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Smart Technology Prioritization for Sustainable Manufacturing in Emergency Situation by Integrated Spherical Fuzzy Bounded Rationality Decision-Making Approach

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Abstract: The delays and disruptions during the pandemic have awakened interest in the sustainability and resilience of production systems to emergencies. In that context, the deployment of smart technologies has emerged as an almost mandatory development orientation to ensure the stability of manufacturing. The core value of smart technologies is to reduce the dependence on human labor in production systems. Thereby, the negative impacts caused by emergency situations are mitigated. However, the implementation of smart technologies in a specific production system that already exists requires a high degree of suitability. Motivated by this fact, this study proposes an integrated spherical fuzzy bounded rationality decision-making approach, which is composite of the spherical fuzzy decision-making trial and evaluation laboratory (SF DEMATEL) and the spherical fuzzy regret theory-based combined compromise solution (R-SF CoCoSo) method. The proposed approach reflects both the ambiguities and psychological behaviors of decision-makers in prioritization problems. It was applied to prioritize seven smart technologies for manufacturing in Vietnam. The results show that reliability, costs, and maturity are the most important criteria for choosing smart technology which is suitable for an existing production system in Vietnam. Our findings seem to suggest that the automatic inspection, remote machine operation, and robots are the most suitable smart technologies to stabilize and sustain production in Vietnam for emergency situations.

Keywords: multiple criteria decision-making; bounded rationality decision-making; the combined compromise solution method; the decision-making trial and evaluation laboratory; spherical fuzzy sets; regret theory; sustainable manufacturing; smart technology

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1. Introduction

Strong global competition along with many fierce events cause instability in production. These have strongly demanded that production operations be re-examined from a flexible perspective [1]. In manufacturing organizations, manufacturing is a core competency and plays a crucial part in giving firms a competitive advantage. Therefore, the development of production strategy should be given maximum attention [2]. The production function consists of a complex structure, consisting of many different components, such as workers, equipment, raw materials, machines, etc., and necessary management functions in production. The main task of production management is to maintain the link between components to create an efficient production structure [3]. However, disturbance by unexpected factors without precaution will cause failure to components in the production organization as well as the production function. That is why when past events happen, the production system is vulnerable. For example, the ongoing COVID-19 pandemic has disrupted the operations of manufacturing organizations, resulting in production flow disruptions. As of now, this is believed to be the longest disruption the world has ever seen [4].

As another example, many semiconductor firms' manufacturing facilities had to shut down owing to a shortage of raw materials during the 2016 Taiwan earthquake. As a result, Korea, Japan, and the United States have all been directly impacted by this situation [5]. In other abrupt events, shipments of hard disks have plummeted due to floods in Thailand in 2011, causing prices globally to rise unexpectedly [6]. Therefore, to minimize internal or external failure due to disruption, manufacturing organizations should emphasize building production resilience [7]. For the purpose of mitigating economic shocks, the advanced digital technology of Industry 4.0 is a promising solution [8–10]. In addition, advancements in advanced technology such as artificial intelligence, blockchain, digital twin, virtual reality, etc. have attracted the attention of researchers to build resilience recovery of production function in manufacturing organizations [11]. The correct application of technologies in production is the most important factor for efficiency, saving costs, and risk reduction for companies. However, choosing the right technology for the actual context is very important. In particular, this study focuses on manufacturing companies in Vietnam [12]. This is one of the countries that integrates strongly with the regional supply chain, especially with China. However, the investigations to prioritize smart technologies to ensure sustainable production in emergency situations are still lacking in the case of Vietnam. This has been the inspiration and starting point for the research.

According to the literature, prioritization problems, which consider multiple factors or criteria, are wisely handled by multiple criteria decision-making (MCDM) methods [13,14]. Amongst famous MCDM approaches, the decision-making trial and evaluation laboratory method (DEMATEL) is an emerging and robust method. The DEMATEL is frequently applied in studies to determine the weight of evaluation criteria. In addition, it is a useful practical tool for identifying potential relationships between criteria in complex systems [15]. As one of the newest MCDM approaches, the combined compromise solution (CoCoSo) method has been applied in various applications and fields such as supply chain management [16], technology [17,18], transportation [19], etc. In decision-making problems, crisp scales struggle to accurately express the judgments of decision-makers because of their intrinsic complexity and ambiguity [20]. Uncertainty information is defined by a membership function by Zadeh, which marks the birth of the original fuzzy set [21]. In parallel with the development and evolution of multi-criteria decision-making methods, fuzzy sets have been studied and proposed continuously for decades [13]. Milestones in this development can be listed as type-2 fuzzy sets by Zadeh [22], intuitionistic fuzzy sets by Atanassov [23], interval type-2 fuzzy sets by Jerry et al. [24], Pythagorean fuzzy sets by Yager [25], neutrosophic fuzzy sets by Smarandache [26], hesitant fuzzy sets by Torra [27], etc. Based on the synthesis of Pythagorean fuzzy sets and neutrosophic fuzzy sets, Kutlu Gündoğdu and Kahraman introduced spherical fuzzy sets (SFSs) in 2019 [28]. Accordingly, spherical fuzzy numbers (SFNs) are defined using three parameters including membership, non-membership, and hesitancy. As a result, decision-makers are not only able to demonstrate their hesitancy, but are also provided with a larger domain of preference for judgments. Moreover, the intrinsic complexity of decision-makers is also reflected in other psychological behaviors [29]. Regret theory is one of the important bounded rational decision theories for decision-making processes by capturing the regret aversion psychological behavior of decision-makers [30].

The primary objective of the present investigation is to propose a powerful and novel MCDM approach, which must reflect both the ambiguities and psychological behaviors of decision-makers, in the problem of prioritizing smart technologies in sustainable production. Therefore, an integrated spherical fuzzy bounded rationality decision-making approach is developed and introduced in this study. The proposed approach is developed based on the advantages of DEMATEL and CoCoSo methods in the spherical fuzzy environment. Furthermore, it is enhanced by the principles of regret theory that capture the psychological behaviors of decision-makers. Then, the proposed approach is applied to prioritize smart technologies for manufacturing in Vietnam to increase the ability to respond to emergency situations. The findings of the prioritization process are the secondary research objective of this article.

The organization of this study begins with motivation, research objectives, and novelty in Section 1. In Section 2, a systematic review of related studies is conducted and discussed. The proposed method and numerical results of applying technologies in smart manufacturing are presented in Sections 3 and 4, respectively. A comparative study is presented in Section 5. Finally, conclusions are presented to close this article.

2. Literature Review

Over the decades, MCDM techniques have been applied with increasing frequency to decision-making problems in many fields as shown in Table 1. Common problems of decision-making in manufacturing include determining sustainable production strategies, evaluating innovations, and choosing smart technologies. Among them, technology selection is one of the most rigorous multi-criteria decision-making issues, especially in cases where sustainability is concerned. Kabir et al. proposed the strengths, weaknesses, opportunities, and threats (SWOT) analysis and analytic hierarchy process (AHP) integration method to support the technology selection process for the implementation of intelligent power management [31]. As a result, potential technologies have been introduced to make it easier to deploy smart power management programs. Kaa et al. introduced the MCDM model based on the AHP and logarithmic fuzzy preference programming (LFPP) to support the evaluation of photovoltaic technologies [32]. The results of this study are useful to energy policy-makers as well as those who must make decisions about which standards should be supported for photovoltaic technology. Shen et al. developed an MCDM model that integrates Delphi fuzzy methods, DEMATEL, and analytical network processes (ANPs) for the problem of technology selection related to economic and industrial prospects [33]. The results of this paper can help the top managers of companies to apply accurate and effective technologies. Büyüközkan et al. introduced a cloud computing technology selection method based on AHP, complex proportional assessment (COPRAS), multiple objective optimization on the basis of ratio analysis plus full multiplicative form (MULTIMOORA), and multi-criteria optimization and compromise solution (Višekriterijumsko Kompromisno Rangiranjein, VIKOR, in Serbian) methods [34]. Onur developed spherical fuzzy AHP and sensitivity analysis to aid in the mining technology selection and evaluation process [35].

According to previous studies, the DEMATEL method is a most advanced way to construct and examine a structural model for examining the relationship between influences among complicated criteria [15,36,37]. On another hand, the CoCoSo, a novel MCDM technique that combines straightforward additive weights with exponentially weighted product models, was created by Yazdani et al. in 2019 [38]. This is an effective method of ranking alternatives and is one of the most modern multi-criteria decision-making strategies based on compromise solutions. In recent years, MCDM integration approaches from the CoCoSo method have been introduced more and more. For spray-painting robot identification in the automotive industry, a novel combination of the CoCoSo method and SWARA method is introduced [39]. Moreover, the fuzzy extensions of the CoCoSo method are also vigorously developed by scholars. In 2021, Lahane and Ravi introduced a Pythagorean fuzzy extension of integrated AHP and CoCoSo approach for performance outcome ranking of a circular supply chain [40]. As another example, Deveci et al. proposed a hybrid q-rung fuzzy extension of the CoCoSo approach for offshore wind farm location selection problems in Norway [41]. On the other hand, prospect and regret theories are increasingly applied in the bounded rationality decision-making process [42,43]. For example, Ilbahar et al. assessed the risk of investments in renewable energy based on prospect theory and intuitive fuzzy AHP [44]. In 2022, Zhang et al. applied the spherical gray relational analysis (SF-GRA) method based on cumulative prospect theory to select suppliers of materials [45].

From the literature review, the development, application, and widespread integration of MCDM methods with each other as well as with fuzzy theories can be seen. Among them, the highlight is the rapid development of combinations from DEMATEL and CoCoSo methods. Furthermore, theories that reflect psychological behavior in decision-making such as prospect theory and regret theory are widely reinforced in MCDM approaches. Our new approach, which is presented in the following section, is motivated by these conclusions.

Table 1. Application of MCDM approaches in manufacturing.

No.	Authors	Year	MCDM Approach							Other Approach	Fuzzy Set
			AHP	ANP	DEMATEL	VIKOR	TOPSIS	CoCoSo	Others		
1	Tzeng and Huang [46]	2011		X	X	X					-
2	Shen et al. [33]	2011		X	X						Triangular fuzzy
3	Kaa et al. [32]	2014	X							LFPP	-
4	Büyüközkan et al. [34]	2018	X			X			X		Triangular fuzzy
5	Dogan [35]	2021	X								Spherical fuzzy
6	Kabir et al. [31]	2021	X							SWOT	-
7	Wang et al. [47]	2021	X				X			DEA	Triangular fuzzy
8	Le and Nhieu [12]	2022							X		Triangular fuzzy
9	Guan et al. [48]	2022	X				X				Triangular fuzzy
10	Garg et al. [49]	2022						X	X		Triangular fuzzy
11	Krstić et al. [50]	2022		X					X		Triangular fuzzy
12	Gamal et al. [51]	2022		X					X		Triangular fuzzy
13	Peng et al. [52]	2022						X			Spherical fuzzy
14	Le et al. [53]	2022	X					X		DEA	Spherical fuzzy
15	This study	2022			X			X		Regret theory	Spherical fuzzy

3. Methodology

3.1. Regret Theory in Decision-Making

For the risk decision-making problems, the decision-maker's opinions are bounded rational with their psychological behaviors such as loss aversion, risk aversion, reference dependence, regret aversion [42]. Regret theory is one of important bounded rational decision theories for decision-making processes by capturing the regret aversion psychological behavior of decision-makers [30]. The core idea of regret theory is to care not only about the utility of the chosen alternatives, but also the utility of the remaining alternatives. This is to avoid choosing alternatives that could lead to regret for decision-makers. In other words, decision-makers will feel regret if their choices yield utility that is less than the expected utility, otherwise, they feel rejoiceful. The important principles of regret theory are represented by the following definitions.

Definition 1. *Let b be a consequence of choosing alternative B, the utility value obtained by alternative B with a given decision-maker's risk aversion coefficient (λ) can be determined as:*

$$v(b) = b^{\lambda}, \quad 0 < \lambda < 1 \tag{1}$$

The smaller the risk aversion of the decision-makers, the larger the value of the risk aversion coefficient.

Definition 2. *Let b_1 and b_2 be consequences of choosing alternatives B_1 and B_2. The regret–rejoice utility of choosing alternative B_1 rather than B_2 with a given decision-maker's regret aversion coefficient (θ) is defined as:*

$$r(b_1, b_2) = 1 - e^{-\theta(v(b_1) - v(b_2))}, \quad \theta > 0 \tag{2}$$

The smaller the regret aversion of the decision-makers, the smaller the value of the regret aversion coefficient.

Definition 3. *Let $b_i(i = 1 \ldots n)$ be a consequence of choosing alternative $B_i(i = 1 \ldots I)$. The overall utility obtained by alternative B_i can be defined as:*

$$u(b_i) = v(b_i) + r(b_i, b^*) \tag{3}$$

where

$$b^* = \max_{1 \leq i \leq I} b_i \quad r(b_i, b^*) \leq 0 \tag{4}$$

3.2. Fuzzy Sets and Spherical Fuzzy Sets

To deal with ambiguity in human judgments, linguistic variables are seen as more effective descriptors than crisp numbers. To quantify linguistic terms, fuzzy theories have been introduced, developed, and widely used in the field of decision-making. Based on the synthesis of Pythagorean fuzzy sets and neutrosophic fuzzy sets, Kutlu Gündoğdu and Kahraman introduced spherical fuzzy sets (SFSs) in 2019 [28]. Accordingly, spherical fuzzy numbers (SFNs) are defined using three parameters including membership, non-membership, and hesitancy. As a result, decision-makers are not only able to demonstrate their hesitancy, but are also provided with a larger domain of preference for judgments. The definition of the SFN and its operators are presented as follows:

Definition 4. *Considering the universe of discourse T, a spherical fuzzy number $\widetilde{A}$ of T, with the degree of membership $\left(\alpha_{\widetilde{A}}\right)$, non-membership $\left(\beta_{\widetilde{A}}\right)$, and hesitancy $\left(\delta_{\widetilde{A}}\right)$, is defined as:*

$$\widetilde{A} = \left\{ \langle t, \left(\alpha_{\widetilde{A}}(t), \beta_{\widetilde{A}}(t), \delta_{\widetilde{A}}(t)\right) \middle| t \in T \right\} \tag{5}$$

where $\alpha_{\widetilde{A}} : T \to [0,1],\ \beta_{\widetilde{A}} : T \to [0,1], \delta_{\widetilde{A}} : T \to [0,\ 1]$

and

$$0 \leq \alpha^2_{\widetilde{A}}(t) + \beta^2_{\widetilde{A}}(t) + \delta^2_{\widetilde{A}}(t) \leq 1 \quad \forall t \in T \tag{6}$$

Definition 5. *Consider two SFNs $\widetilde{A} = \left(\alpha_{\widetilde{A}}, \beta_{\widetilde{A}}, \delta_{\widetilde{A}}\right)$ and $\widetilde{B} = \left(\alpha_{\widetilde{B}}, \beta_{\widetilde{B}}, \delta_{\widetilde{B}}\right)$ from the universe of discourse T_1 and T_2. Here are the basic operators [28]:*

Addition

$$\widetilde{A} \oplus \widetilde{B} = \left\{ \sqrt{\alpha^2_{\widetilde{A}} + \alpha^2_{\widetilde{B}} - \alpha^2_{\widetilde{A}}\alpha^2_{\widetilde{B}}}, \beta_{\widetilde{A}}\beta_{\widetilde{B}}, \sqrt{\left(1 - \alpha^2_{\widetilde{B}}\right)\delta^2_{\widetilde{A}} + \left(1 - \alpha^2_{\widetilde{A}}\right)\delta^2_{\widetilde{B}} - \delta^2_{\widetilde{A}}\delta^2_{\widetilde{B}}} \right\} \tag{7}$$

Multiplication

$$\widetilde{A} \otimes \widetilde{B} = \left\{ \alpha_{\widetilde{A}}\alpha_{\widetilde{B}}, \sqrt{\beta^2_{\widetilde{A}} + \beta^2_{\widetilde{B}} - \beta^2_{\widetilde{A}}\beta^2_{\widetilde{B}}}, \sqrt{\left(1 - \beta^2_{\widetilde{B}}\right)\delta^2_{\widetilde{A}} + \left(1 - \beta^2_{\widetilde{A}}\right)\delta^2_{\widetilde{B}} - \delta^2_{\widetilde{A}}\delta^2_{\widetilde{B}}} \right\} \tag{8}$$

Multiplication by a scalar $(\varepsilon > 0)$

$$\varepsilon\widetilde{A} = \left\{ \sqrt{1 - \left(1 - \alpha^2_{\widetilde{A}}\right)^{\varepsilon}}, \beta^{\varepsilon}_{\widetilde{A}}, \sqrt{\left(1 - \alpha^2_{\widetilde{A}}\right)^{\varepsilon} - \left(1 - \alpha^2_{\widetilde{A}} - \delta^2_{\widetilde{A}}\right)^{\varepsilon}} \right\} \tag{9}$$

Power of $\widetilde{A}$ $(\varepsilon > 0)$

$$\widetilde{A}^{\varepsilon} = \left\{ \alpha^{\varepsilon}_{\widetilde{A}}, \sqrt{1 - \left(1 - \beta^2_{\widetilde{A}}\right)^{\varepsilon}}, \sqrt{\left(1 - \beta^2_{\widetilde{A}}\right)^{\varepsilon} - \left(1 - \beta^2_{\widetilde{A}} - \delta^2_{\widetilde{A}}\right)^{\varepsilon}} \right\} \tag{10}$$

Definition 6. *The spherical weighted arithmetic mean (WAM) and spherical weighted geometric mean (WGM) with the weights* $w = (w_1, w_2, \ldots, w_I)$, *where* $0 \leq w_i \leq 1$ *and* $\sum_{i=1}^{I} w_i = 1$, *are calculated as [28]:*

$$\begin{aligned} &WAM_w\left(\widetilde{A}_1, \widetilde{A}_2, \ldots, \widetilde{A}_I\right) = w_1\widetilde{A}_1 + w_2\widetilde{A}_2 + \ldots + w_I\widetilde{A}_I \\ &= \left\{ \sqrt{1 - \prod_{i=1}^{I}\left(1 - \alpha^2_{\widetilde{A}_i}\right)^{w_i}}, \prod_{i=1}^{I} \beta^{w_i}_{\widetilde{A}_i}, \sqrt{\prod_{i=1}^{I}\left(1 - \alpha^2_{\widetilde{A}_i}\right)^{w_i} - \prod_{i=1}^{I}\left(1 - \alpha^2_{\widetilde{A}_i} - \delta^2_{\widetilde{A}_i}\right)^{w_i}} \right\} \end{aligned} \tag{11}$$

$$\begin{aligned} &WGM_w\left(\widetilde{A}_1, \widetilde{A}_2, \ldots, \widetilde{A}_I\right) = \widetilde{A}_1^{w_1} + \widetilde{A}_2^{w_2} + \ldots + \widetilde{A}_I^{w_I} \\ &= \left\{ \prod_{i=1}^{I} \alpha^{w_i}_{\widetilde{A}_i}, \sqrt{1 - \prod_{i=1}^{I}\left(1 - \beta^2_{\widetilde{A}_i}\right)^{w_i}}, \sqrt{\prod_{i=1}^{I}\left(1 - \beta^2_{\widetilde{A}_i}\right)^{w_i} - \prod_{i=1}^{I}\left(1 - \beta^2_{\widetilde{A}_i} - \gamma^2_{\widetilde{A}_i}\right)^{w_i}} \right\} \end{aligned} \tag{12}$$

Definition 7. *Consider two SFNs* $\widetilde{A} = \left(\alpha_{\widetilde{A}}, \beta_{\widetilde{A}}, \delta_{\widetilde{A}}\right)$ *and* $\widetilde{B} = \left(\alpha_{\widetilde{B}}, \beta_{\widetilde{B}}, \delta_{\widetilde{B}}\right)$ *from the universe of discourse* T_1 *and* T_2. *The following equations from (13) to (18) are valid with the positive value of* ε, ε_1, *and* ε_2 *[28].*

$$\widetilde{A} \oplus \widetilde{B} = \widetilde{B} \oplus \widetilde{A} \tag{13}$$

$$\widetilde{A} \otimes \widetilde{B} = \widetilde{B} \otimes \widetilde{A} \tag{14}$$

$$\varepsilon\left(\widetilde{A} \oplus \widetilde{B}\right) = \varepsilon\widetilde{A} \oplus \varepsilon\widetilde{B} \tag{15}$$

$$\varepsilon_1\widetilde{A} \oplus \varepsilon_2\widetilde{A} = (\varepsilon_1 + \varepsilon_2)\widetilde{A} \tag{16}$$

$$\left(\widetilde{A} \otimes \widetilde{B}\right)^{\varepsilon} = \widetilde{A}^{\varepsilon} \otimes \widetilde{B}^{\varepsilon} \tag{17}$$

$$\widetilde{A}^{\varepsilon_1} \otimes \widetilde{A}^{\varepsilon_2} = \widetilde{A}^{\varepsilon_1 + \varepsilon_2} \tag{18}$$

Definition 8. *The score function and accuracy function of SFSs are defined as follows for defuzzification and comparison.*

$$\begin{gathered} \widetilde{A} < \widetilde{B} \ if \ and \ only \ if \\ i.Score\left(\widetilde{A}\right) < Score\left(\widetilde{B}\right) \ or \\ ii.Score\left(\widetilde{A}\right) = Score\left(\widetilde{B}\right) \ and \ Accuracy\left(\widetilde{A}\right) < Accuracy\left(\widetilde{B}\right) \end{gathered} \tag{19}$$

where

$$Score\left(\widetilde{A}\right) = \left(\alpha_{\widetilde{A}} - \delta_{\widetilde{A}}\right)^2 + \left(\beta_{\widetilde{A}} - \delta_{\widetilde{A}}\right)^2 \tag{20}$$

$$Accuracy\left(\widetilde{A}\right) = \alpha^2_{\widetilde{A}} + \beta^2_{\widetilde{A}} + \delta^2_{\widetilde{A}} \tag{21}$$

3.3. Integrated Spherical Fuzzy Bounded Rationality Decision-Making Approach (SFBRDM)

In this section, an integrated spherical fuzzy bounded rationality decision-making approach (SFBRDM), which has been developed based on the advantages of the spherical fuzzy DEMATEL (SF DEMATEL) and regret theory-based CoCoSo methods (R-SF CoCoSo), is proposed and illustrated as Figure 1.

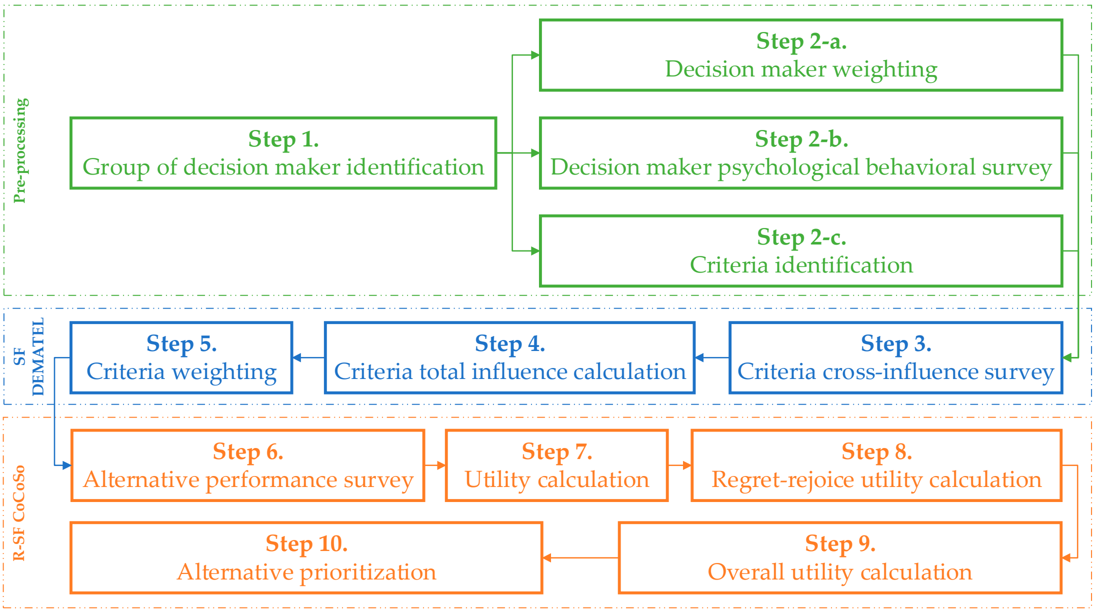

Figure 1. The proposed spherical fuzzy bounded rationality decision-making approach.

Step 1. Group of decision-maker identification

A group of decision-makers (DMs) $(k = 1 \ldots K)$, which have expertise and experience, is identified.

Step 2-a. DM weighting

The weights of the kth DMs are determined based on a given SFN $\widetilde{A}_k = \left(\alpha_{\widetilde{A}_k}, \beta_{\widetilde{A}_k}, \delta_{\widetilde{A}_k}\right)$, which represents their expertise, as Equation (22) [37,54].

$$\gamma_k = \frac{1 - \left(\left(\left(1 - \alpha^2_{\widetilde{A}_k}\right) + \beta^2_{\widetilde{A}_k} + \delta^2_{\widetilde{A}_k}\right)/3\right)^{\frac{1}{2}}}{\sum_{k=1}^{K} 1 - \left(\left(\left(1 - \alpha^2_{\widetilde{A}_k}\right) + \beta^2_{\widetilde{A}_k} + \delta^2_{\widetilde{A}_k}\right)/3\right)^{\frac{1}{2}}} \tag{22}$$

where $\sum_{k=1}^{K} \gamma_k = 1$ and $0 \leq \alpha^2_{\widetilde{A}_k} + \beta^2_{\widetilde{A}_k} + \delta^2_{\widetilde{A}_k} \leq 1$.

Step 2-b. DMs' psychological behavior survey

The risk aversion coefficient (λ_k) and the regret aversion coefficient (θ_k) of DMs are surveyed with $0 < \lambda_k < 1$ and $\theta_k > 0$. These coefficients are aggregated according to Equations (23) and (24).

$$\lambda = \frac{1}{K} \sum_{k=1}^{K} \lambda_k \tag{23}$$

$$\theta = \frac{1}{K} \sum_{k=1}^{K} \theta_k \tag{24}$$

Step 2-c. Criteria identification

The evaluation criteria $(j = 1 \ldots J)$ are determined according to the recommendations of DMs and references.

Step 3. Criteria cross-influence survey

Each DM provides pairwise comparisons of influence among the criteria in the form of linguistic terms. The linguistic terms are transformed into SFNs according to the scale shown in Table 2. As a result, direct influence matrices are formed of the criteria from each DM's point of view. The SF direct influence evaluation matrix of the kth decision-maker is shown by $\widetilde{X}^k = \left[\widetilde{x}^k_{jl}\right]_{JxJ} = \left[\left(\alpha_{\widetilde{x}^k_{jl}}, \beta_{\widetilde{x}^k_{jl}}, \delta_{\widetilde{x}^k_{jl}}\right)\right]_{JxJ}$. By using the spherical weighted arithmetic mean as described in Equation (11), the SF aggregated direct influence matrix is constructed as Equations (25) and (26).

$$\widetilde{X} = \left[\widetilde{x}_{jl}\right]_{JxJ} \tag{25}$$

where

$$\widetilde{x}_{jl} = WAM_{\gamma_k}\left(\widetilde{x}^1_{jl}, \widetilde{x}^2_{jl}, \ldots, \widetilde{x}^k_{jl}, \ldots, \widetilde{x}^K_{jl}\right) = \gamma_1\widetilde{x}^1_{jl} + \gamma_2\widetilde{x}^2_{jl} + \cdots + \gamma_k\widetilde{x}^k_{jl} + \cdots + \gamma_K\widetilde{x}^K_{jl} \tag{26}$$

Table 2. SF DEMETAL linguistic scale [55].

Degree of Influence	Spherical Fuzzy Number (α,β,δ)
Insignificant	(0.00, 0.30, 0.15)
Low	(0.35, 0.25, 0.25)
Medium	(0.60, 0.20, 0.35)
High	(0.85, 0.15, 0.45)

Step 4. Criteria total influence calculation

The SF aggregated direct influence matrix is divided into three submatrices corresponding to membership, non-membership, and hesitancy for normalization. These matrices are represented as Equation (27). According to Equations (28), (29), (30), the normalized submatrices are defined. After that, the total influence submatrices are calculated with the identity matrix (IM) according to Equations (31), (32), (33). By concatenating total influence submatrices, the SF total influence matrix is constructed as shown in Equation (34).

$$X^\alpha = \left[\alpha_{\widetilde{X}_{jl}}\right]_{JxJ}, X^\beta = \left[\beta_{\widetilde{X}_{jl}}\right]_{JxJ}, \ X^\delta = \left[\delta_{\widetilde{X}_{jl}}\right]_{JxJ} \tag{27}$$

$$Y^\alpha = s^\alpha \times X^\alpha, \text{where } s^\alpha = min\left(\frac{1}{\max\limits_j \sum_{l=1}^J \alpha_{\widetilde{X}_{jl}}}, \frac{1}{\max\limits_l \sum_{j=1}^J \alpha_{\widetilde{X}_{jl}}}\right) \tag{28}$$

$$Y^\beta = s^\beta \times X^\beta, \text{where } s^\beta = min\left(\frac{1}{\max\limits_j \sum_{l=1}^J \beta_{\widetilde{X}_{jl}}}, \frac{1}{\max\limits_l \sum_{j=1}^J \beta_{\widetilde{X}_{jl}}}\right) \tag{29}$$

$$Y^\delta = s^\gamma \times X^\delta, \text{where } s^\gamma = min\left(\frac{1}{\max\limits_j \sum_{l=1}^J \delta_{\widetilde{X}_{jl}}}, \frac{1}{\max\limits_l \sum_{j=1}^J \delta_{\widetilde{X}_{jl}}}\right) \tag{30}$$

$$Z^\alpha = Y^\alpha + Y^{\alpha'} = Y^\alpha(IM - Y^\alpha)^{-1} \tag{31}$$

$$Z^\beta = Y^\beta + Y^{\beta'} = Y^\alpha\left(IM - Y^\beta\right)^{-1} \tag{32}$$

$$Z^\delta = Y^\delta + Y^{\delta'} = Y^\alpha\left(IM - Y^\delta\right)^{-1} \tag{33}$$

$$\widetilde{Z} = \left[\widetilde{z}_{jl}\right]_{JxJ} \tag{34}$$

Step 5. Criteria weighting

To determine the weight of the criteria, the SF total influence matrix is defuzzied according to Equation (20). As a result, the total influence matrix is established and presented as Equation (35). Based on the total influence matrix, the weights of the criteria (w_j) are determined according to Equations (36) and (37).

$$Z = \left[z_{jl}\right]_{JxJ} \tag{35}$$

$$z_j^{row} = \sum_{l=1}^{J} c_{jl};\ z_j^{column} = \sum_{l=1}^{J} c_{lj} \tag{36}$$

$$w_j = \frac{c_j^{row} + c_j^{column}}{\sum_{j=1}^{J}\left(c_j^{row} + c_j^{column}\right)} \tag{37}$$

Step 6. Alternative performance survey

The DMs provide performance evaluations of alternatives $(i = 1 \ldots I)$ according to the criteria in the form of linguistic terms. The SF decision matrices were established by transforming to SFNs according to Table 3. The SF decision matrix of the kth decision-maker is shown by $\widetilde{S}^k = \left[\widetilde{s}_{ij}^k\right]_{IxJ} = \left[\left(\alpha_{\widetilde{s}_{ij}^k}, \beta_{\widetilde{s}_{ij}^k}, \delta_{\widetilde{s}_{ij}^k}\right)\right]_{IxJ}$. Then, the spherical weighted arithmetic mean is applied to aggregate and construct the SF aggregated decision matrix as shown in Equations (38) and (39).

$$\widetilde{S} = \left[\widetilde{s}_{ij}\right]_{IxJ} \tag{38}$$

where

$$\widetilde{s}_{ij} = WAM_{\gamma_k}\left(\widetilde{s}_{ij}^1, \widetilde{s}_{ij}^2, \ldots, \widetilde{s}_{ij}^k, \ldots, \widetilde{s}_{ij}^K\right) = \gamma_1\widetilde{s}_{ij}^1 + \gamma_2\widetilde{s}_{ij}^2 + \cdots + \gamma_k\widetilde{s}_{ij}^k + \cdots + \gamma_K\widetilde{s}_{ij}^K \tag{39}$$

Table 3. R-SF CoCoSo linguistic scale [12].

Linguistic Term	Spherical Fuzzy Number (α,β,δ)	Linguistic Term	Spherical Fuzzy Number (α,β,δ)
Absolutely Low	(0.1, 0.9, 0.1)	Slightly High	(0.6, 0.4, 0.4)
Very Low	(0.2, 0.8, 0.2)	High	(0.7, 0.3, 0.3)
Low	(0.3, 0.7, 0.3)	Very High	(0.8, 0.2, 0.2)
Slightly Low	(0.4, 0.6, 0.4)	Absolutely High	(0.9, 0.1, 0.1)
Neutral	(0.5, 0.5, 0.5)		

Step 7. Alternative utility calculation

The weighted arithmetic sequence $\left(\widetilde{WA}_{ij}\right)$ and the weighted geometric sequence $\left(\widetilde{WG}_{ij}\right)$ of alternatives are determined based on the criteria weights (w_j) according to Equations (9) and (10) and shown in Equations (40) and (41). After that, the score function as shown in Equation (20) is used to defuzzy the weighted sequences. As the results, the defuzzied weighted arithmetic sequence and the weighted geometric sequence are constructed as shown in Equations (42) and (43).

$$\widetilde{WA}_{ij} = \left[\widetilde{wa}_{ij}\right]_{IxJ}\ where\ \widetilde{wa}_{ij} = w_j\widetilde{s}_{ij} \tag{40}$$

$$\widetilde{WG}_{ij} = \left[\widetilde{wg}_{ij}\right]_{IxJ}\ where\ \widetilde{wg}_{ij} = \left(\widetilde{s}_{ij}\right)^{w_j} \tag{41}$$

$$WA_{ij} = \left[wa_{ij}\right]_{IxJ}\ where\ \ wa_{ij} = Score\left(\widetilde{wa}_{ij}\right) \tag{42}$$

$$WG_{ij} = \left[wg_{ij}\right]_{IxJ}\ where\ \ wg_{ij} = Score\left(\widetilde{wg}_{ij}\right) \tag{43}$$

According to regret theory, the utility of sequences is determined based on the aggregated risk aversion coefficient (λ) as Equations (44) and (45). Then, the vector of ideal points (V^*) is defined as Equations (46) and (47).

$$V^{WA} = \left[v_{ij}^{WA}\right]_{IxJ} \ where \ v_{ij}^{WA} = \left(wa_{ij}\right)^{\lambda} \quad (44)$$

$$V^{WG} = \left[v_{ij}^{WG}\right]_{IxJ} \ where \ v_{ij}^{WG} = \left(wg_{ij}\right)^{\lambda} \quad (45)$$

$$V^{WA*} = \left[v_{j}^{WA*}\right]_{J} \ where \ v_{j}^{WA*} = \max_{1 \le i \le I}\left(v_{ij}^{WA}\right) \quad (46)$$

$$V^{WG*} = \left[v_{j}^{WG*}\right]_{J} \ where \ v_{j}^{WG*} = \max_{1 \le i \le I}\left(v_{ij}^{WG}\right) \quad (47)$$

Step 8. Alternative regret–rejoice utility calculation

Additionally, the regret–rejoice utility of sequences is determined based on the aggregated regret aversion coefficient (θ) as shown in Equations (48) and (49):

$$R^{WA} = \left[r_{ij}^{WA}\right]_{IxJ} \ where \ r_{ij}^{WA} = 1 - e^{-\theta\left(v_{ij}^{WA} - v_{j}^{WA*}\right)} \quad (48)$$

$$R^{WG} = \left[r_{ij}^{WG}\right]_{IxJ} \ where \ r_{ij}^{WG} = 1 - e^{-\theta\left(v_{ij}^{WG} - v_{j}^{WG*}\right)} \quad (49)$$

Step 9. Alternative overall utility determination

According to regret theory, the overall utility of sequences is calculated as represented in Equations (50) and (51). After that, the sum value of overall utility is calculated as Equations (52) and (53).

$$U^{WA} = \left[u_{ij}^{WA}\right]_{IxJ} \ where \ u_{ij}^{WA} = v_{ij}^{WA} + r_{ij}^{WA} \quad (50)$$

$$U^{WG} = \left[u_{ij}^{WG}\right]_{IxJ} \ where \ u_{ij}^{WG} = v_{ij}^{WG} + r_{ij}^{WG} \quad (51)$$

$$SU^{WA} = \left[su_{i}^{WA}\right]_{I} \ where \ su_{i}^{WA} = \sum_{j=1}^{J} u_{ij}^{WA} \quad (52)$$

$$SU^{WG} = \left[su_{i}^{WG}\right]_{I} \ where \ su_{i}^{WG} = \sum_{j=1}^{J} u_{ij}^{WG} \quad (53)$$

Step 10. Alternative prioritization

Based on the sum value of overall utility, the additive normalized importance (ψ_i^a) and the relative importance (ψ_i^b) of alternatives are defined as Equations (54) and (55), respectively. Meanwhile, the trade-off importance (ψ_i^c) of the alternatives is determined as Equation (56) with the flexibility and stability coefficient $(0 < \omega < 1)$. Finally, the final score (ψ_i) of alternatives is calculated according to Equation (57). The higher value of ψ_i, the better the alternative.

$$\psi_i^a = \frac{su_i^{WA} + su_i^{WG}}{\sum_{i=1}^{I}\left(su_i^{WA} + su_i^{WG}\right)} \quad (54)$$

$$\psi_i^b = \frac{su_i^{WA}}{\min\limits_{1 \le i \le I}\left(su_i^{WA}\right)} + \frac{su_i^{WG}}{\min\limits_{1 \le i \le I}\left(su_i^{WG}\right)} \quad (55)$$

$$\psi_i^c = \frac{\omega su_i^{WA} + (1-\omega) su_i^{WG}}{\omega \max\limits_{1 \le i \le I}\left(su_i^{WA}\right) + (1-\omega)\max\limits_{1 \le i \le I}\left(su_i^{WG}\right)} \quad (56)$$

$$\psi_i = \frac{\left(\psi_i^a + \psi_i^b + \psi_i^c\right)}{3} + \sqrt[3]{\psi_i^a \times \psi_i^b \times \psi_i^c} \tag{57}$$

4. Case Study

In this section, the proposed approach is applied to prioritize smart technologies in production systems in Vietnam to increase the ability to respond to emergency situations. To ensure production in unexpected conditions, the core value of smart technologies is to free the dependence on human labor. Therefore, in this study, seven smart technologies, which support the three objectives as illustrated in Figure 2, are prioritized.

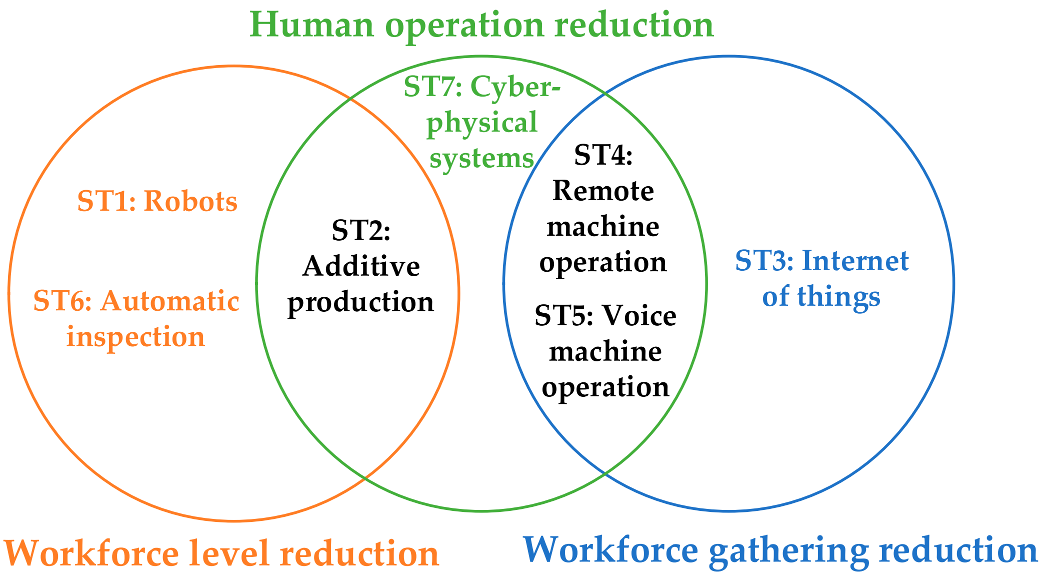

Figure 2. Smart technologies and objectives in sustainable manufacturing.

In the 1st step, ten experts in different manufacturing sectors in Vietnam were identified as DMs. Their qualifications, experience, and fields of production are shown in Table A1 in the Appendix A. In the 2nd step, the authors provide judgments about the expertise of DMs to determine their weights. By applying Equation (22), DMs' weights are calculated as shown in Figure 3. Experts are scored in order to increase the accuracy of their judgments because the expertise of the experts is different. Therefore, the authors of this study performed linguistic assessments of experts based on their expertise such as qualifications, years of experience, manufacture fields, etc. In addition, DMs provided their risk and regret aversion coefficients. The aggregated risk and regret aversion coefficients were calculated according to Equations (23) and (24) as shown in Figure 4. According to DMs, criteria to evaluate the performance of smart technologies in production include costs, flexibility, productivity, agility, reliability, quality, energy consumption (Ener. Cons.), profitability, complexity, maturity.

In the 3rd step, the linguistic pairwise comparisons of influence among the criteria are provided by DMs. Based on those comparisons, the SF aggregated direct influence evaluation matrix is constructed as shown in Table A2.

According to Equations (27)–(34), the SF total influence matrices are defined as discussed in the 4th step and represented in Table A3. By applying Equation (20) to defuzzy the SF total influence matrix, the criteria are weighted according to Equations (35)–(37). The criteria weighting results are presented in Figure 5. From these results, it is clear that reliability, local maturity, and costs are the major concerns for manufacturers in Vietnam when implementing smart technologies in their production systems. In contrast, according to decision-makers, mobility was identified as having the lowest weight in smart technology selection.

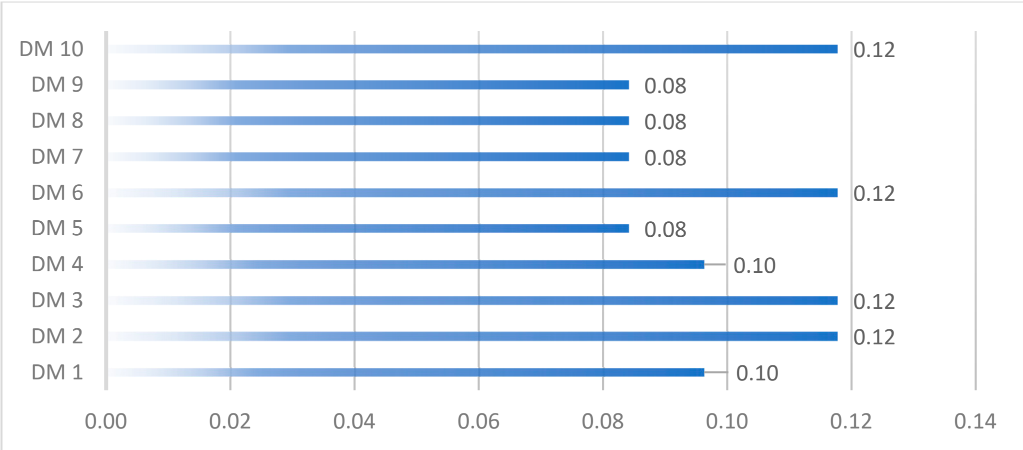

Figure 3. Decision-makers' weighting results.

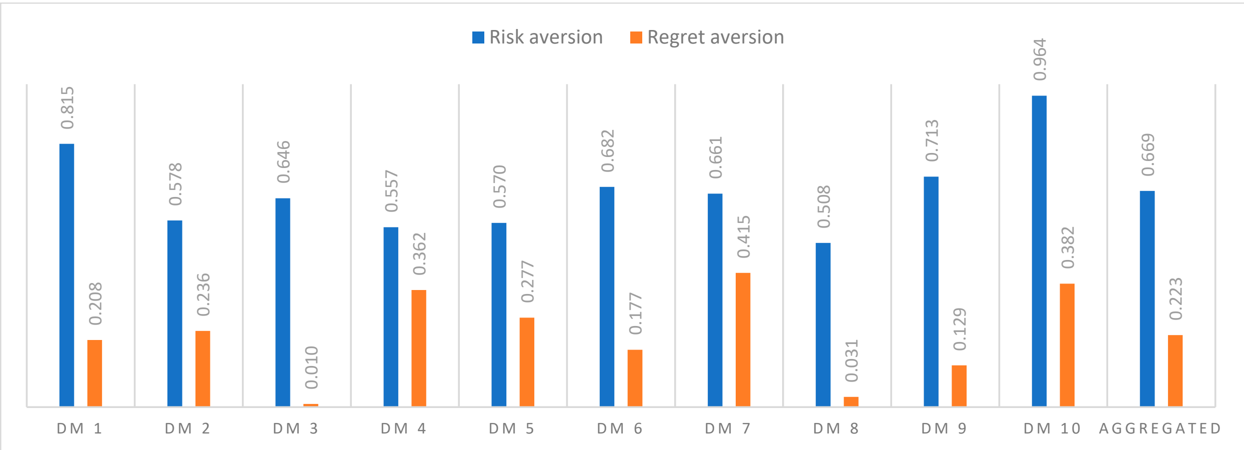

Figure 4. Psychological behavior coefficients of decision-makers.

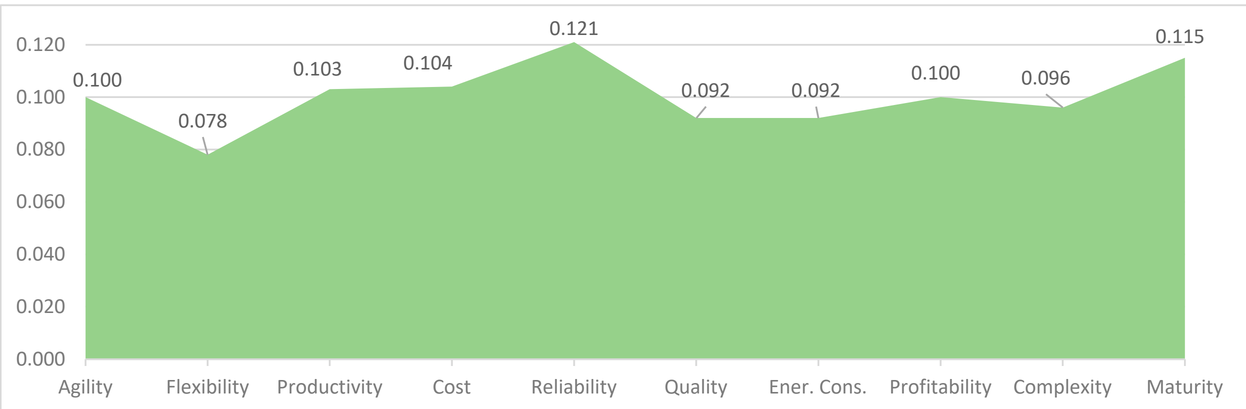

Figure 5. Criteria weighting results.

In the 6th step, DMs provide the linguistic evaluations about the performance of smart technologies according to criteria. The respective linguistic evaluations and SFNs are presented in Table 3. The evaluation process considers all criteria as benefit criteria. In other words, for all criteria, the greater the value of SFNs, the better the effect of smart technology. According to Equations (38) and (39), the SF aggregated decision matrix is defined as shown in Table A4. In the 7th step, the weighted arithmetic sequence $\left(\widetilde{WA}_{ij}\right)$ and the weighted geometric sequence $\left(\widetilde{WG}_{ij}\right)$ of technologies are determined according to Equations (40) and (41). Then, the sequences are defuzzied according to Equations (42) and (43) as shown in Tables A5 and A6.

Applying regret theory, the utility, regret–rejoice utility, and overall utility matrices are constructed with the aggregated risk aversion coefficient $(\lambda = 0.669)$ and regret aversion coefficient $(\theta = 0.223)$ according to Equations (44)–(51). In the common case, those coefficients are suggested to be $\lambda = 0.88$ and $\theta = 0.3$ as validated in experiments [56]. Those matrices are presented as Tables A7–A12 in Appendix A.

Finally, the final score (ψ_i) of smart technologies is determined based on their additive normalized importance (ψ_i^a), relative importance (ψ_i^b), and the trade-off importance (ψ_i^c) according to Equations (54)–(57). The final results of the R-SF CoCoSo method with the flexibility and stability coefficient $(\omega = 0.5)$ are shown in Table 4.

Table 4. The R-SF CoCoSo results with $\omega = 0.5$.

Technology	The Additive Normalized Importance (ψ_i^a)	The Relative Importance (ψ_i^b)	The Trade-Off Importance with $\omega = 0.5$ (ψ_i^c)	The Final Score (ψ_i)	Rank
Robots	0.144	2.075	0.954	1.716	3
Additive production	0.142	2.050	0.937	1.691	5
Internet of Things	0.143	2.055	0.944	1.698	4
Remote machine operation	0.144	2.080	0.951	1.717	2
Voice machine operation	0.141	2.032	0.941	1.684	6
Automatic inspection	0.145	2.093	0.996	1.750	1
Cyber-physical systems	0.141	2.033	0.922	1.673	7

In the final step, the value of flexibility and stability coefficients is changed to analyze the sensitivity of this factor to the prioritization result. The results of this analysis are summarized in Figure 6. As seen in Figure 6, there are three priority groups in the deployment of smart technologies for production systems in Vietnam. The high-priority groups include automatic inspection, remote machine operation, and robots. The maturity of these technologies is said to be in line with the level of scientific and technical development in developing countries. Therefore, their feasibility, ease of deployment, and estimated cost make them more suitable for manufacturers in Vietnam. The additive production and Internet of Things belong to the second group, which has medium priority for deployment in Vietnam. The low-priority group includes voice machine operation and cyber-physical systems because of their certain strangeness to production systems in developing countries.

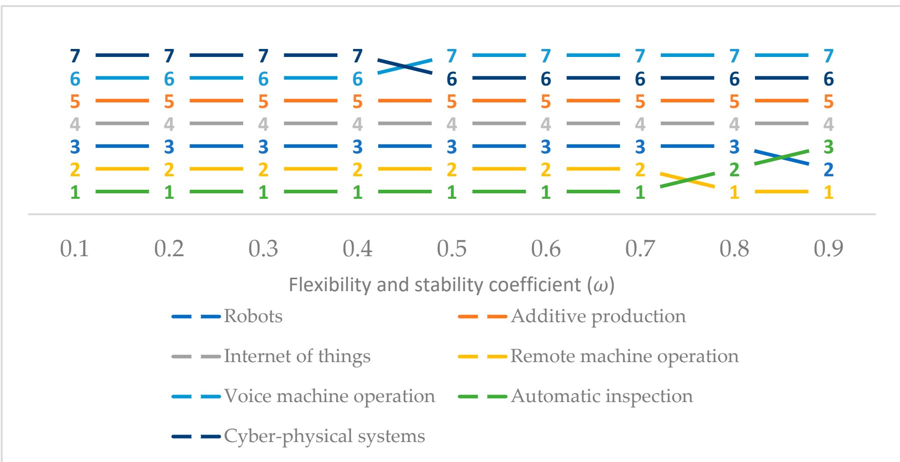

Figure 6. Stability coefficient sensitivity analysis results.

5. Comparative Study

In this section, the values of the flexibility and stability coefficients of the three methods, R-SF CoCoSo, SF TOPSIS, and SF EDAS, are given for comparison. The results of this comparison are summarized in Table 5. As shown in Table 5, additive production, Internet of Things, and voice machine operation are the smart technologies with unchanged results in the rankings for all three methods. The next groups are robots and remote machine operation, and these two technologies have similar results in the rankings, with slight differences. However, automatic inspection and cyber-physical systems are very different, almost opposite in rankings. Automatic inspection technology ranked 7th when applying the SF TOPSIS method, but ranked first when applying the other two methods, R-SF CoCoSo and SF EDAS. For cyber-physical systems technology, when applying the SF TOPSIS method, it is ranked second, but when applying the other two methods, it ranks last. In general, through the table analysis of the comparison ranking results, we can see that the application of the R-SF CoCoSo method is quite similar in terms of results to the SF EDAS method. However, the R-SF CoCoSo method applied in the case of this paper is more prominent in its novelty.

Table 5. The comparison ranking results.

Smart Technology	R-SF CoCoSo	SF TOPSIS	SF EDAS
Robots	3	1	2
Additive production	5	5	5
Internet of Things	4	4	4
Remote machine operation	2	3	3
Voice machine operation	6	6	6
Automatic inspection	1	7	1
Cyber-physical systems	7	2	7

6. Conclusions

The delays and disruptions during the pandemic have awakened interest in the sustainability and resilience of production systems to emergencies. In that context, the deployment of smart technologies has emerged as an almost mandatory development orientation to ensure the stability of manufacturing. The core value of smart technologies is to reduce the dependence on human labor in production systems. Thereby, the negative impacts caused by emergency situations are mitigated. However, the implementation of smart technologies in a specific production system that already exists requires a high degree of suitability. Motivated by this fact, this study proposes an integrated spherical fuzzy bounded rationality decision-making approach.

The remarkable and key contribution of this study is the novel proposed SFBRDM approach which is a composite of the SF DEMATEL and R-SF CoCoSo methods. It reflects both the ambiguities and psychological behaviors of decision-makers in prioritization problems. As the secondary contribution, this study's findings show that reliability, costs, and maturity are the most important criteria for choosing smart technology which is suitable for an existing production system in Vietnam. The results also suggest that automatic inspection, remote machine operation, and robots are the most suitable smart technologies to stabilize and sustain production in Vietnam for emergency situations. In future studies, manufacturers can apply this proposed approach to identify the smart technology which is best suited to their existing system, based on their criteria and psychological characteristics.

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Appendix A

Table A1. Decision-makers' qualifications, experience, and manufacture field.

DM	Qualification	Year of Experience	Manufacture Fields	SFN Expertise Judgment
DM 1	Master	13	Textile	(0.60, 0.20, 0.35)
DM 2	Ph.D.	9	High-tech product	(0.85, 0.15, 0.45)
DM 3	Ph.D.	11	High-tech product	(0.85, 0.15, 0.45)
DM 4	Master	9	Textile	(0.60, 0.20, 0.35)
DM 5	Master	6	Dairy product	(0.35, 0.25, 0.25)
DM 6	Ph.D.	15	Renewable energy device	(0.85, 0.15, 0.45)
DM 7	Master	5	High-tech product	(0.35, 0.25, 0.25)
DM 8	Master	8	Automotive industry	(0.35, 0.25, 0.25)
DM 9	Ph.D.	7	Automotive industry	(0.35, 0.25, 0.25)
DM 10	Master	14	High-tech product	(0.85, 0.15, 0.45)

Table A2. The SF direct influence matrix.

Criteria	Agility	Flexibility	Productivity	Cost	Reliability
Agility	(0.00, 0.30, 0.20)	(0.63, 0.22, 0.48)	(0.46, 0.25, 0.37)	(0.75, 0.18, 0.48)	(0.60, 0.21, 0.44)
Flexibility	(0.63, 0.21, 0.47)	(0.00, 0.30, 0.20)	(0.66, 0.20, 0.46)	(0.61, 0.22, 0.47)	(0.53, 0.23, 0.40)
Productivity	(0.65, 0.21, 0.49)	(0.61, 0.22, 0.47)	(0.00, 0.30, 0.20)	(0.51, 0.23, 0.38)	(0.59, 0.22, 0.44)
Cost	(0.66, 0.20, 0.46)	(0.73, 0.19, 0.50)	(0.68, 0.21, 0.50)	(0.00, 0.30, 0.20)	(0.59, 0.23, 0.48)
Reliability	(0.61, 0.22, 0.46)	(0.63, 0.21, 0.46)	(0.69, 0.20, 0.49)	(0.53, 0.23, 0.40)	(0.00, 0.30, 0.20)
Quality	(0.46, 0.25, 0.37)	(0.61, 0.22, 0.47)	(0.64, 0.21, 0.46)	(0.47, 0.25, 0.38)	(0.61, 0.22, 0.46)
Ener. Cons.	(0.71, 0.20, 0.50)	(0.60, 0.22, 0.46)	(0.58, 0.22, 0.41)	(0.58, 0.22, 0.43)	(0.65, 0.21, 0.48)
Profitability	(0.67, 0.20, 0.47)	(0.68, 0.20, 0.48)	(0.49, 0.24, 0.39)	(0.56, 0.23, 0.43)	(0.56, 0.22, 0.39)
Complexity	(0.64, 0.22, 0.48)	(0.63, 0.21, 0.47)	(0.69, 0.20, 0.49)	(0.59, 0.22, 0.44)	(0.49, 0.24, 0.40)
Maturity	(0.58, 0.22, 0.43)	(0.61, 0.22, 0.47)	(0.48, 0.24, 0.39)	(0.48, 0.23, 0.31)	(0.70, 0.19, 0.47)
Criteria	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Agility	(0.72, 0.19, 0.48)	(0.47, 0.25, 0.42)	(0.23, 0.28, 0.22)	(0.49, 0.24, 0.38)	(0.49, 0.23, 0.37)
Flexibility	(0.61, 0.22, 0.48)	(0.46, 0.25, 0.37)	(0.64, 0.22, 0.49)	(0.66, 0.20, 0.47)	(0.34, 0.26, 0.26)
Productivity	(0.61, 0.22, 0.44)	(0.76, 0.18, 0.49)	(0.58, 0.22, 0.44)	(0.62, 0.21, 0.46)	(0.50, 0.24, 0.39)
Cost	(0.71, 0.19, 0.48)	(0.68, 0.20, 0.49)	(0.66, 0.21, 0.49)	(0.63, 0.21, 0.47)	(0.73, 0.19, 0.49)
Reliability	(0.58, 0.22, 0.44)	(0.60, 0.21, 0.41)	(0.74, 0.18, 0.48)	(0.58, 0.21, 0.39)	(0.72, 0.19, 0.48)
Quality	(0.00, 0.30, 0.20)	(0.57, 0.22, 0.43)	(0.67, 0.21, 0.48)	(0.54, 0.23, 0.39)	(0.58, 0.22, 0.45)
Ener. Cons.	(0.60, 0.22, 0.45)	(0.00, 0.30, 0.20)	(0.57, 0.24, 0.48)	(0.46, 0.24, 0.37)	(0.57, 0.24, 0.46)
Profitability	(0.49, 0.24, 0.40)	(0.70, 0.20, 0.49)	(0.00, 0.30, 0.20)	(0.46, 0.24, 0.37)	(0.48, 0.24, 0.39)
Complexity	(0.59, 0.23, 0.46)	(0.60, 0.22, 0.44)	(0.66, 0.21, 0.47)	(0.00, 0.30, 0.20)	(0.58, 0.22, 0.43)
Maturity	(0.68, 0.20, 0.49)	(0.56, 0.23, 0.43)	(0.38, 0.25, 0.28)	(0.52, 0.24, 0.43)	(0.00, 0.30, 0.20)

Table A3. The SF total influence matrix.

Criteria	Agility	Flexibility	Productivity	Cost	Reliability
Agility	(0.60, 0.43, 0.46)	(0.71, 0.39, 0.53)	(0.65, 0.41, 0.48)	(0.66, 0.39, 0.48)	(0.66, 0.40, 0.49)
Flexibility	(0.72, 0.39, 0.53)	(0.64, 0.42, 0.50)	(0.70, 0.39, 0.52)	(0.67, 0.40, 0.50)	(0.68, 0.40, 0.51)
Productivity	(0.75, 0.38, 0.55)	(0.76, 0.38, 0.56)	(0.63, 0.42, 0.48)	(0.68, 0.40, 0.49)	(0.72, 0.39, 0.53)
Cost	(0.83, 0.36, 0.58)	(0.85, 0.35, 0.60)	(0.80, 0.37, 0.57)	(0.67, 0.41, 0.49)	(0.78, 0.38, 0.57)
Reliability	(0.78, 0.37, 0.54)	(0.79, 0.37, 0.56)	(0.76, 0.37, 0.53)	(0.71, 0.39, 0.50)	(0.65, 0.41, 0.48)
Quality	(0.70, 0.40, 0.52)	(0.73, 0.39, 0.55)	(0.70, 0.39, 0.52)	(0.65, 0.41, 0.48)	(0.69, 0.40, 0.52)
Ener. Cons.	(0.75, 0.38, 0.55)	(0.75, 0.39, 0.56)	(0.71, 0.40, 0.52)	(0.68, 0.40, 0.50)	(0.71, 0.39, 0.54)
Profitability	(0.72, 0.38, 0.53)	(0.74, 0.38, 0.54)	(0.67, 0.40, 0.50)	(0.65, 0.41, 0.48)	(0.68, 0.40, 0.50)
Complexity	(0.76, 0.38, 0.56)	(0.77, 0.38, 0.57)	(0.74, 0.38, 0.54)	(0.70, 0.40, 0.51)	(0.71, 0.40, 0.53)
Maturity	(0.70, 0.39, 0.51)	(0.72, 0.39, 0.53)	(0.66, 0.41, 0.49)	(0.63, 0.41, 0.45)	(0.69, 0.39, 0.50)
Criteria	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Agility	(0.70, 0.39, 0.51)	(0.65, 0.41, 0.49)	(0.59, 0.43, 0.44)	(0.61, 0.42, 0.46)	(0.61, 0.41, 0.46)
Flexibility	(0.72, 0.39, 0.53)	(0.68, 0.41, 0.50)	(0.68, 0.40, 0.51)	(0.66, 0.40, 0.50)	(0.62, 0.42, 0.45)
Productivity	(0.75, 0.38, 0.54)	(0.75, 0.37, 0.54)	(0.69, 0.40, 0.51)	(0.68, 0.39, 0.51)	(0.67, 0.40, 0.49)
Cost	(0.83, 0.36, 0.58)	(0.81, 0.36, 0.57)	(0.77, 0.37, 0.56)	(0.75, 0.38, 0.54)	(0.76, 0.37, 0.54)
Reliability	(0.77, 0.37, 0.54)	(0.75, 0.37, 0.52)	(0.74, 0.37, 0.52)	(0.70, 0.38, 0.49)	(0.72, 0.37, 0.51)
Quality	(0.63, 0.42, 0.48)	(0.69, 0.40, 0.51)	(0.68, 0.40, 0.51)	(0.65, 0.41, 0.48)	(0.65, 0.40, 0.49)
Ener. Cons.	(0.73, 0.39, 0.55)	(0.62, 0.42, 0.48)	(0.68, 0.41, 0.52)	(0.65, 0.41, 0.49)	(0.67, 0.41, 0.51)
Profitability	(0.70, 0.40, 0.51)	(0.70, 0.39, 0.52)	(0.57, 0.43, 0.45)	(0.63, 0.41, 0.47)	(0.63, 0.41, 0.47)
Complexity	(0.75, 0.39, 0.55)	(0.73, 0.39, 0.53)	(0.71, 0.39, 0.53)	(0.59, 0.43, 0.46)	(0.68, 0.40, 0.51)
Maturity	(0.71, 0.39, 0.52)	(0.67, 0.40, 0.50)	(0.62, 0.42, 0.45)	(0.63, 0.42, 0.47)	(0.55, 0.44, 0.43)

Table A4. The SF decision matrix.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	(0.39, 0.65, 0.32)	(0.68, 0.33, 0.3)	(0.66, 0.4, 0.24)	(0.53, 0.52, 0.29)	(0.67, 0.36, 0.3)
Additive production	(0.51, 0.54, 0.32)	(0.48, 0.57, 0.34)	(0.66, 0.38, 0.28)	(0.57, 0.47, 0.32)	(0.59, 0.45, 0.31)
Internet of Things	(0.55, 0.51, 0.31)	(0.54, 0.49, 0.36)	(0.68, 0.34, 0.31)	(0.51, 0.53, 0.33)	(0.57, 0.48, 0.26)
Remote machine operation	(0.69, 0.35, 0.25)	(0.64, 0.38, 0.31)	(0.58, 0.47, 0.32)	(0.56, 0.49, 0.27)	(0.69, 0.36, 0.23)
Voice machine operation	(0.61, 0.43, 0.31)	(0.65, 0.38, 0.31)	(0.66, 0.39, 0.25)	(0.55, 0.5, 0.33)	(0.54, 0.48, 0.41)
Automatic inspection	(0.73, 0.29, 0.24)	(0.72, 0.32, 0.24)	(0.75, 0.28, 0.21)	(0.65, 0.38, 0.31)	(0.69, 0.33, 0.29)
Cyber-physical systems	(0.63, 0.4, 0.28)	(0.69, 0.34, 0.31)	(0.46, 0.58, 0.36)	(0.57, 0.47, 0.33)	(0.53, 0.51, 0.33)
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	(0.67, 0.36, 0.24)	(0.53, 0.52, 0.33)	(0.72, 0.31, 0.23)	(0.49, 0.55, 0.34)	(0.71, 0.31, 0.28)
Additive production	(0.63, 0.41, 0.29)	(0.67, 0.36, 0.27)	(0.52, 0.54, 0.27)	(0.52, 0.52, 0.34)	(0.7, 0.32, 0.31)
Internet of Things	(0.77, 0.24, 0.23)	(0.54, 0.49, 0.33)	(0.61, 0.42, 0.31)	(0.54, 0.5, 0.3)	(0.67, 0.37, 0.25)
Remote machine operation	(0.56, 0.5, 0.24)	(0.59, 0.43, 0.34)	(0.6, 0.44, 0.32)	(0.51, 0.56, 0.27)	(0.51, 0.52, 0.35)
Voice machine operation	(0.64, 0.39, 0.27)	(0.54, 0.52, 0.31)	(0.56, 0.47, 0.35)	(0.68, 0.34, 0.3)	(0.75, 0.27, 0.26)
Automatic inspection	(0.79, 0.22, 0.19)	(0.63, 0.4, 0.32)	(0.67, 0.35, 0.27)	(0.7, 0.33, 0.27)	(0.66, 0.37, 0.29)
Cyber-physical systems	(0.63, 0.4, 0.24)	(0.69, 0.33, 0.28)	(0.57, 0.45, 0.36)	(0.34, 0.69, 0.3)	(0.56, 0.48, 0.33)

Table A5. The defuzzied weighted arithmetic sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.718	0.654	0.669	0.682	0.568
Additive production	0.679	0.713	0.632	0.644	0.603
Internet of Things	0.668	0.679	0.582	0.656	0.658
Remote machine operation	0.644	0.667	0.639	0.684	0.628
Voice machine operation	0.637	0.664	0.656	0.649	0.549
Automatic inspection	0.626	0.690	0.637	0.610	0.559
Cyber-physical systems	0.650	0.644	0.658	0.634	0.621
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.677	0.680	0.645	0.675	0.569
Additive production	0.659	0.651	0.710	0.663	0.550
Internet of Things	0.623	0.666	0.639	0.683	0.625
Remote machine operation	0.735	0.636	0.636	0.725	0.622
Voice machine operation	0.665	0.690	0.626	0.611	0.566
Automatic inspection	0.651	0.636	0.631	0.631	0.593
Cyber-physical systems	0.694	0.636	0.610	0.750	0.616

Table A6. The defuzzied weighted geometric sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.615	0.776	0.764	0.689	0.704
Additive production	0.666	0.681	0.739	0.682	0.666
Internet of Things	0.683	0.699	0.727	0.647	0.692
Remote machine operation	0.773	0.758	0.685	0.709	0.761
Voice machine operation	0.709	0.756	0.757	0.667	0.577
Automatic inspection	0.791	0.817	0.808	0.717	0.717
Cyber-physical systems	0.739	0.771	0.606	0.676	0.627
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.785	0.684	0.793	0.654	0.742
Additive production	0.742	0.767	0.704	0.663	0.719
Internet of Things	0.817	0.685	0.710	0.697	0.744
Remote machine operation	0.754	0.699	0.699	0.707	0.614
Voice machine operation	0.755	0.697	0.665	0.744	0.767
Automatic inspection	0.847	0.722	0.754	0.771	0.714
Cyber-physical systems	0.773	0.768	0.665	0.613	0.651

Table A7. The utility matrix of weighted arithmetic sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.801	0.753	0.764	0.774	0.685
Additive production	0.772	0.798	0.736	0.745	0.713
Internet of Things	0.763	0.771	0.696	0.754	0.756
Remote machine operation	0.745	0.762	0.741	0.776	0.732
Voice machine operation	0.740	0.760	0.754	0.749	0.670
Automatic inspection	0.731	0.780	0.740	0.718	0.678
Cyber-physical systems	0.749	0.745	0.756	0.737	0.727
Ideal	0.801	0.798	0.764	0.776	0.756
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.770	0.773	0.745	0.769	0.686
Additive production	0.756	0.751	0.795	0.759	0.670
Internet of Things	0.728	0.762	0.741	0.775	0.730
Remote machine operation	0.814	0.739	0.739	0.806	0.728
Voice machine operation	0.761	0.780	0.731	0.719	0.684
Automatic inspection	0.750	0.739	0.735	0.735	0.705
Cyber-physical systems	0.783	0.739	0.718	0.825	0.723
Ideal	0.814	0.780	0.795	0.825	0.730

Table A8. The utility matrix of weighted geometric sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.722	0.844	0.835	0.779	0.791
Additive production	0.762	0.773	0.817	0.774	0.762
Internet of Things	0.775	0.787	0.808	0.748	0.782
Remote machine operation	0.842	0.831	0.776	0.795	0.833
Voice machine operation	0.794	0.829	0.830	0.763	0.692
Automatic inspection	0.854	0.874	0.867	0.800	0.800
Cyber-physical systems	0.816	0.840	0.715	0.769	0.731
Ideal	0.854	0.874	0.867	0.800	0.833
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.851	0.776	0.856	0.753	0.819
Additive production	0.819	0.837	0.791	0.759	0.802
Internet of Things	0.873	0.776	0.795	0.785	0.821
Remote machine operation	0.828	0.787	0.787	0.793	0.722
Voice machine operation	0.829	0.785	0.761	0.821	0.838
Automatic inspection	0.895	0.804	0.828	0.840	0.798
Cyber-physical systems	0.841	0.838	0.761	0.720	0.750
Ideal	0.895	0.838	0.856	0.840	0.838

Table A9. The regret–rejoice utility matrix of weighted arithmetic sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.000	−0.010	0.000	0.000	−0.016
Additive production	−0.007	0.000	−0.006	−0.007	−0.010
Internet of Things	−0.009	−0.006	−0.015	−0.005	0.000
Remote machine operation	−0.013	−0.008	−0.005	0.000	−0.005
Voice machine operation	−0.014	−0.008	−0.002	−0.006	−0.019
Automatic inspection	−0.016	−0.004	−0.005	−0.013	−0.018
Cyber-physical systems	−0.012	−0.012	−0.002	−0.009	−0.006
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	−0.010	−0.002	−0.011	−0.013	−0.010
Additive production	−0.013	−0.007	0.000	−0.015	−0.013
Internet of Things	−0.019	−0.004	−0.012	−0.011	0.000
Remote machine operation	0.000	−0.009	−0.013	−0.004	0.000
Voice machine operation	−0.012	0.000	−0.014	−0.024	−0.010
Automatic inspection	−0.014	−0.009	−0.014	−0.020	−0.006
Cyber-physical systems	−0.007	−0.009	−0.017	0.000	−0.001

Table A10. The regret–rejoice utility matrix of weighted geometric sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	−0.03	−0.01	−0.01	0.00	−0.01
Additive production	−0.02	−0.02	−0.01	−0.01	−0.02
Internet of Things	−0.02	−0.02	−0.01	−0.01	−0.01
Remote machine operation	0.00	−0.01	−0.02	0.00	0.00
Voice machine operation	−0.01	−0.01	−0.01	−0.01	−0.03
Automatic inspection	0.00	0.00	0.00	0.00	−0.01
Cyber-physical systems	−0.01	−0.01	−0.03	−0.01	−0.02
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	−0.01	−0.01	0.00	−0.02	0.00
Additive production	−0.02	0.00	−0.01	−0.02	−0.01
Internet of Things	0.00	−0.01	−0.01	−0.01	0.00
Remote machine operation	−0.01	−0.01	−0.02	−0.01	−0.03
Voice machine operation	−0.01	−0.01	−0.02	0.00	0.00
Automatic inspection	0.00	−0.01	−0.01	0.00	−0.01
Cyber-physical systems	−0.01	0.00	−0.02	−0.03	−0.02

Table A11. The overall utility matrix of weighted arithmetic sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.8012	0.7427	0.7637	0.7735	0.6686
Additive production	0.7651	0.7976	0.7296	0.7376	0.7031
Internet of Things	0.7546	0.7656	0.6812	0.7494	0.7559
Remote machine operation	0.7325	0.7543	0.7361	0.7756	0.7271
Voice machine operation	0.7259	0.7516	0.7523	0.7425	0.6501
Automatic inspection	0.7150	0.7765	0.7344	0.7051	0.6599
Cyber-physical systems	0.7379	0.7332	0.7537	0.7284	0.7204
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.7603	0.7709	0.7343	0.7563	0.6759
Additive production	0.7433	0.7441	0.7950	0.7445	0.6565
Internet of Things	0.7093	0.7580	0.7284	0.7636	0.7300
Remote machine operation	0.8138	0.7298	0.7259	0.8022	0.7275
Voice machine operation	0.7490	0.7801	0.7165	0.6955	0.6731
Automatic inspection	0.7361	0.7298	0.7210	0.7144	0.6989
Cyber-physical systems	0.7767	0.7294	0.7009	0.8249	0.7219

Table A12. The overall utility matrix of weighted geometric sequence.

Technology	Agility	Flexibility	Productivity	Cost	Reliability
Robots	0.6919	0.8376	0.8281	0.7748	0.7811
Additive production	0.7409	0.7506	0.8056	0.7686	0.7461
Internet of Things	0.7567	0.7675	0.7941	0.7357	0.7700
Remote machine operation	0.8391	0.8211	0.7555	0.7936	0.8329
Voice machine operation	0.7805	0.8192	0.8213	0.7543	0.6606
Automatic inspection	0.8544	0.8737	0.8671	0.8000	0.7927
Cyber-physical systems	0.8080	0.8323	0.6809	0.7623	0.7086
Technology	Quality	Ener. Cons.	Profitability	Complexity	Maturity
Robots	0.8406	0.7615	0.8561	0.7332	0.8406
Additive production	0.8019	0.8371	0.7760	0.7413	0.8019
Internet of Things	0.8684	0.7620	0.7812	0.7730	0.8684
Remote machine operation	0.8129	0.7752	0.7716	0.7823	0.8129
Voice machine operation	0.8141	0.7733	0.7394	0.8163	0.8141
Automatic inspection	0.8946	0.7962	0.8213	0.8401	0.8946
Cyber-physical systems	0.8295	0.8381	0.7392	0.6934	0.8295

References

1. Farid, A.M. Measures of reconfigurability and its key characteristics in intelligent manufacturing systems. *J. Intell. Manuf.* **2017**, *28*, 353–369. [CrossRef]
2. Hill, T.; Hill, A. *Operations Strategy: Design, Implementation and Delivery*; Bloomsbury Publishing: London, UK, 2017.
3. Säfsten, K.; Winroth, M. Analysis of the congruence between manufacturing strategy and production system in SMME. *Comput. Ind.* **2002**, *49*, 91–106. [CrossRef]
4. Leung, M.K.W. Challenges for Primary Care in the 'New Normal' Era. *Hong Kong Pract.* **2021**, *43*, 1–2.
5. Wan, S. Taiwan Earthquake Will Affect TSMC Fab More Than Expected. eTeknix. 2015. Available online: https://www.eteknix.com/taiwan-earthquake-will-affect-tsmc-fab-more-than-expected/ (accessed on 25 September 2022).
6. Coughlin, T. Thailand Floods will Impact Hard Disk Drive Components. Forbes. 2011. Available online: https://www.forbes.com/sites/tomcoughlin/2011/10/17/thailand-floods-will-impact-hard-disk-drive-components/?sh=33a388cf71d6 (accessed on 25 September 2022).
7. Qin, T.; Du, R.; Kusiak, A.; Tao, H.; Zhong, Y. Designing a resilient production system with reconfigurable machines and movable buffers. *Int. J. Prod. Res.* **2022**, *60*, 5277–5292. [CrossRef]
8. Kumar, A.; Luthra, S.; Mangla, S.K.; Kazançoğlu, Y. COVID-19 impact on sustainable production and operations management. *Sustain. Oper. Comput.* **2020**, *1*, 1–7. [CrossRef]
9. Queiroz, M.M.; Ivanov, D.; Dolgui, A.; Fosso Wamba, S. Impacts of epidemic outbreaks on supply chains: Mapping a research agenda amid the COVID-19 pandemic through a structured literature review. *Ann. Oper. Res.* **2022**, *319*, 1159–1196. [CrossRef]

10. Owida, A.; Galal, N.M.; Elrafie, A. Decision-making framework for a resilient sustainable production system during COVID-19: An evidence-based research. *Comput. Ind. Eng.* **2022**, *164*, 107905. [CrossRef]
11. Dohale, V.; Akarte, M.; Gunasekaran, A.; Verma, P. Exploring the role of artificial intelligence in building production resilience: Learnings from the COVID-19 pandemic. *Int. J. Prod. Res.* **2022**, 1–17. [CrossRef]
12. Le, M.-T.; Nhieu, N.-L. A Novel Multi-Criteria Assessment Approach for Post-COVID-19 Production Strategies in Vietnam Manufacturing Industry: OPA–Fuzzy EDAS Model. *Sustainability* **2022**, *14*, 4732. [CrossRef]
13. Djenadic, S.; Tanasijevic, M.; Jovancic, P.; Ignjatovic, D.; Petrovic, D.; Bugaric, U. Risk Evaluation: Brief Review and Innovation Model Based on Fuzzy Logic and MCDM. *Mathematics* **2022**, *10*, 811. [CrossRef]
14. Shao, M.; Han, Z.; Sun, J.; Xiao, C.; Zhang, S.; Zhao, Y. A review of multi-criteria decision making applications for renewable energy site selection. *Renew. Energy* **2020**, *157*, 377–403. [CrossRef]
15. Si, S.-L.; You, X.-Y.; Liu, H.-C.; Zhang, P. DEMATEL Technique: A Systematic Review of the State-of-the-Art Literature on Methodologies and Applications. *Math. Probl. Eng.* **2018**, *2018*, 3696457. [CrossRef]
16. Ecer, F.; Pamucar, D. Sustainable supplier selection: A novel integrated fuzzy best worst method (F-BWM) and fuzzy CoCoSo with Bonferroni (CoCoSo'B) multi-criteria model. *J. Clean. Prod.* **2020**, *266*, 121981. [CrossRef]
17. Peng, X.; Zhang, X.; Luo, Z. Pythagorean fuzzy MCDM method based on CoCoSo and CRITIC with score function for 5G industry evaluation. *Artif. Intell. Rev.* **2020**, *53*, 3813–3847. [CrossRef]
18. Gupta, H.; Kumar, A.; Wasan, P. Industry 4.0, cleaner production and circular economy: An integrative framework for evaluating ethical and sustainable business performance of manufacturing organizations. *J. Clean. Prod.* **2021**, *295*, 126253. [CrossRef]
19. Deveci, M.; Pamucar, D.; Gokasar, I. Fuzzy Power Heronian function based CoCoSo method for the advantage prioritization of autonomous vehicles in real-time traffic management. *Sustain. Cities Soc.* **2021**, *69*, 102846. [CrossRef]
20. Xu, Y.-Q.; Jin, L.-S.; Chen, Z.-S.; Yager, R.R.; Špirková, J.; Kalina, M.; Borkotokey, S. Weight Vector Generation in Multi-Criteria Decision-Making with Basic Uncertain Information. *Mathematics* **2022**, *10*, 572. [CrossRef]
21. Zadeh, L.A. Fuzzy Sets. *Inf. Control* **1965**, *8*, 335–338. [CrossRef]
22. Zadeh, L.A. The concept of a linguistic variable and its application to approximate reasoning—I. *Inf. Sci.* **1975**, *8*, 199–249. [CrossRef]
23. Atanassov, K.T. Intuitionistic fuzzy sets. In *Intuitionistic Fuzzy Sets*; Springer: Cham, Switzerland, 1999; 137p.
24. Jerry, M.; Dongrui, W. Interval Type2 Fuzzy Sets. In *Perceptual Computing: Aiding People in Making Subjective Judgments*; IEEE: New York, NY, USA, 2010; pp. 35–63.
25. Yager, R.R. On the theory of bags. *Int. J. Gen. Syst.* **1986**, *13*, 23–37. [CrossRef]
26. Smarandache, F. *A Unifying Field in Logics. Neutrosophy: Neutrosophic Probability, Set and Logic*; American Research Press: Champaign, IL, USA, 1999.
27. Torra, V. Hesitant fuzzy sets. *Int. J. Intell. Syst.* **2010**, *25*, 529–539. [CrossRef]
28. Kutlu Gündoğdu, F.; Kahraman, C. Spherical fuzzy sets and spherical fuzzy TOPSIS method. *J. Intell. Fuzzy Syst.* **2019**, *36*, 337–352. [CrossRef]
29. Kahneman, D. Prospect theory: An analysis of decisions under risk. *Econometrica* **1979**, *47*, 278. [CrossRef]
30. Bell, D.E. Regret in decision making under uncertainty. *Oper. Res.* **1982**, *30*, 961–981. [CrossRef]
31. Kabir, K.H.; Aurko, S.Y.; Rahman, M.S. Smart Power Management in OIC Countries: A Critical Overview Using SWOT-AHP and Hybrid MCDM Analysis. *Energies* **2021**, *14*, 6480. [CrossRef]
32. Van de Kaa, G.; Rezaei, J.; Kamp, L.; de Winter, A. Photovoltaic technology selection: A fuzzy MCDM approach. *Renew. Sustain. Energy Rev.* **2014**, *32*, 662–670. [CrossRef]
33. Shen, Y.-C.; Lin, G.T.R.; Tzeng, G.-H. Combined DEMATEL techniques with novel MCDM for the organic light emitting diode technology selection. *Expert Syst. Appl.* **2011**, *38*, 1468–1481. [CrossRef]
34. Büyüközkan, G.; Göçer, F.; Feyzioğlu, O. Cloud computing technology selection based on interval-valued intuitionistic fuzzy MCDM methods. *Soft Comput.* **2018**, *22*, 5091–5114. [CrossRef]
35. Dogan, O. Process mining technology selection with spherical fuzzy AHP and sensitivity analysis. *Expert Syst. Appl.* **2021**, *178*, 114999. [CrossRef]
36. Pribićević, I.; Doljanica, S.; Momčilović, O.; Das, D.K.; Pamučar, D.; Stević, Ž. Novel extension of DEMATEL method by trapezoidal fuzzy numbers and D numbers for management of decision-making processes. *Mathematics* **2020**, *8*, 812. [CrossRef]
37. Le, M.-T.; Nhieu, N.-L. An Offshore Wind–Wave Energy Station Location Analysis by a Novel Behavioral Dual-Side Spherical Fuzzy Approach: The Case Study of Vietnam. *Appl. Sci.* **2022**, *12*, 5201. [CrossRef]
38. Yazdani, M.; Zarate, P.; Zavadskas, E.K.; Turskis, Z. A Combined Compromise Solution (CoCoSo) method for multi-criteria decision-making problems. *Manag. Decis.* **2019**, *57*, 2501–2519. [CrossRef]
39. Kumar, V.; Kalita, K.; Chatterjee, P.; Zavadskas, E.K.; Chakraborty, S. A SWARA-CoCoSo-based approach for spray painting robot selection. *Informatica* **2022**, *33*, 35–54. [CrossRef]
40. Lahane, S.; Kant, R. A hybrid Pythagorean fuzzy AHP–CoCoSo framework to rank the performance outcomes of circular supply chain due to adoption of its enablers. *Waste Manag.* **2021**, *130*, 48–60. [CrossRef] [PubMed]
41. Deveci, M.; Pamucar, D.; Cali, U.; Kantar, E.; Kolle, K.; Tande, J.O. A hybrid q-rung orthopair fuzzy sets based CoCoSo model for floating offshore wind farm site selection in Norway. *CSEE J. Power Energy Syst.* **2022**, *8*, 1261–1280. [CrossRef]

42. Ramos, G.M.; Daamen, W.; Hoogendoorn, S. A state-of-the-art review: Developments in utility theory, prospect theory and regret theory to investigate travellers' behaviour in situations involving travel time uncertainty. *Transp. Rev.* **2014**, *34*, 46–67. [CrossRef]
43. Wang, C.-N.; Nhieu, N.-L.; Dao, T.-H.; Huang, C.-C. Simulation-Based Optimized Weighting TODIM Decision-Making Approach for National Oil Company Global Benchmarking. *IEEE Trans. Eng. Manag.* **2022**, 1–15. [CrossRef]
44. Ilbahar, E.; Kahraman, C.; Cebi, S. Risk assessment of renewable energy investments: A modified failure mode and effect analysis based on prospect theory and intuitionistic fuzzy AHP. *Energy* **2022**, *239*, 121907. [CrossRef]
45. Zhang, H.; Wei, G.; Chen, X. SF-GRA method based on cumulative prospect theory for multiple attribute group decision making and its application to emergency supplies supplier selection. *Eng. Appl. Artif. Intell.* **2022**, *110*, 104679. [CrossRef]
46. Tzeng, G.-H.; Huang, C.-Y. Combined DEMATEL technique with hybrid MCDM methods for creating the aspired intelligent global manufacturing & logistics systems. *Ann. Oper. Res.* **2012**, *197*, 159–190.
47. Wang, C.-N.; Pham, T.-D.T.; Nhieu, N.-L. Multi-Layer Fuzzy Sustainable Decision Approach for Outsourcing Manufacturer Selection in Apparel and Textile Supply Chain. *Axioms* **2021**, *10*, 262. [CrossRef]
48. Guan, X.; Zhao, J. A Two-Step Fuzzy MCDM method for implementation of sustainable precision manufacturing: Evidence from China. *Sustainability* **2022**, *14*, 8085. [CrossRef]
49. Garg, C.P.; Görçün, Ö.F.; Kundu, P.; Küçükönder, H. An integrated fuzzy MCDM approach based on Bonferroni functions for selection and evaluation of industrial robots for the automobile manufacturing industry. *Expert Syst. Appl.* **2023**, *213*, 118863. [CrossRef]
50. Krstić, M.; Agnusdei, G.P.; Miglietta, P.P.; Tadić, S. Evaluation of the smart reverse logistics development scenarios using a novel MCDM model. *Clean. Environ. Syst.* **2022**, *7*, 100099. [CrossRef]
51. Gamal, A.; Abdel-Basset, M.; Chakrabortty, R.K. Intelligent model for contemporary supply chain barriers in manufacturing sectors under the impact of the COVID-19 pandemic. *Expert Syst. Appl.* **2022**, *205*, 117711. [CrossRef] [PubMed]
52. Peng, X.; Li, W. Spherical fuzzy decision making method based on combined compromise solution for IIoT industry evaluation. *Artif. Intell. Rev.* **2022**, *55*, 1857–1886. [CrossRef]
53. Le, M.-T.; Nhieu, N.-L.; Pham, T.-D.T. Direct-Use Geothermal Energy Location Multi-Criteria Planning for On-Site Energy Security in Emergencies: A Case Study of Malaysia. *Sustainability* **2022**, *14*, 15132. [CrossRef]
54. Liu, F.; Aiwu, G.; Lukovac, V.; Vukic, M. A multicriteria model for the selection of the transport service provider: A single valued neutrosophic DEMATEL multicriteria model. *Decis. Mak. Appl. Manag. Eng.* **2018**, *1*, 121–130. [CrossRef]
55. Gül, S. Spherical fuzzy extension of DEMATEL (SF-DEMATEL). *Int. J. Intell. Syst.* **2020**, *35*, 1329–1353. [CrossRef]
56. Tversky, A.; Kahneman, D. Advances in prospect theory: Cumulative representation of uncertainty. *J. Risk Uncertain.* **1992**, *5*, 297–323. [CrossRef]