ..., m$ and $i, j = 1, 2, ..., n$.

Step 2: Selecting an evaluation measure for linguistic assessment.

In developing the evaluation measure for the linguistic assessment of SBFS-DEMATEL, we built upon the work of Kutlu Gündoğdu and Kahraman [16]. They created a linguistic scale that corresponds to the evaluation terms of AHP, treating these as score index (SI) values, as outlined below:

$$SI = \sqrt{|100 \times [(\mu - \pi)]^2 - (\nu - \pi)]^2|}$$

Then, we applied the score index ($SI^{(+,-)}$) for the Spherical bipolar fuzzy A defined by

$$SI_A^{(+,-)} = |50 \times [(\mu_A^+ - \pi_A^+)^2 - (\nu_A^+ - \pi_A^+)^2 + (\mu_A^- - \pi_A^-)^2 - (\nu_A^- - \pi_A^-)^2]|^{1/2}$$

TABLE I
LINGUISTIC TERMS FOR SBFS-DEMATEL AND CORRESPONDING SBFS VALUES

Definition	Abb	μ^+	ν^+	π^+	μ^-	ν^-	π^-	$SI^{(+,-)}$
Stong	S	0.85	0.15	0.45	-0.75	-0.30	-0.40	3
Moderate	M	0.60	0.20	0.35	-0.65	-0.20	-0.38	2
Weak	W	0.35	0.25	0.25	-0.30	-0.15	-0.19	1
No influence	NI	0.00	0.30	0.15	0.00	-0.30	-0.15	0

The calculate of $SI^{(+,-)}$ for SBFS-DEMATEL is shown in Table I.

To define a suitable SBFS term for SBFS-DEMATEL applications as indicated in Table I, we consistently apply the same formula to assign the values of $SI^{(+,-)}$ as 3, 2, 1, and 0, respectively.

For strong influence,

$$\begin{aligned} SI_S^{(+,-)} =& |50 \times [(0.85-0.45)^2 - (0.15-0.45)^2 + \\ & (-0.75-(-0.40))^2 - (-0.30-(-0.40))^2]|^{1/2} \\ =& 3.02 \approx 3. \end{aligned}$$

For moderate influence,

$$\begin{aligned} SI_M^{(+,-)} =& |50 \times [(0.60-0.35)^2 - (0.20-0.35)^2 + \\ & (-0.65-(-0.38))^2 - (-0.20-(-0.38))^2]|^{1/2} \\ =& 2.01 \approx 2. \end{aligned}$$

For weak influence,

$$\begin{aligned} SI_W^{(+,-)} =& |50 \times [(0.35-0.25)^2 - (0.25-0.25)^2 + \\ & (-0.35-(-0.19))^2 - (-0.15-(-0.19))^2]|^{1/2} \\ =& 1.01 \approx 1. \end{aligned}$$

For no influence,

$$\begin{aligned} SI_{NI}^{(+,-)} =& |50 \times [(0.00-0.15)^2 - (0.30-0.15)^2 + \\ & (0.00-(-0.15))^2 - (-0.30-(-0.15))^2]|^{1/2} \\ =& 0. \end{aligned}$$

Step 3: Defining decision-makers weights w as follows: Let $\hat{w}$ be a set of weights by a decision-maker in Table II. The priority value of kth decision-maker is calculated by $w_k = \hat{w}_k / \sum_{k=1}^{m} \hat{w}_k$, where $w = \sum_{k=1}^{m} w_k = 1$. The selection of weighting values is contingent upon the prioritization determined by those authorized to make decisions. The significance is set above 0.5, as illustrated in Table II. The importance of each decision-maker is assessed such that if every decision-maker is deemed crucial for this decision, the value will be equal to 1. Otherwise, the weighting can be adjusted according to the relative importance of each decision-maker as deemed appropriate.

Step 4: Consolidating diverse decision-maker $D^k = [d_{ij}^k]_{n\times n}$ where $i,j = 1,2,3,\ldots,n$ and $k = 1,2,3,\ldots,m$, and $d_{ij}^k = \langle \mu^+_{d_{ij}^k}, \nu^+_{d_{ij}^k}, \pi^+_{d_{ij}^k}, \mu^-_{d_{ij}^k}, \nu^-_{d_{ij}^k}, \pi^-_{d_{ij}^k} \rangle$, which is utilized to construct an aggregated direct average influence matrix $D = [d_{ij}]_{n\times n}$, where $d_{ij} = \langle \mu^+_{ij}, \nu^+_{ij}, \pi^+_{ij}, \mu^-_{ij}, \nu^-_{ij}, \pi^-_{ij} \rangle = SBWAM_w(d_{ij}^1, d_{ij}^2, ..., d_{ij}^m) = w_1 d_{ij}^1 + w_2 d_{ij}^2 + ... + w_m d_{ij}^m$, which can be calculated as follows:

$$\begin{aligned} d_{ij} = \Bigg\langle & [1 - \prod_{k=1}^{m} (1 - (\mu^+_{d_{ij}^k})^2)^{w_i})]^{1/2}, \prod_{k=1}^{m} (\nu^+_{d_{ij}^k})^{w_i}, \\ & [\prod_{k=1}^{m} (1 - (\mu^+_{d_{ij}^k})^2)^{w_i} - \prod_{k=1}^{m} (1 - (\mu^+_{d_{ij}^k})^2 - (\pi^+_{d_{ij}^k})^2)^{w_i}]^{1/2}, \\ & -\prod_{k=1}^{m} ((\mu^-_{d_{ij}^k})^2)^{w_i}, -(1 - \prod_{k=1}^{m} (1 - (\nu^-_{d_{ij}^k})^2)^{w_i})^{1/2}, \\ & -[\prod_{k=1}^{m} (1 - (\nu^-_{d_{ij}^k})^2)^{w_i} - \prod_{k=1}^{m} (1 - (\nu^-_{d_{ij}^k})^2 - (\pi^-_{d_{ij}^k})^2)^{w_i}]^{1/2} \Bigg\rangle. \end{aligned}$$

Step 5: The score influence matrix (S) is derived by calculating the score value of the same attribute pairs in the various direct influence evaluation matrices of the experts obtained from aggregate direct average influence matrix D, which were used as the score function by

$$S = [s_{ij}]_{n\times n},$$

where s_{ij} = Score$(d_{ij}) = \frac{1}{2}[(\mu^+_{ij} - \pi^+_{ij})^2 - (\nu^+_{ij} - \pi^+_{ij})^2 + (\mu^-_{ij} - \pi^-_{ij})^2 - (\nu^-_{ij} - \pi^-_{ij})^2]$

Step 6: The initial direct influence matrix, Matrix S, is normalized to determine the initial direct influences of the attributes. Let X represent the normalization index, where all principal diagonal attributes are zero. The matrix X is derived as follows:

$$X = qS,$$

where $q = \min \left[\frac{1}{\max_i \sum_{j=1}^{n} |s_{ij}|}, \frac{1}{\max_j \sum_{i=1}^{n} |s_{ij}|} \right]$.

Step 7: Constructing the total-relation matrix X as follows:

$$T = X(I-X)^{-1} = [t_{ij}]_{n\times n} = \begin{bmatrix} t_{11} & \cdots & t_{1n} \\ \vdots & \ddots & \vdots \\ t_{n1} & \cdots & t_{nn} \end{bmatrix},$$

where $T = [t_{ij}]_{n\times n}$ represents the total influences between each pair of attributes. The method introduces the row sum (R) and the column sum (D).

The sum of rows R,

$$R = \left[\sum_{j=1}^{n} t_{ij} \right]$$

The sum of columns D,

$$D = \left[\sum_{i=1}^{n} t_{ij} \right]$$

The row sum (R) quantifies the total influence exerted by attribute i on all other attributes, reflecting its overall

TABLE II
THE SCALE OF LINGUISTIC JUDGMENTS OF DMS' WEIGHTS

Definition of linguistic terms	Weights ($\hat{w}$)
Equally Important (E)	0.6
Slightly Important (SI)	0.7
Fairly Important (FI)	0.8
Moderately Important (MI)	0.9
Very Important (VI)	1.0

strength. On the contrary, the column sum (D) measures the degree to which attribute j is influenced by others, thereby illustrating its relative vulnerability.

Step 8: Drawing a cause-effect diagram of prominence and relation values. The sums of the rows and columns across all relationship matrices (R) and (D) are expressed by $R + D$, forming a horizontal axis vector referred to as *Prominence*, which highlights the importance of a criterion. Meanwhile, $R - D$ forms a vertical axis called *Relation*, indicating whether values are positive or negative, classifying the attributes into *cause* and *effect* groups.

- $R - D > 0$: Attribute i predominantly exerts influence on other attributes, classifying it within the *cause* group.
- $R - D < 0$: Attribute i is predominantly influenced by other attributes, placing it in the *effect* group.

The organization of attributes into cause-and-effect groups is essential for effectively analyzing problems, discerning influences, and prioritizing attributes. Enhancements within the cause group will inherently improve the effect group. Consequently, when resources are scarce, it is strategic to prioritize the elements of the cause group.

IV. ILLUSTRATIVE EXAMPLE

Doing business is an activity that is very important to the economic system. At present, it is found that the number of small and micro enterprises is the largest number of business units in the country. The operation of micro and small enterprises in the agricultural business sector requires planning or creating a strategy for conducting business in risky conditions. Therefore, there must be a method for finding causes or affecting factors using mathematical and statistical methods, which confirm the model in a principled manner based on reliable theoretical principles. Therefore, in this simulation, we will study the causes and effects of small and micro enterprises using the SBFS-DEMATEL method by setting the situation as follows:

Step 1: Consider decision-makers D^k for $k = 1, 2, 3$, who are experts on small and micro enterprises with over ten years of experience from various sectors, including government, state enterprises, and entrepreneurship. The setting of criteria involves 20 factors (C_i), where $k = 1, 2, \ldots, m$ and $i, j = 1, 2, \ldots, 20$. These factors are considered across three aspects: business environment, entrepreneurial characteristics, and innovative ability. The determination of factors influencing the performance of small and micro enterprises is outlined in Table III.

Step 2: Specify the weights $\hat{w} = \{SI, FI, E\}$. Thus, $w = \{w_1, w_2, w_3\} = \{0.333, 0.381, 0.286\}$, the scale of linguistic judgments for the decision makers' weights from Table II.

Step 3: The decision makers' (D^1, D^2, D^3) individualism directly influences the evaluation, as shown in Table IV.

Step 4: Consolidation of diverse decision-maker matrix D is shown in Table V.

An example for calculation,
$d_{12} = \langle \mu^+_{12}, \nu^+_{12}, \pi^+_{12}, \mu^-_{12}, \nu^-_{12}, \pi^-_{12} \rangle$ as follow:

$$
\begin{aligned}
d_{12} = \Bigg\langle & [1 - \prod_{k=1}^{m} (1 - (\mu^+_{d^k_{12}})^2)^{w_i})]^{1/2}, \prod_{k=1}^{m} (\nu^+_{d^k_{12}})^{w_i}, \\
& [\prod_{k=1}^{m} (1 - (\mu^+_{d^k_{12}})^2)^{w_i} - \prod_{k=1}^{m} (1 - (\mu^+_{d^k_{12}})^2 - (\pi^+_{d^k_{12}})^2)^{w_i}]^{1/2}, \\
& - \prod_{k=1}^{m} ((\mu^-_{d^k_{12}})^2)^{w_i}, -(1 - \prod_{k=1}^{m} (1 - (\nu^-_{d^k_{12}})^2)^{w_i})^{1/2}, \\
& - [\prod_{k=1}^{m} (1 - (\nu^-_{d^k_{12}})^2)^{w_i} - \prod_{k=1}^{m} (1 - (\nu^-_{d^k_{12}})^2 - (\pi^-_{d^k_{12}})^2)^{w_i}]^{1/2} \Bigg\rangle \\
= & \langle [1 - (1 - (0.85)^2)^{0.333})(1 - (0.85)^2)^{0.381}) \\
& (1 - (0.60)^2)^{0.286})]^{1/2}, (0.15)^{0.333}(0.15)^{0.333}(0.20)^{0.333} \\
& [(1 - (0.85)^2)^{0.333}(1 - (0.85)^2)^{0.381}(1 - (0.60)^2)^{0.286} - \\
& (1 - (0.85)^2 - (0.45)^2)^{0.333}(1 - (0.85)^2 - (0.45)^2)^{0.381} \\
& (1 - (0.15)^2 - (0.35)^2)^{0.286}]^{1/2}, -((-0.75)^2)^{0.333} \\
& ((-0.75)^2)^{0.381}((-0.65)^2)^{0.286}, -(1 - (1 - (-0.30)^2)^{0.333} \\
& (1 - (-0.30)^2)^{0.381}(1 - (-0.20)^2)^{0.286})^{1/2}, \\
& - [\prod_{k=1}^{m} (1 - (-0.75)^2)^{0.333}(1 - (-0.75)^2)^{0.381} \\
& (1 - (-0.20)^2)^{0.286} - ((1 - (-0.30)^2 - (-0.40)^2))^{0.333} \\
& ((1 - (-0.30)^2 - (-0.40)^2))^{0.381}((1 - (-0.20)^2 - \\
& (-0.38)^2))^{0.286}]^{1/2} \rangle \\
= & \langle 0.805, 0.163, 0.471, -0.369, -0.276, -0.283 \rangle.
\end{aligned}
$$

Thus,
$d_{12} = \langle 0.805, 0.163, 0.471, -0.369, -0.276, -0.283 \rangle$,
where

$$
\begin{aligned}
d^1_{12} = & \langle \mu^+_{d^1_{12}}, \nu^+_{d^1_{12}}, \pi^+_{d^1_{12}}, \mu^-_{d^1_{12}}, \nu^-_{d^1_{12}}, \pi^-_{d^1_{ij}} \rangle \\
= & \langle 0.85, 0.15, 0.45, -0.75, -0.30, -0.40 \rangle, \\
d^2_{12} = & \langle \mu^+_{d^2_{12}}, \nu^+_{d^2_{12}}, \pi^+_{d^2_{12}}, \mu^-_{d^1_{12}}, \nu^-_{d^2_{12}}, \pi^-_{d^2_{ij}} \rangle \\
= & \langle 0.85, 0.15, 0.45, -0.75, -0.30, -0.40 \rangle, \\
d^3_{12} = & \langle \mu^+_{d^3_{12}}, \nu^+_{d^3_{12}}, \pi^+_{d^3_{12}}, \mu^-_{d^3_{12}}, \nu^-_{d^3_{12}}, \pi^-_{d^3_{ij}} \rangle \\
= & \langle 0.60, 0.20, 0.35, -0.65, -0.20, -0.38 \rangle.
\end{aligned}
$$

Step 5: Calculate score influence matrix (S) in Table VI as follows:

For example, the calculation of score influence matrix

TABLE III
FACTORS INFLUENCING PERFORMANCE OF SMALL AND MICRO ENTERPRISES

Aspects of evaluation	Criteria
Business environment	Creating satisfaction for customers(C_1)
	Building customer trust(C_2)
	Having more than one supplier(C_3)
	The quality of raw materials is by market demand.(C_4)
	Product quality can compete with business competitors.(C_5)
	The product price is reasonable(C_6)
Entrepreneurial characteristics	Business owners dare to experiment and create new business models.(C_7)
	Business owners accept the risk of failure. (C_8)
	Business owners always look for market opportunities to advance their business.(C_9)
	Business owners create new products for new markets. (C_{10})
	Business owners overcome difficulties or problems that arise on their own (C_{11})
	Business owners solve problems themselves without waiting for help from customers. (C_{12})
	Business owners create partnerships with other micro and small enterprises. (C_{13})
	Business owners are open to customer reviews. (C_{14})
Innovative ability	Create products that are unique and different.(C_{15})
	Create products with harmonious color combinations.(C_{16})
	Use technology to create new, unique products. (C_{17})
	Apply ideas to create new and interesting identities through technology. (C_{18})
	Provide new product options that meet the needs of consumers through online media. (C_{19})
	Expand their marketing reach through online media (Facebook, WhatsApp, and Instagram) (C_{20})

$s_{12} = Score(d_{12})$ as follows:

$$\begin{aligned} s_{12} =& \frac{1}{2}[(\mu_{12}^{+} - \pi_{12}^{+})^2 - (\nu_{12}^{+} - \pi_{12}^{+})^2 + \\ & (\mu_{12}^{-} - \pi_{12}^{-})^2 - (\nu_{12}^{-} - \pi_{12}^{-})^2] \\ =& \frac{1}{2}[(0.805 - 0.471)^2 - (0.163 - 0.471)^2 + \\ & (-0.369 - (-0.276))^2 - (-0.276 - (-0.283))^2] \\ =& 0.012. \end{aligned}$$

Step 6: Calculate $X = qS$,
where

$$\begin{aligned} q =& \min\left[\frac{1}{0.451}, \frac{1}{0.552}\right] \\ =& \min[2.217, 1.813] = 1.813, \end{aligned}$$

which represents the normalization index in Table VII, as follows:

Step 7: Construct the total-relation matrix T in Table VIII.

Step 8: The total-relation matrix X and cause-effect diagram of small and micro enterprises in Table IX ranking of cause and effect group in Table X and Figure 2.

The threshold value is determined based on the average of the total relation matrix, which is $\alpha = 0.0917$. A new total relational matrix is then formed. If the corresponding entries of the total relation matrix are greater than α, then the element of the new total relation matrix is 1. Otherwise, the element is assigned as 0. The total relation matrix is shown in Table XI.

A. Sensitivity Analysis

Sensitivity analysis is employed to evaluate a model's robustness and detect potential biases introduced by individual experts. This approach also enhances the methodological generalizability of the proposed system. In this study, the authors applied the weight variation method, as suggested by Biswas and Gupta [17]. The analysis involved three scenarios:

Test 1: The first expert was assigned a higher weight of 50%, while the remaining experts received weightings of 30% and 20%, respectively.

Test 2 and Test 3: The second and third experts, were given a higher weight of 50%, with the others being assigned a weight of 30% and 20%, respectively. These weight distributions are summarized in Table XII.

The results of the cause and effect rankings changed according to the evaluator's weight, as shown in Table XIII and Figure 3, 4, and 5. Considering that the cause and effect changes are located between the positive and negative y-axis, the overlapping criteria between these values affect the cause and effect changes: c_8, c_9 change from effect to cause, and c_{13}, c_{14} change from cause to effect. Considering these events shows that the weighting of the third expert affects the cause and effect order changes.

V. Conclusion

This study introduced the use of the Spherical Bipolar Fuzzy Sets DEMATEL (SBFS-DEMATEL) method to analyze cause-and-effect relationships in decision-making scenarios. Our research demonstrated the efficacy of this method in constructing detailed cause-effect diagrams, particularly in the context of subcontractor selection, which is crucial for project management in various industries. By integrating the principles of Spherical Bipolar Fuzzy Sets with the established fuzzy DEMATEL framework, we have provided a comprehensive tool that enhances the decision-making process. Using linguistic variables and incorporating expert weights and transformation equations enable the method to handle the ambiguities and uncertainties inherent in complex decision-making scenarios. The application of the SBFS-DEMATEL method to small and micro-enterprise case studies has not only validated the method's applicability but also highlighted its potential to contribute significantly to the field of multi-criteria decision-making (MCDM). Our findings suggest that decision-makers can benefit from the nuanced insights provided by this method, which accommodate both positive and negative criteria in a balanced manner. Future research should explore the adaptation of the SBFS-DEMATEL method to other domains and compare its performance with other fuzzy set approaches to further establish its versatility and robustness. The potential for this method to be tailored to specific industry creates opportunities for new research and application, promising substantial improvements in how organizations approach complex decision-making tasks.

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TABLE IV
DECISION-MAKERS EVALUATIONS ON INFLUENCES

DM	C_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
	C_1	0	S	W	M	NI	M	W	M	NI	M	NI	M	W	M	NI	M	W	M	NI	S
	C_2	S	0	W	M	NI	M	W	M	NI	M	NI	M	W	M	NI	M	W	M	NI	S
	C_3	W	W	0	W	M	NI	M	NI	M	W	M	NI	M	W	M	NI	S	M	NI	S
	C_4	M	W	M	0	W	M	NI	M	W	W	M	W	M	NI	M	W	M	NI	S	S
	C_5	NI	W	M	M	0	W	M	NI	M	W	M	NI	M	W	M	NI	M	W	M	NI
	C_6	M	W	M	M	M	0	W	M	NI	M	W	NI	M	W	W	M	NI	W	M	NI
	C_7	W	W	M	NI	M	M	0	W	M	NI	S	M	W	M	NI	S	W	M	NI	S
	C_8	M	W	M	NI	M	M	S	0	W	M	NI	S	M	S	M	W	W	M	NI	S
	C_9	NI	W	M	NI	M	M	S	M	0	W	M	NI	S	M	M	W	M	NI	W	M
D^1	C_{10}	M	W	W	NI	NI	M	S	M	W	0	W	M	M	M	NI	S	W	M	NI	S
	C_{11}	NI	W	W	NI	W	M	NI	M	W	W	0	M	M	W	M	NI	S	M	W	M
	C_{12}	M	W	W	M	NI	M	W	M	NI	S	M	0	W	M	NI	W	M	NI	S	S
	C_{13}	W	W	W	M	W	M	NI	M	W	M	NI	W	0	W	M	NI	S	W	M	NI
	C_{14}	M	M	W	M	NI	M	W	M	NI	S	M	W	M	0	S	W	M	NI	S	NI
	C_{15}	NI	W	W	M	W	M	NI	M	W	M	NI	W	M	M	0	W	M	NI	S	NI
	C_{16}	M	M	NI	M	W	M	M	W	M	NI	S	M	M	M	M	0	W	M	NI	NI
	C_{17}	W	W	M	NI	M	W	M	NI	M	W	M	NI	NI	S	M	M	0	W	M	NI
	C_{18}	M	W	W	W	M	W	M	NI	M	W	M	NI	W	M	NI	M	S	0	W	M
	C_{19}	NI	W	W	W	M	W	M	NI	M	W	M	W	W	S	M	M	S	W	0	W
	C_{20}	S	W	W	M	W	M	NI	M	W	M	W	W	W	M	NI	M	S	W	W	0
	C_1	0	S	W	M	M	W	M	NI	S	W	M	M	NI	S	W	M	M	NI	S	W
	C_2	M	0	W	M	NI	M	W	M	NI	S	M	NI	M	W	M	S	W	M	M	NI
	C_3	M	M	0	W	M	NI	M	W	M	NI	S	M	W	M	NI	S	W	M	M	NI
	C_4	M	M	M	0	M	M	NI	M	W	M	M	W	M	NI	M	W	M	NI	S	M
	C_5	M	M	M	M	0	M	M	M	M	M	M	M	M	M	M	S	W	M	M	NI
	C_6	W	M	NI	S	M	0	M	M	NI	M	W	M	M	NI	S	M	M	M	M	M
	C_7	M	M	M	M	M	M	0	M	M	M	M	M	M	M	M	M	M	M	M	M
	C_8	M	NI	M	W	M	NI	M	0	M	M	NI	M	W	M	W	M	NI	S	M	M
	C_9	M	NI	M	W	M	NI	M	M	0	M	M	M	W	M	W	M	W	M	NI	S
D^2	C_{10}	M	W	M	NI	S	M	M	M	M	0	M	M	M	NI	M	W	M	NI	NI	M
	C_{11}	M	M	NI	M	W	M	NI	M	M	M	0	M	M	NI	M	M	W	M	NI	NI
	C_{12}	M	NI	M	W	M	NI	M	M	M	M	M	0	M	NI	M	NI	M	W	M	NI
	C_{13}	M	M	M	M	W	M	NI	S	M	M	M	M	0	M	M	NI	M	W	M	M
	C_{14}	M	W	M	NI	M	W	M	W	M	NI	M	W	M	0	M	NI	M	W	M	M
	C_{15}	M	NI	M	W	M	NI	M	W	M	NI	S	M	M	M	0	NI	M	W	M	M
	C_{16}	NI	M	W	M	NI	M	W	M	W	M	NI	M	W	M	M	0	M	M	M	M
	C_{17}	NI	M	NI	M	W	M	NI	M	W	M	NI	S	W	M	M	M	0	M	M	M
	C_{18}	NI	M	M	NI	M	W	M	NI	M	M	NI	M	W	M	NI	M	M	0	M	M
	C_{19}	NI	M	NI	M	W	M	NI	M	W	M	NI	S	M	M	M	M	M	M	0	M
	C_{20}	W	M	NI	S	M	NI	M	W	M	NI	M	M	W	M	NI	S	M	M	M	0
	C_1	0	M	M	W	M	NI	M	W	M	M	W	M	NI	M	M	M	M	NI	S	M
	C_2	M	0	W	M	NI	M	W	M	W	M	M	W	M	NI	S	M	M	M	S	M
	C_3	S	M	0	NI	M	M	M	M	NI	S	NI	M	W	M	M	NI	S	M	S	M
	C_4	M	M	M	0	NI	M	M	M	M	NI	S	M	NI	M	W	M	M	M	M	M
	C_5	M	M	M	M	0	M	NI	M	M	M	M	NI	S	W	M	W	NI	S	M	M
	C_6	M	M	NI	S	M	0	NI	M	M	NI	M	W	M	NI	M	W	M	W	M	M
	C_7	NI	M	W	M	M	M	0	M	M	M	M	M	M	S	NI	M	M	W	M	M
	C_8	NI	M	W	M	NI	M	M	0	M	M	NI	M	W	M	NI	M	W	M	W	M
	C_9	M	M	M	W	M	NI	S	M	0	M	M	NI	S	S	W	M	NI	M	W	M
D^3	C_{10}	W	M	NI	M	W	M	W	M	M	0	M	M	M	NI	M	W	M	NI	M	M
	C_{11}	NI	M	W	M	NI	M	W	M	M	M	0	W	M	NI	M	W	M	M	M	M
	C_{12}	M	W	M	NI	M	W	M	W	M	M	M	0	M	M	NI	S	W	M	M	M
	C_{13}	M	NI	M	W	M	NI	M	W	M	M	M	M	0	M	M	M	NI	S	M	M
	C_{14}	M	M	NI	M	W	M	NI	M	M	M	M	M	M	0	M	NI	M	W	M	M
	C_{15}	M	M	W	M	NI	M	W	M	W	M	M	M	M	M	0	NI	M	W	M	M
	C_{16}	M	M	NI	M	W	M	NI	M	W	M	M	M	M	M	M	0	NI	M	W	M
	C_{17}	M	NI	M	W	M	NI	M	W	M	M	NI	M	W	M	M	M	0	M	W	M
	C_{18}	M	M	NI	M	W	M	NI	M	M	M	M	M	M	M	M	M	M	0	W	M
	C_{19}	M	M	M	M	M	NI	M	W	M	NI	M	W	M	M	M	M	M	M	0	M
	C_{20}	NI	M	W	M	M	M	NI	M	W	M	NI	M	NI	M	W	M	M	M	M	0

TABLE V
CONSOLIDATION OF DIVERSE DECISION-MAKER MATRIX D

C_i	C_1	C_2	$\cdots$	C_{20}
C_1	0	$\langle 0.805, 0.163, 0.471, -0.369, -0.276, -0.283 \rangle$	$\cdots$	$\langle 0.674, 0.198, 0.472, -0.183, -0.225, -0.252 \rangle$
C_2	$\langle 0.718, 0.182, 0.461, -0.331, -0.239, -0.248 \rangle$	0	$\cdots$	$\langle 0.653, 0.212, 0.477, 0.000, 0.000, -0.284 \rangle$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
C_{20}	$\langle 0.616, 0.222, 0.483, 0.000, -0.25, 5-0.280 \rangle$	$\langle 0.538, 0.215, 0.330, -0.223, -0.185, -0.192 \rangle$	$\cdots$	0

TABLE VI
SCORE INFLUENCE MATRIX S

C_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	0.000	0.012	0.011	0.016	0.016	0.032	0.015	0.034	-0.014	0.015	0.017	0.023	0.029	-0.005	0.016	0.023	0.015	0.040	-0.007	-0.015
C_2	-0.003	0.000	0.007	0.023	0.045	0.023	0.007	0.023	0.030	-0.005	0.016	0.034	0.015	0.032	-0.011	-0.005	0.011	0.023	-0.011	0.021
C_3	-0.015	0.015	0.000	0.022	0.023	0.040	0.023	0.016	0.039	0.017	0.021	0.016	0.013	0.015	0.040	0.022	-0.011	0.023	-0.011	0.021
C_4	0.023	0.015	0.023	0.000	0.033	0.023	0.040	0.023	0.011	0.033	-0.003	0.011	0.039	0.040	0.016	0.011	0.023	0.040	0.012	-0.003
C_5	0.016	0.015	0.023	0.023	0.000	0.015	0.039	0.016	0.023	0.015	0.023	0.040	-0.003	0.012	0.023	-0.011	0.032	-0.015	0.023	0.040
C_6	0.015	0.015	0.040	0.006	0.023	0.000	0.033	0.023	0.040	0.039	0.011	0.017	0.023	0.029	-0.017	0.016	0.016	0.012	0.023	0.016
C_7	0.033	0.015	0.016	0.016	0.023	0.023	0.000	0.015	0.023	0.016	-0.003	0.023	0.015	-0.003	0.040	-0.003	0.015	0.016	0.016	-0.003
C_8	0.039	0.033	0.016	0.016	0.039	0.040	-0.003	0.000	0.015	0.023	0.045	-0.003	0.013	-0.003	0.032	0.015	0.024	-0.005	0.017	-0.003
C_9	0.016	0.033	0.023	0.013	0.023	0.040	0.005	0.023	0.000	0.015	0.023	0.040	-0.011	-0.003	0.013	0.015	0.032	0.016	0.024	-0.005
C_{10}	0.016	0.011	0.033	0.040	-0.011	0.023	-0.014	0.023	0.015	0.000	0.015	0.023	0.023	0.040	0.016	-0.016	0.015	0.040	0.040	-0.003
C_{11}	0.040	0.015	0.024	0.016	0.022	0.023	0.030	0.023	0.015	0.015	0.000	0.016	0.023	0.029	0.023	0.017	-0.015	0.023	0.033	0.040
C_{12}	0.023	0.024	0.015	0.032	0.016	0.034	0.015	0.016	0.016	-0.003	0.023	0.000	0.015	0.040	0.040	0.017	0.016	0.016	-0.003	0.021
C_{13}	0.015	0.033	0.015	0.016	0.011	0.039	0.040	-0.014	0.015	0.023	0.016	0.015	0.000	0.015	0.023	0.040	0.021	-0.017	0.023	0.016
C_{14}	0.023	0.015	0.033	0.040	0.017	0.015	0.033	0.015	0.016	0.021	0.023	0.011	0.023	0.000	-0.003	0.029	0.023	0.013	-0.003	0.016
C_{15}	0.016	0.033	0.012	0.015	0.033	0.040	0.017	0.015	0.012	0.040	-0.014	0.015	0.023	0.023	0.000	0.029	0.023	0.013	-0.003	0.016
C_{16}	0.040	0.023	0.029	0.023	0.024	0.023	0.032	0.015	0.013	0.016	0.021	0.023	0.015	0.023	0.023	0.000	0.033	0.023	0.017	0.016
C_{17}	0.033	0.033	0.040	0.017	0.015	0.033	0.040	0.017	0.015	0.015	0.040	-0.014	0.013	-0.003	0.023	0.023	0.000	0.015	0.016	0.016
C_{18}	0.040	0.015	0.033	0.033	0.016	0.011	0.039	0.040	0.023	0.015	0.040	0.016	0.011	0.023	0.040	0.023	-0.003	0.000	0.012	0.023
C_{19}	0.040	0.015	0.033	0.015	0.015	0.033	0.040	0.017	0.015	0.033	0.040	-0.021	0.015	-0.003	0.023	0.023	-0.003	0.015	0.000	0.015
C_{20}	0.014	0.015	0.024	-0.005	0.015	0.040	0.040	0.015	0.012	0.040	0.033	0.015	0.022	0.023	0.030	-0.005	-0.003	0.015	0.015	0.000

TABLE VII
THE NORMALIZATION INDEX MATRIX $X = qS$

C_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	0.000	0.023	0.020	0.029	0.030	0.059	0.027	0.064	-0.023	0.028	0.032	0.041	0.053	-0.009	0.031	0.041	0.027	0.074	-0.015	-0.029
C_2	-0.007	0.000	0.014	0.041	0.082	0.041	0.014	0.041	0.056	-0.009	0.030	0.064	0.027	0.059	-0.017	-0.009	0.020	0.041	-0.017	0.038
C_3	-0.026	0.027	0.000	0.040	0.041	0.073	0.041	0.031	0.072	0.032	0.039	0.030	0.025	0.027	0.073	0.041	-0.019	0.041	-0.017	0.038
C_4	0.041	0.027	0.041	0.000	0.060	0.041	0.073	0.041	0.020	0.060	-0.006	0.020	0.072	0.073	0.029	0.020	0.041	0.073	0.023	-0.007
C_5	0.030	0.027	0.041	0.041	0.000	0.027	0.072	0.030	0.041	0.027	0.041	0.074	-0.006	0.021	0.041	-0.018	0.059	-0.026	0.041	0.073
C_6	0.028	0.027	0.074	0.007	0.041	0.000	0.060	0.041	0.073	0.072	0.020	0.032	0.041	0.053	-0.033	0.029	0.030	0.021	0.041	0.030
C_7	0.060	0.027	0.029	0.030	0.041	0.041	0.000	0.027	0.041	0.030	-0.007	0.041	0.027	-0.006	0.074	-0.007	0.027	0.029	0.030	-0.007
C_8	0.072	0.059	0.029	0.031	0.072	0.073	-0.007	0.000	0.027	0.041	0.082	-0.007	0.025	-0.007	0.059	0.027	0.044	-0.009	0.032	-0.007
C_9	0.030	0.059	0.041	0.025	0.041	0.074	0.009	0.041	0.000	0.027	0.041	0.074	-0.019	-0.006	0.025	0.027	0.059	0.030	0.044	-0.009
C_{10}	0.029	0.020	0.060	0.073	-0.018	0.041	-0.026	0.041	0.027	0.000	0.027	0.041	0.041	0.074	0.030	-0.030	0.027	0.074	0.073	-0.007
C_{11}	0.074	0.027	0.044	0.030	0.040	0.041	0.056	0.041	0.027	0.027	0.000	0.029	0.041	0.053	0.041	0.032	-0.029	0.041	0.059	0.073
C_{12}	0.041	0.044	0.027	0.059	0.030	0.064	0.027	0.029	0.030	-0.007	0.041	0.000	0.027	0.073	0.074	0.032	0.029	0.031	-0.007	0.038
C_{13}	0.027	0.060	0.027	0.029	0.020	0.072	0.073	-0.025	0.027	0.041	0.030	0.027	0.000	0.027	0.041	0.073	0.039	-0.028	0.041	0.030
C_{14}	0.041	0.028	0.060	0.073	0.032	0.028	0.060	0.028	0.030	0.038	0.041	0.020	0.041	0.000	-0.007	0.053	0.041	0.025	-0.007	0.030
C_{15}	0.030	0.059	0.021	0.028	0.060	0.073	0.032	0.028	0.021	0.073	-0.023	0.027	0.041	0.041	0.000	0.053	0.041	0.025	-0.007	0.030
C_{16}	0.073	0.041	0.053	0.041	0.044	0.041	0.059	0.027	0.025	0.030	0.038	0.041	0.028	0.041	0.041	0.000	0.060	0.041	0.032	0.030
C_{17}	0.059	0.060	0.073	0.032	0.028	0.060	0.073	0.032	0.028	0.027	0.074	-0.023	0.025	-0.007	0.041	0.041	0.000	0.027	0.029	0.030
C_{18}	0.073	0.027	0.060	0.059	0.029	0.020	0.072	0.073	0.041	0.027	0.073	0.030	0.020	0.041	0.073	0.041	-0.007	0.000	0.021	0.041
C_{19}	0.073	0.027	0.059	0.027	0.028	0.060	0.073	0.032	0.028	0.060	0.073	-0.037	0.027	-0.007	0.041	0.041	-0.007	0.027	0.000	0.027
C_{20}	0.025	0.027	0.044	-0.009	0.027	0.073	0.074	0.028	0.021	0.073	0.060	0.027	0.040	0.041	0.056	-0.009	-0.007	0.027	0.027	0.000

TABLE VIII
THE TOTAL-RELATION MATRIX T

C_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	0.057	0.073	0.079	0.080	0.083	0.126	0.088	0.108	0.025	0.076	0.077	0.083	0.096	0.040	0.081	0.078	0.065	0.109	0.020	0.008
C_2	0.050	0.052	0.074	0.091	0.133	0.111	0.078	0.089	0.102	0.042	0.080	0.107	0.067	0.102	0.032	0.026	0.058	0.076	0.013	0.072
C_3	0.038	0.089	0.071	0.098	0.107	0.154	0.111	0.086	0.128	0.093	0.090	0.086	0.073	0.086	0.126	0.078	0.028	0.088	0.021	0.076
C_4	0.118	0.101	0.127	0.076	0.133	0.142	0.157	0.109	0.088	0.130	0.065	0.082	0.130	0.131	0.101	0.071	0.096	0.126	0.066	0.041
C_5	0.091	0.089	0.111	0.098	0.066	0.118	0.140	0.086	0.097	0.090	0.098	0.120	0.048	0.074	0.103	0.020	0.098	0.028	0.077	0.107
C_6	0.096	0.094	0.149	0.080	0.108	0.096	0.135	0.103	0.133	0.134	0.088	0.087	0.094	0.107	0.039	0.071	0.075	0.076	0.084	0.068
C_7	0.111	0.082	0.087	0.079	0.097	0.116	0.060	0.078	0.088	0.081	0.043	0.086	0.071	0.039	0.121	0.033	0.068	0.070	0.057	0.027
C_8	0.133	0.120	0.101	0.089	0.137	0.157	0.071	0.061	0.085	0.104	0.136	0.051	0.078	0.052	0.111	0.069	0.087	0.045	0.070	0.039
C_9	0.093	0.119	0.113	0.084	0.108	0.155	0.081	0.102	0.059	0.086	0.101	0.120	0.032	0.050	0.082	0.068	0.098	0.079	0.079	0.034
C_{10}	0.092	0.081	0.131	0.132	0.046	0.127	0.051	0.100	0.084	0.064	0.088	0.085	0.096	0.125	0.086	0.023	0.066	0.122	0.104	0.034
C_{11}	0.147	0.099	0.126	0.099	0.116	0.144	0.141	0.110	0.093	0.104	0.069	0.091	0.104	0.114	0.114	0.079	0.025	0.100	0.101	0.113
C_{12}	0.111	0.111	0.105	0.122	0.103	0.154	0.111	0.092	0.090	0.066	0.101	0.059	0.087	0.130	0.132	0.079	0.078	0.084	0.034	0.080
C_{13}	0.090	0.118	0.100	0.087	0.084	0.155	0.143	0.032	0.086	0.103	0.080	0.081	0.053	0.083	0.096	0.109	0.082	0.025	0.078	0.066
C_{14}	0.109	0.091	0.133	0.133	0.098	0.117	0.136	0.087	0.087	0.100	0.101	0.076	0.097	0.057	0.062	0.095	0.087	0.079	0.037	0.067
C_{15}	0.091	0.121	0.097	0.091	0.124	0.157	0.104	0.086	0.082	0.132	0.037	0.084	0.094	0.099	0.058	0.091	0.092	0.074	0.036	0.067
C_{16}	0.150	0.117	0.139	0.117	0.124	0.149	0.149	0.101	0.094	0.104	0.108	0.105	0.093	0.106	0.117	0.053	0.112	0.105	0.073	0.076
C_{17}	0.128	0.125	0.147	0.094	0.101	0.154	0.150	0.096	0.091	0.097	0.132	0.037	0.082	0.054	0.107	0.086	0.045	0.086	0.070	0.071
C_{18}	0.154	0.108	0.147	0.136	0.116	0.134	0.161	0.146	0.112	0.109	0.141	0.097	0.090	0.110	0.151	0.096	0.053	0.068	0.068	0.088
C_{19}	0.137	0.089	0.131	0.088	0.094	0.148	0.143	0.092	0.086	0.125	0.126	0.022	0.084	0.051	0.104	0.082	0.039	0.084	0.043	0.065
C_{20}	0.090	0.089	0.116	0.056	0.092	0.158	0.141	0.086	0.082	0.134	0.115	0.083	0.094	0.098	0.114	0.035	0.038	0.079	0.069	0.041

TABLE IX
SUMMATIONS OF ROWS AND COLUMNS

Criteria	R	D	$R+D$	$R-D$	Influence group
C_1	1.4516	2.0856	3.5372	-0.6340	Effect
C_2	1.4538	1.9683	3.4221	-0.5146	Effect
C_3	1.7260	2.2811	4.0070	-0.5551	Effect
C_4	2.0884	1.9323	4.0207	0.1561	Cause
C_5	1.7610	2.0688	3.8298	-0.3078	Effect
C_6	1.9170	2.7714	4.6884	-0.8544	Effect
C_7	1.4922	2.3490	3.8411	-0.8568	Effect
C_8	1.7968	1.8489	3.6458	-0.0521	Effect
C_9	1.7417	1.7907	3.5324	-0.0490	Effect
C_{10}	1.7361	1.9757	3.7117	-0.2396	Effect
C_{11}	2.0877	1.8733	3.9611	0.2144	Cause
C_{12}	1.9272	1.6407	3.5679	0.2865	Cause
C_{13}	1.7519	1.6630	3.4149	0.0889	Cause
C_{14}	1.8497	1.7054	3.5551	0.1443	Cause
C_{15}	1.8154	1.9363	3.7516	-0.1209	Effect
C_{16}	2.1922	1.3402	3.5323	0.8520	Cause
C_{17}	1.9528	1.3912	3.3440	0.5616	Cause
C_{18}	2.2852	1.6047	3.8899	0.6805	Cause
C_{19}	1.8324	1.1994	3.0318	0.6330	Cause
C_{20}	1.8072	1.2402	3.0474	0.5670	Cause

TABLE X
RANKING OF CAUSE-AND-EFFECT GROUPS

Cause group	Ranking	Effect group	Ranking
C_{16}	1	C_9	1
C_{18}	2	C_8	2
C_{19}	3	C_{15}	3
C_{20}	4	C_{10}	4
C_{17}	5	C_5	5
C_{12}	6	C_2	6
C_{11}	7	C_3	7
C_4	8	C_1	8
C_{14}	9	C_6	9
C_{13}	10	C_7	10

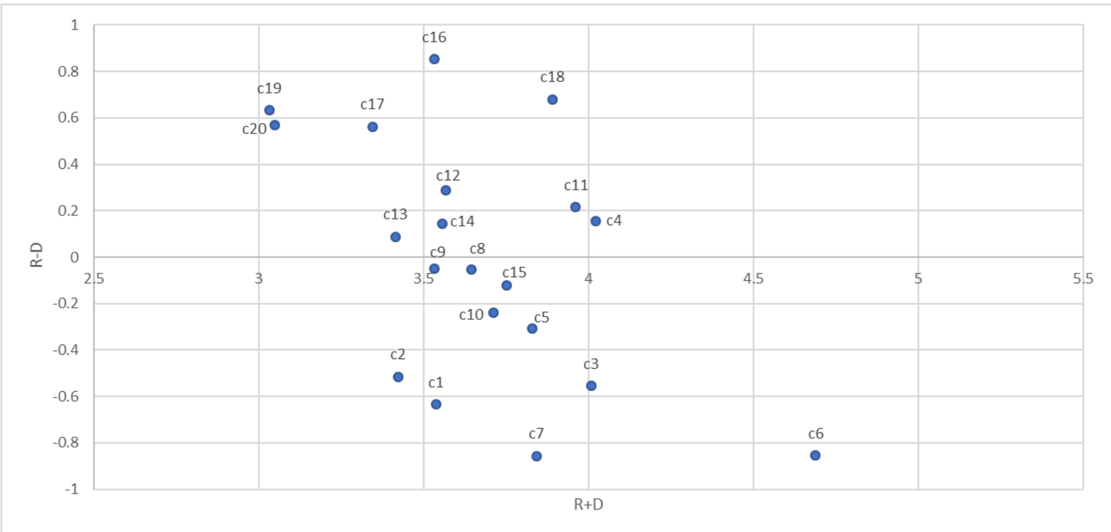

Fig. 2. Cause-effect diagram of small and micro enterprises.

TABLE XI
THE NEW TOTAL RELATION MATRIX

C_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}
C_1	0	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1	0	0
C_2	0	0	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0
C_3	0	0	0	1	1	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0
C_4	1	1	1	0	1	1	1	1	0	1	0	0	1	1	1	0	1	1	0	0
C_5	0	0	1	1	0	1	1	0	1	0	1	1	0	0	1	0	1	0	0	1
C_6	1	1	1	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0
C_7	1	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
C_8	1	1	1	0	1	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0
C_9	1	1	1	0	1	1	0	1	0	0	1	1	0	0	0	0	1	0	0	0
C_{10}	1	0	1	1	0	1	0	1	0	0	0	0	1	1	0	0	0	1	1	0
C_{11}	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	0	0	1	1	1
C_{12}	1	1	1	1	1	1	1	1	0	0	1	0	0	1	1	0	0	0	0	0
C_{13}	0	1	1	0	0	1	1	0	0	1	0	0	0	0	1	1	0	0	0	0
C_{14}	1	0	1	1	1	1	1	0	0	1	1	0	1	0	0	1	0	0	0	0
C_{15}	0	1	1	0	1	1	1	0	0	1	0	0	1	1	0	0	1	0	0	0
C_{16}	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0
C_{17}	1	1	1	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0
C_{18}	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0
C_{19}	1	0	1	0	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0
C_{20}	0	0	1	0	1	1	1	0	0	1	1	0	1	1	1	0	0	0	0	0

TABLE XII
WEIGHT ASSIGNMENT OF EXPERTS DURING SENSITIVITY TESTS

Test	Expert1	Expert 2	Expert 3
Test 1	0.5	0.3	0.2
Test 2	0.3	0.5	0.2
Test 3	0.2	0.3	0.5

TABLE XIII
RANKING OF EXPERTS BASED ON SENSITIVITY

	Original		Test 1		Test 2		Test 3	
Criteria	Ranking	Influence group	Ranking	Influence group	Ranking	Influence group	Ranking	Influence group
C_1	18	Effect	18	Effect	18	Effect	19	Effect
C_2	16	Effect	14	Effect	16	Effect	17	Effect
C_3	17	Effect	16	Effect	17	Effect	16	Effect
C_4	8	Cause	9	Cause	7	Cause	8	Cause
C_5	15	Effect	17	Effect	14	Effect	14	Effect
C_6	19	Effect	19	Effect	20	Effect	20	Effect
C_7	20	Effect	20	Effect	19	Effect	18	Effect
C_8	12	Effect	12	Effect	11	Effect	9	Cause
C_9	11	Effect	11	Effect	12	Effect	10	Cause
C_{10}	14	Effect	15	Effect	15	Effect	15	Effect
C_{11}	7	Cause	10	Cause	8	Cause	7	Cause
C_{12}	6	Cause	5	Cause	6	Cause	6	Cause
C_{13}	10	Cause	8	Cause	9	Cause	11	Effect
C_{14}	9	Cause	7	Cause	10	Cause	12	Effect
C_{15}	13	Effect	13	Effect	13	Effect	13	Effect
C_{16}	1	Cause	1	Cause	1	Cause	3	Cause
C_{17}	5	Cause	2	Cause	4	Cause	5	Cause
C_{18}	2	Cause	3	Cause	2	Cause	1	Cause
C_{19}	3	Cause	4	Cause	5	Cause	2	Cause
C_{20}	4	Cause	6	Cause	3	Cause	4	Cause

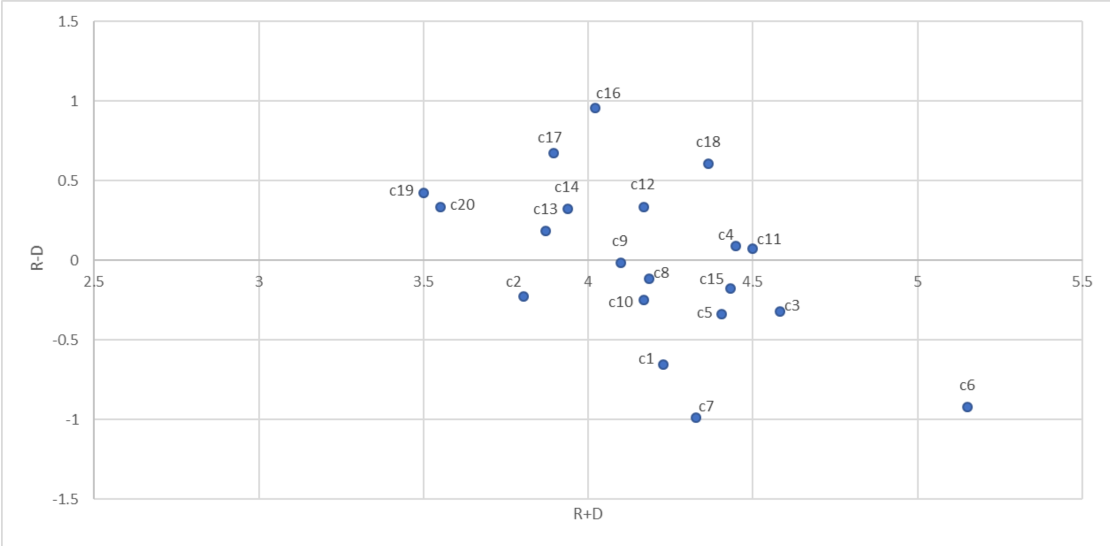

Fig. 3. Cause-effect diagram of small and micro enterprises of Test 1.

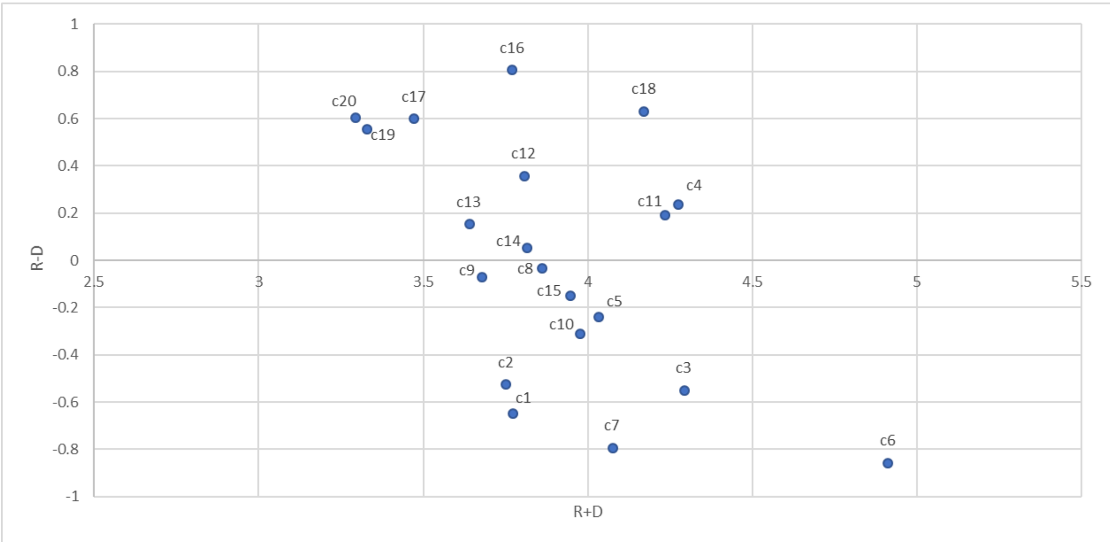

Fig. 4. Cause-effect diagram of small and micro enterprises of Test 2.

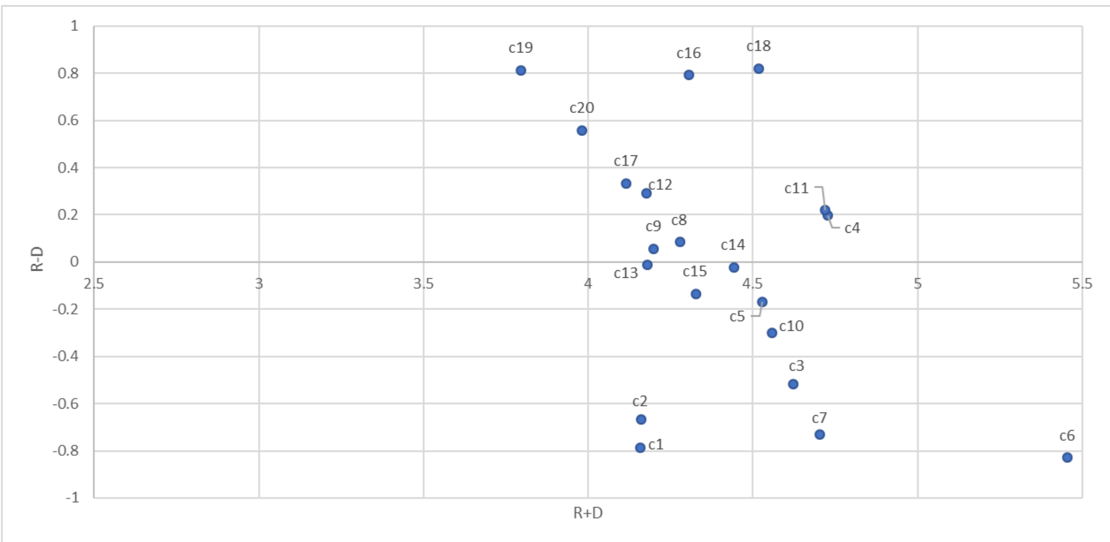

Fig. 5. Cause-effect diagram of small and micro enterprises of Test 3.