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A Hybrid Group Decision Approach Based on MARCOS and Regret Theory for Pharmaceutical Enterprises Assessment under a Single-Valued Neutrosophic Scenario

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Abstract: Evaluating pharmaceutical enterprises with sustainable and high-quality development ability (SHQDA) can not only provide strategies for the pharmaceutical management department in formulating enterprise development plans, but also provide suggestions and guidance for enterprises to enhance their core competitiveness. Nevertheless, the prior research possesses several deficiencies in coping with the assessment of enterprises with SHQDA under uncertain environments to predict the psychological behavior of the evaluator and the correlation among the evaluation criteria. To conquer the aforementioned defects, we propose an integrated framework for rating pharmaceutical enterprises that incorporates regret theory, measurement alternatives and ranking based on the compromise solution (MARCOS) and Heronian mean operating within a single-value neutrosophic set (SVNS) environment. First, the single-valued neutrosophic number (SVNN) is employed to portray the assessment information of experts. Then, a novel single-valued neutrosophic score function is presented to enhance the rationality of the SVNN comparison. Next, a combined criteria weight model is constructed by synthesizing the best and worst method (BWM) and criteria importance through intercriteria correlation (CRITIC) approach to attain more reasonable and credible weight information. Furthermore, the integrated assessment framework combining regret theory-MARCOS method and Heronian mean operator is put forward to assess and select the enterprises with SHQDA under a single-valued neutrosophic setting. Ultimately, an empirical concerning the pharmaceutical enterprises assessment is presented within SVNS to illustrate the usefulness and effectiveness of the presented SVNS regret theory-MARCOS method. Thereafter, the sensitivity analysis and comparison analysis are implemented to provide evidence for the rationality and superiority of the proposed method.

Keywords: SVNS; multi criteria group decision-making; regret theory; MARCOS method; SHQDA

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1. Introduction

With the deepening and development of global economic integration, the world economy has developed rapidly. However, rapid economic development has also brought a series of challenges to environmental protection, ecological governance and social stability. At the same time of rapid economic development, maintaining a beautiful environment and ecological balance is an important guarantee for the development of the green economy. Therefore, it is of great significance to evaluate enterprises from the perspective of SHQDA to improve the quality of economic development [1]. Because the evaluation process involves evaluation criteria of different dimensions and experts and scholars in different fields, the evaluation of enterprises with SHQDA can be regarded as a multi criteria group decision-making (MCGDM) problem. Although scholars put forward some models to solve such problems, the above results rarely consider the factors such as expert preference and the uncertainty and incompleteness of decision environment. Therefore, it is necessary to establish an evaluation model under fuzzy uncertainty environment to provide scientific and reasonable decision support for evaluation experts.

In the analysis of practical decision problems, it is difficult for experts to meet the requirements of experts in dealing with complex and uncertain decision-making problems by expressing the preferences of experts through accurate values. Limited by the objective complexity of decision-making problems and the limitations of decision makers' subjective understanding, a new mathematical tool called fuzzy set [2] is propounded to utilize membership degree to represent uncertain information. Because of the limitation that fuzzy set only uses membership function to describe fuzzy information, the intuitionistic fuzzy set (IFS) [3] theory is developed to more reasonably represent uncertain information by adding non membership and hesitation functions on the basis of fuzzy set. At present, the research on intuitionistic fuzziness has achieved fruitful results and has been widely used in the fields [4–8]. Although IFSs have been deeply studied and solved many uncertain decision and evaluation problems, they cannot represent indeterminate and inconsistent information. In order to conquer this defect, Smarandache [9] originated a novel uncertain model called neutrosophic set (NS) from the perspective of philosophy to describe people's judgment of actual information. NS is made up of the truth-membership, indeterminacy-membership and falsity-membership functions and their ranges are all $[0^-, 1^+]$. Although NS further popularizes fuzzy set and IFS, it is difficult to be directly applied to realistic problems because of the rang of the membership-functions. Therefore, Wang et al. [10] firstly developed the single-valued neutrosophic (SVN) set to further enrich the applications of neutrosophic theory in practical issues. Owing to its superiority for depicting uncertain information, the investigations on SVNS receive an increasing attention in basic theory construction and practical application extension. Those research achievements can be mainly divided into the following three aspects: theories exploration [11–13], decision methodology establishment [14–16] and actual applications [17–20]. In addition, Ye [21] introduced some SVN cross-entropy to build the MCDM decision approach. Smarandache [22] and Nafei et al. [23] presented the constructed innovative MCDM decision algorithm on the basis of the novel SVN score functions. Rong et al. [24] proposed a novel MCDM approach based on some new generalized SVN archimedean copula power aggregation operators. Mishra et al. [25] propounded a SVN-WASPAS decision model based on some novel similarity measures to select the optimal sustainable biomass crop. Afterwards, Rani et al. [26] suggested the SVN-CRITIC-MULTIMOORA decision framework to choose the best food waste treatment method. Tan et al. [27] brought an integrated assessment framework through combining the game theory and grey relational analysis within SVN setting to assess the typhoon disaster. Furthermore, Pamucar et al. [28] settled the sustainable road transportation alternative fuel vehicles assessment problem by a hybrid FUCOM and neutrosophic fuzzy MARCOS approach using the Dombi operators. From the mentioned works on SVNS, research on combined weight determination and behavioral decision theory are not integrated to provide decision support for actual applications.

The most important process of MCGDM is to develop decision analysis by utilizing different decision methodologies. To date, lots of decision techniques, such as TOPSIS [29], VIKOR [30], MACONT [31] and so on, are propounded to provide decision support for coping with the realistic complex decision and evaluation problems. Recently, Stević et al. [32] originated a novel decision algorithm called the MARCOS method to select the most desirable supplier. The MARCOS method takes into consideration the ideal and anti-ideal solution and the utility function of alternatives and can obtain a more robust and credible decision utility value of alternative than other methods. In light of its superiority in handling decision issues, lots of research based on MARCOS method and uncertain tools has been completed. Fan et al. [33] suggested an innovative risk assessment model by combining the BWM method and MARCOS method under D numbers environment for enhancing the application of Failure modes and effects analysis, where the D-BWM method is introduced to figure out the subjective weight of the risk parameters. Pamucar et al. [34] constructed a comprehensive airport service quality evaluation framework based on the presented grey Step-wise Weight Assessment Ratio Analysis grey MAR-

COS method. Gong et al. [35] introduced an evaluation model through synthesizing the MARCOS method and BWM approach under interval type-2 fuzzy seeting to evaluate the renewable energy accommodation potential. Torkayesh et al. [36] propounded an integrated uncertain decision model to select the optimal landfill location for the healthcare waste system with the aid of Geographic Information System (GIS), the MARCOS method and BWM approach within grey interval information. Furthermore, considering that the uncertain and vagueness of the realistics decision problems, Ecer and Pamucar [37] offered the intuitionistic fuzzy group MARCOS algorithm to evaluate the performance of insurance companies in terms of healthcare services in the COVID-19 pandemic. Kundu et al. [38] proffered a fuzzy MCGDM model to select a appropriate magnetic resonance imaging on the basis of the MARCOS method, wherein the preference selection index is utilized to determine the importance of the assessment index. Ali [39] brought forward a q-rung orthopair fuzzy MARCOS MCGDM methodology based on a novel score function and CRITIC method to solid waste management problems. Vesković et al. [40] presented a large-scale MCGDM approach by integrating fuzzy FUCOM (full consistency method) and fuzzy MARCOS approach to choose the optimal reach stacker in a container terminal when the criteria weight is unknown for experts. Darko and Liang [41] put forward an innovative decision support model with the aid of probabilistic linguistic MARCOS and LINMAP methods to recommend satisfactory restaurants by the online reviews. The existing works enrich decision support models for experts to develop decision analysis in different fields. The more investigations under uncertain settings for solving decision problems can be studied in [42–45]. Nevertheless, those extensions of the MARCOS method ignore the psychological behavioral of decision experts in the process of practical decision analysis, which will lead to unreasonable decision outcomes. On the other hand, there is no research to combine the MARCOS method and SVNNs to build a decision model. Accordingly, it is necessary for experts to take into account this defect and further strengthen the feasibility of the MARCOS technique in dealing with decision and assessment problems.

In view of the mentioned literature analysis and discussion, we can find that the SVNS has a powerful capability to portray the uncertainty and vagueness of practical assessment information. The MARCOS decision technique can exhibit a more efficient performance in the course of the actual decision analysis. Accordingly, the motivations of this research can be listed as below:

♠ The prior score functions of SVNS possess several deficiencies in the aspect of ranking SVNNs and can produce ambiguous and inconsistent ranking results.
♠ Considering the complexity and conflict of actual decision and assessment problems, it is necessary for decision makers to predict the combination of the subjective and objective weight of criteria for analyzing the decision issues. In order to enhance the practicability of the designed method in this paper, the combined weight of criteria is employed to acquire a more exact rank of pharmaceutical enterprises.
♠ The extant extensions of MARCOS decision technique fail to consider the psychology factor of decision makers during the decision analysis procedure. Hence, it is essential to fuse the behavioral decision theory to the MARCOS algorithm to achieve more robust results.
♠ There is no research on pharmaceutical enterprises assessment with SHQDA by considering the uncertainty and ambiguity of the assessment procedure.

Based on the motivations of this research, the goals and contributions of this investigation are epitomized as below:

✓ A novel score function is brought forward and the corresponding elegant properties are taken over;
✓ A synthesize criteria weight determination method is developed based on the BWM approach and improved CRITIC method using the novel score function to ascertain a more rational weight information of criterion;
✓ An integrated assessment framework combining the regret theory-MARCOS method and Heronian mean operator is put forward on the basis of the presented score function;

- ✓ A pharmaceutical enterprises assessment problem is utilized to elucidate the practicability and robustness of the advanced approach;
- ✓ An analysis of the contrast and an examination of the parameter discussion demonstrate, respectively, the validity and stability of the suggested method.

The following is an overview of the organization of this paper. Section 2 succinctly retrospects some essential preliminaries of this research. Section 3 propounds a novel SVNS score function and explores some valuable properties of it. Section 4 builds up a hybrid SVNS regret theory-MARCOS group decision framework for the evaluating pharmaceutical enterprise with SHQDA. Section 4 employs the constructed approach to resolve the pharmaceutical enterprises evaluation problem and the sensitivity analysis and contrast analysis are implemented with the previous decision approaches. Some conclusion remarks are given in the end. A diagram of this research is displayed in Figure 1 to improve the readability of the paper.

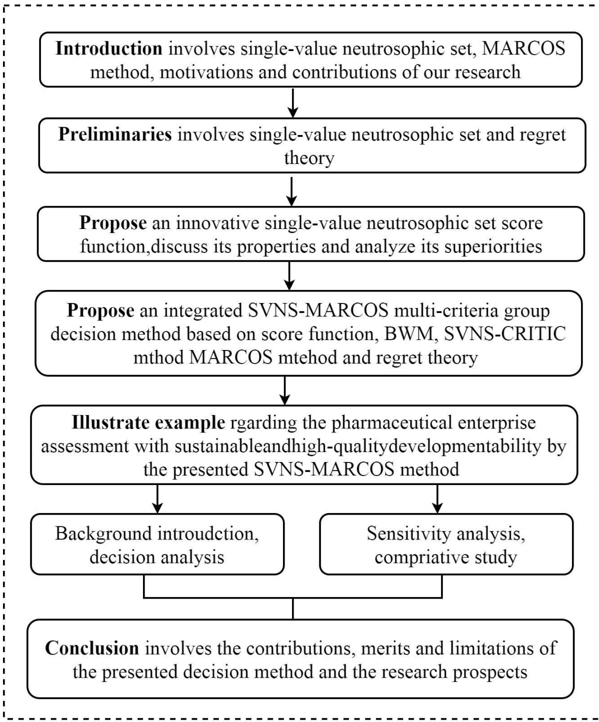

Figure 1. The diagram of this research.

2. Preliminaries

In this section, we briefly review several background knowledge of this research, including the related theories of the SVNS and regret theory.

2.1. Single Valued Neutrosophic

Definition 1 ([10])**.** *Let Y be a finite universe of discourse. A SVNS H in Y is stipulated by a truth-membership $\zeta_H(y_i)$, an indeterminacy-membership $\eta_H(y_i)$ and a falsity-membership function $\theta_H(y_i)$, wherein the functions $\zeta_H(y_i), \eta_H(y_i)$ and $\theta_H(y_i)$ are the real subset of $[0,1]$. Formally, the SVNS is defined as follows:*

$$H = \{\langle y, \zeta_H(y_i), \eta_H(y_i), \theta_H(y_i)\rangle | y_i \in Y\}, \tag{1}$$

where $\zeta_H(y_i) : Y \to [0,1]$, $\eta_H(y_i) : Y \to [0,1]$ and $\theta_H(y_i) : Y \to [0,1]$. Besides, the sum of $\zeta_H(y_i), \eta_H(y_i)$ and $\theta_H(y_i)$ is specified as $0 \leq \zeta_H(y_i) + \eta_H(y_i) + \theta_H(y_i) \leq 3$. For simplicity, the triplet $(\zeta_H, \eta_H, \theta_H)$ is called a SVNN and signified as $\ell = (\zeta_H, \eta_H, \theta_H)$.

In addition, several fundamental logical operations of SVNN are defined by [10,22], which are described as below.

Definition 2. *Consider that* $\ell_1 = (\zeta_{\ell_1}, \eta_{\ell_1}, \theta_{\ell_1})$ *and* $\ell_2 = (\zeta_{\ell_2}, \eta_{\ell_2}, \theta_{\ell_2})$ *are two SVNNs and* $\lambda > 0$*. Then, the basic operations for two SVNNs are stated as below:*

(1) *If* $\zeta_{\ell_1} \leq \zeta_{\ell_2}, \eta_{\ell_1} \geq \eta_{\ell_2}$ *and* $\theta_{\ell_1} \geq \theta_{\ell_2}$ *for all* $y \in Y$*, then* $\ell_1 \subseteq \ell_2$;
(2) $\ell_1 = \ell_2$ *iff* $\ell_1 \subseteq \ell_2$ *and* $\ell_1 \supseteq \ell_2$;
(3) $\ell_1 \cup \ell_2 = \{\langle y, \max\{\zeta_{\ell_1}, \zeta_{\ell_2}\}, \min\{\eta_{\ell_1}, \eta_{\ell_2}\}, \min\{\theta_{\ell_1}, \theta_{\ell_2}\}\rangle | y \in Y\}$;
(4) $\ell_1 \cap \ell_2 = \{\langle y, \min\{\zeta_{\ell_1}, \zeta_{\ell_2}\}, \min\{\eta_{\ell_1}, \eta_{\ell_2}\}, \max\{\theta_{\ell_1}, \theta_{\ell_2}\}\rangle | y \in Y\}$.

Definition 3 ([12])**.** *Consider that* $\ell_1 = (\zeta_{\ell_1}, \eta_{\ell_1}, \theta_{\ell_1})$ *and* $\ell_2 = (\zeta_{\ell_2}, \eta_{\ell_2}, \theta_{\ell_2})$ *are two SVNNs and* $\lambda > 0$*. Then, the Einstein operations for two SVNNs are depicted as below:*

$$(1)\ \ell_1 \oplus \ell_2 = \left(\frac{\zeta_{\ell_1}\zeta_{\ell_2}}{1+(1-\zeta_{\ell_1})(1-\zeta_{\ell_2})}, \frac{\eta_{\ell_1}+\eta_{\ell_2}}{1+\eta_{\ell_1}\eta_{\ell_2}}, \frac{\theta_{\ell_1}+\theta_{\ell_2}}{1+\theta_{\ell_1}\theta_{\ell_2}} \right);$$

$$(2)\ \ell_1 \otimes \ell_2 = \left(\frac{\zeta_{\ell_1}+\zeta_{\ell_2}}{1+\zeta_{\ell_1}\zeta_{\ell_2}}, \frac{\eta_{\ell_1}\eta_{\ell_2}}{1+(1-\eta_{\ell_1})(1-\eta_{\ell_2})}, \frac{\theta_{\ell_1}\theta_{\ell_2}}{1+(1-\theta_{\ell_1})(1-\theta_{\ell_2})} \right);$$

$$(3)\ \lambda\ell_1 = \left(\frac{(1+\zeta_{\ell_1})^\lambda - (1-\zeta_{\ell_1})^\lambda}{(1+\zeta_{\ell_1})^\lambda + (1-\zeta_{\ell_1})^\lambda}, \frac{2(\eta_{\ell_1})^\lambda}{(2-\eta_{\ell_1})^\lambda - (\eta_{\ell_1})^\lambda}, \frac{2(\theta_{\ell_1})^\lambda}{(2-\theta_{\ell_1})^\lambda - (\theta_{\ell_1})^\lambda} \right);$$

$$(4)\ \ell_1^\lambda = \left(\frac{2(\zeta_{\ell_1})^\lambda}{(2-\zeta_{\ell_1})^\lambda - (\zeta_{\ell_1})^\lambda}, \frac{(1+\eta_{\ell_1})^\lambda - (1-\eta_{\ell_1})^\lambda}{(1+\eta_{\ell_1})^\lambda + (1-\eta_{\ell_1})^\lambda}, \frac{(1+\theta_{\ell_1})^\lambda - (1-\theta_{\ell_1})^\lambda}{(1+\theta_{\ell_1})^\lambda + (1-\theta_{\ell_1})^\lambda} \right);$$

$$(5)\ (\ell_1)^c = (\theta_{\ell_1}, 1-\eta_{\ell_1}, \zeta_{\ell_1}).$$

Based on the Einstein operations of two SVNNs, the correspondingly aggregation operators are introduced as follows.

Definition 4 ([12])**.** *Assume that* $\ell_t = (\zeta_{\ell_t}, \eta_{\ell_t}, \theta_{\ell_t})$ *is a family of SVNNs. Then:*

$$SVNEWA(\ell_1, \ell_2, \cdots, \ell_n) = \left(\frac{\prod_{t=1}^{n}(1+\zeta_{\ell_t})^{\mu_t} - \prod_{t=1}^{n}(1-\zeta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(1+\zeta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(1-\zeta_{\ell_t})^{\mu_t}}, \frac{2\prod_{t=1}^{n}(\eta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(2-\eta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(\eta_{\ell_t})^{\mu_t}}, \frac{2\prod_{t=1}^{n}(\theta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(2-\theta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(\theta_{\ell_t})^{\mu_t}} \right), \quad (2)$$

$$SVNEWG(\ell_1, \ell_2, \cdots, \ell_n) = \left(\frac{2\prod_{t=1}^{n}(\zeta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(2-\eta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(\eta_{\ell_t})^{\mu_t}}, \frac{\prod_{t=1}^{n}(1+\eta_{\ell_t})^{\mu_t} - \prod_{t=1}^{n}(1-\eta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(1+\eta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(1-\eta_{\ell_t})^{\mu_t}}, \frac{\prod_{t=1}^{n}(1+\theta_{\ell_t})^{\mu_t} - \prod_{t=1}^{n}(1-\theta_{\ell_t})^{\mu_t}}{\prod_{t=1}^{n}(1+\theta_{\ell_t})^{\mu_t} + \prod_{t=1}^{n}(1-\theta_{\ell_t})^{\mu_t}}, \right), \quad (3)$$

where μ_t *is the weight of* ℓ_t *with* $\mu_t \in [0,1]$ *with* $\sum_{t=1}^{n} \mu_t = 1$*. SVNEWA and SVNEWG are the SVN Einstein weighted averaging operator and SVN Einstein weighted geometric operator, respectively.*

In order to measure the difference of two SVNNs, the single-valued neutrosophic distance measure is defined as below.

Definition 5 ([20])**.** *Given two SVNNs* $\ell_1 = (\zeta_{\ell_1}, \eta_{\ell_1}, \theta_{\ell_1})$ *and* $\ell_2 = (\zeta_{\ell_2}, \eta_{\ell_2}, \theta_{\ell_2})$ *there are two SVNNs and* $\lambda > 0$*. Then, the Euclidean distance on two SVNN* ℓ_1 *and* ℓ_2 *is defined as:*

$$D(\ell_1, \ell_2) = \sqrt{\frac{1}{3n}\sum_{i=1}^{m}\left(|\zeta_{\ell_1} - \zeta_{\ell_2}|^2 + |\eta_{\ell_1} - \eta_{\ell_2}|^2 + |\theta_{\ell_1} - \theta_{\ell_2}|^2 \right)}. \quad (4)$$

2.2. Regret Theory

As an important behavioral decision theory, the core of regret theory [46] is to compare the outcomes of the selected scheme with the possible results of other schemes, so as to measure the degree of rejoice and regret of the decision maker, and choose the outcome that the decision maker will not regret. In short, decision makers will feel regretful when the selected scheme is worse than the others, and decision makers will feel rejoice when the selected scheme is better than the others.

Definition 6 ([46])**.** *Assume the a is the outcome of choosing scheme $\mathcal{A}$, then the utility value deduced from $\mathcal{A}$ can be ascertained by the following formulation:*

$$\nu(a) = a^{\vartheta}, \tag{5}$$

where $\nu(\cdot)$ is a monotonically increasing concave utility function meeting $\nu'(\cdot) > 0$ and $\nu''(\cdot) < 0$. ϑ signifies the risk aversion of decision maker. The higher the degree of risk aversion of decision maker, the smaller the value of ϑ.

Definition 7 ([46])**.** *Suppose that a_1 and a_2 are the outcomes of scheme $\mathcal{A}_1$ and $\mathcal{A}_2$, respectively. Then, the regret-rejoice value of choosing scheme $\mathcal{A}_1$ rather than scheme $\mathcal{A}_2$ is stated as follows:*

$$\Re(a_1, a_1) = 1 - e^{-\gamma(\nu(a_1) - \nu(a_2))}, \tag{6}$$

where $\nu(a_1)$ and $\nu(a_2)$, respectively, indicate the utility values of scheme $\mathcal{A}_1$ and $\mathcal{A}_2$. $\gamma \in [0, \infty]$ signifies the risk aversion of decision maker; the greater the value of γ, the higher the degree of regret avoidance. $\Re(\cdot)$ is a monotonically increasing concave utility regret-rejoice function meeting $\Re(0) = 0$, $\Re'(\cdot) > 0$ and $\Re''(\cdot) < 0$. When $\nu(a_1) - \nu(a_2) > 0$, then the decision maker will feel rejoice to choose scheme $\mathcal{A}_1$ and abandon scheme scheme $\mathcal{A}_2$; on the contrary, they will feel regret.

It is worth noting that the risk aversion parameter ϑ and γ are, respectively, taken as $\vartheta = 0.88$ and $\gamma = 0.3$ based on the experiments analysis [47].

Definition 8 ([48])**.** *Suppose that $a_k(k = 1(1)m)$ are the outcomes of choosing scheme $\mathcal{A}_k(k = 1(1)m)$, then the decision maker's perceived utility value of scheme $\mathcal{A}_k$ can be computed by:*

$$u_k = \nu(a_k) + \Re(\nu(a_k), \nu(a^*)), \tag{7}$$

where $a^* = \max_{1 \le k \le m} \{a_k\}$ and $\Re(\nu(a_k), \nu(a^*)) \le 0$. $\Re(\nu(a_k), \nu(a^*))$ denotes the regret value when the decision maker chooses the scheme $\mathcal{A}_k$ and abandons the ideal scheme. Accordingly, the decision maker's perceived utility value of the scheme includes two parts: the utility value of the current scheme and the regret value of the current scheme compared to the ideal scheme.

3. An Innovative Single-Valued Neutrosophic Score Function

In this part, considering that the extant score function possesses some deficiencies in distinguishing two SVNNs, we propound a novel SVN score function and further probe several momentous properties of it. Then, we further validate the effectiveness and reasonability and analyze the merits of the presented score function.

3.1. Several Prior Single-Valued Neutrosophic Score Functions

The score function is a momentous conception to transform SVNN into a real number, which has been widely applied to the decision analysis field. Based on the definition of SVNS, some SVN score functions are presented for a SVNN $\ell = (\zeta_\ell, \eta_\ell, \theta_\ell)$ and displayed in Table 1.

Table 1. The prior score functions and accuracy functions.

Reference	Score Function	Accuracy Function
Smarandache [22]	$S_1 = \frac{2+\zeta_\ell-\eta_\ell-\theta_\ell}{3}$	$H_1 = \zeta_\ell - \theta_\ell$
Sahin [11]	$S_2 = \frac{1+\zeta_\ell-2\eta_\ell-\theta_\ell}{2}$	$H_2 = \zeta_\ell - 2\eta_\ell - \theta_\ell$
Garg [14]	$S_3 = \frac{1+(\zeta_\ell-2\eta_\ell-\theta_\ell)(2-\zeta_\ell-\theta_\ell)}{2}$	
Nafei et al. [23]	$S_4 = \frac{(4+\zeta_\ell-2\eta_\ell-\theta_\ell)(2-\eta_\ell)(2-\theta_\ell)}{5}$	

3.2. A New SVN Score Function

Definition 9. *Imagine a SVNN $\ell = (\zeta_\ell, \eta_\ell, \theta_\ell)$, a novel score function is defined as follows:*

$$\mathcal{S}(\ell) = \zeta_\ell - \theta_\ell + \frac{3e^{\zeta_\ell-\eta_\ell-\theta_\ell}}{4-\zeta_\ell-\eta_\ell-\theta_\ell} + 1. \tag{8}$$

Theorem 1. *For a SVNN $\ell = (\zeta_\ell, \eta_\ell, \theta_\ell)$, $\mathcal{S}(\ell)$ monotonically increases with the increase of ζ_ℓ, and monotonically decreases with the increase of η_ℓ or θ_ℓ.*

Proof. Based on the propounded score function, we compute the first partial derivative of $\mathcal{S}(\ell)$ to ζ_ℓ as below:

$$\frac{\partial \mathcal{S}(\ell)}{\partial \zeta_\ell} = 1 + \frac{3e^{\zeta_\ell-\eta_\ell-\theta_\ell}(5-\zeta_\ell-\eta_\ell-\theta_\ell)}{(4-\zeta_\ell-\eta_\ell-\theta_\ell)^2} > 0.$$

By the same manner, we can attain the the first partial derivative of $\mathcal{S}(\ell)$ to η_ℓ and θ_ℓ as follows:

$$\frac{\partial \mathcal{S}(\ell)}{\partial \eta_\ell} = \frac{-3e^{\zeta_\ell-\eta_\ell-\theta_\ell}(3-\zeta_\ell-\eta_\ell-\theta_\ell)}{(4-\zeta_\ell-\eta_\ell-\theta_\ell)^2} < 0,$$
$$\frac{\partial \mathcal{S}(\ell)}{\partial \theta_\ell} = -1 + \frac{3e^{\zeta_\ell-\eta_\ell-\theta_\ell}(-3+\zeta_\ell+\eta_\ell+\theta_\ell)}{(4-\zeta_\ell-\eta_\ell-\theta_\ell)^2} < 0.$$

Thus, the proof is achieved. □

Theorem 2. *For a SVNN $\ell = (\zeta_\ell, \eta_\ell, \theta_\ell)$, then one has:*
T1: $e^{-1} \le \mathcal{S}(\ell) \le e+2$;
T2: $\mathcal{S}(\ell) = e^{-1}$ iff $\ell = (0,0,1)$;
T3: $\mathcal{S}(\ell) = e+2$ iff $\ell = (1,0,0)$.

Proof. In view of the monotonicity of the presented score function, we can find that $\mathcal{S}(\ell)$ possesses maximum value when $\ell = (1,0,0)$, and $\mathcal{S}(\ell)$ possesses minimum value when $\ell = (0,0,1)$, namely, $\mathcal{S}_{max}(\ell) = e+2$, $\mathcal{S}_{min}(\ell) = e^{-1}$. Thus, the proof is achieved. □

In order to validate the rationality and superiority of the developed SVN score function, several numerical cases are employed to expound the reasonability of the proffered score function by means of the rank outcomes. The comparison results are displayed in Table 2.

Table 2. Comparison outcomes obtain the extant SVN score functions and the advance score function.

Reference	Case 1 $\ell_1 = (0.6, 0.3, 0.7)$ $\ell_2 = (0.3, 0.3, 0.4)$	Case 2 $\ell_1 = (0.4, 0.1, 0.5)$ $\ell_2 = (0.1, 0.1, 0.2)$	Case 3 $\ell_1 = (0.3, 0.0, 0.3)$ $\ell_2 = (0.5, 0.0, 0.5)$	Case 4 $\ell_1 = (0.7, 0.35, 0.0)$ $\ell_2 = (0.4, 0.0, 0.4)$
Smarandache [22]	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$	$\ell_1 > \ell_2$
Sahin [11]	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$
Garg [14]	$\ell_1 > \ell_2$	$\ell_1 > \ell_2$	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$
Nafei et al. [23]	$\ell_1 > \ell_2$	$\ell_1 > \ell_2$	$\ell_1 = \ell_2$	$\ell_1 = \ell_2$
Proposed SVN scorefunction $\mathcal{S}$	$\ell_1 > \ell_2$	$\ell_1 > \ell_2$	$\ell_1 < \ell_2$	$\ell_1 > \ell_2$

With the aid of Table 2, we can observe that the existing SVN score functions Smarandache [22], Sahin [11], Garg [14] and Nafei et al. [23] have some deficiencies and disadvantages in comparing the SVNNs. Nevertheless, we can easily discover that the proposed SVN score function not only validly avoid the unreasonable results obtained by by the prior SVN score functions but also attain more efficacious and credible ranking outcomes. Furthermore, some conclusions based on Table 2 can be attained as follow:

¶ For the Case 1 and Case 2, the score functions proposed by Smarandache [22] and Sahin [11] is invalid to compare the SVNNs ℓ_1 and ℓ_2; thus, we further compute the corresponding accuracy function and find that the accuracy values of ℓ_1 and ℓ_2 are still equal, namely, $H_1 = H_2 = -0.1$ for Case 1 and $H_1 = H_2 = -0.7$ for Case 1. That means the comparison rules proposed by Smarandache [22] and Sahin [11] cannot rank Case 1 and Case 2. However, the presented score function $\mathcal{S}$ can rapidly acquire the rank result of Case 1 and Case 2 by a step. Accordingly, the propose score function $\mathcal{S}$ is more universal and a shortcut to rank SVNNs.

¶ For the Case 3, we can find that the extant score function presented by Smarandache [22], Sahin [11], Garg [14] and Nafei et al. [23] are all invalid to rank ℓ_1 and ℓ_2. It is obvious that the presented score function $\mathcal{S}$ can effectively deal with this situation.

¶ For the Case 4, the presented extant score functions in Sahin [11], Garg [14] and Nafei et al. [23] are unable to settle this case. It is can be found that the rank outcome obtain by $\mathcal{S}$ is the same as the score function advanced by Smarandache [22], which further tests the validity and feasible of $\mathcal{S}$.

In view of the mentioned discussion and analysis, the propounded score function $\mathcal{S}$ is universal, reasonable and fast in ranking SVNNs compared to some extant works.

4. SVN-MARCOS Method Based on the Regret Theory

4.1. Problem Statement

We consider a pharmaceutical enterprise assessment problem with SVNNs-based assessment information, which can be viewed as a MCGDM problem. In such a situation, we specify several necessary notions of the MCGDM problem to help experts to construct the decision model mathematically. The set $\mathcal{A} = \{\mathcal{A}_1, \mathcal{A}_2, \cdots, \mathcal{A}_k, \cdots \mathcal{A}_m\}$ are a group of m pharmaceutical enterprises. The set $\mathcal{C} = \{\mathcal{C}_1, \mathcal{C}_2, \cdots, \mathcal{C}_t, \cdots \mathcal{C}_n\}$ are a group of n criteria, and the importance degree of criteria $\mathcal{C}_t$ is denoted as ω_t and $\omega_t \in [0,1]$ and $\sum_{t=1}^{n} \omega_t = 1$. The expert group is made up of Q experts $E = \{E_1, E_2, \cdots, E_q, \cdots E_Q\}$ with corresponding weight ε_q and $\varepsilon_q \in [0,1]$ and $\sum_{q=1}^{Q} \varepsilon_q = 1$. Suppose that the matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n}$ are the assessment matrices provided by expert group, where $\overline{\ell_{kt}}^q$ signifies the assessment opinion given by experts E_q for pharmaceutical enterprises $\mathcal{A}_k$ with the respect criteria $\mathcal{C}_t$. It should be pointed out that the assessment opinion $\overline{\ell_{kt}}^q$ is expressed by experts utilizing linguistic terms according to their cognition capability, after which the linguistic assessment opinions are shifted to SVNNs. As a consequence, the SVNNs based assessment matrices $\overline{F}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n}$ from experts E_q can be constructed as follows:

$$\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n} = \begin{pmatrix} \overline{\ell_{11}}^q = \left(\overline{\zeta_{11}}^q, \overline{\eta_{11}}^q, \overline{\theta_{11}}^q\right) & \overline{\ell_{12}}^q = \left(\overline{\zeta_{12}}^q, \overline{\eta_{12}}^q, \overline{\theta_{12}}^q\right) & \cdots & \overline{\ell_{1n}}^q = \left(\overline{\zeta_{1n}}^q, \overline{\eta_{1n}}^q, \overline{\theta_{1n}}^q\right) \\ \overline{\ell_{21}}^q = \left(\overline{\zeta_{21}}^q, \overline{\eta_{21}}^q, \overline{\theta_{21}}^q\right) & \overline{\ell_{22}}^q = \left(\overline{\zeta_{22}}^q, \overline{\eta_{22}}^q, \overline{\theta_{22}}^q\right) & \cdots & \overline{\ell_{2n}}^q = \left(\overline{\zeta_{2n}}^q, \overline{\eta_{2n}}^q, \overline{\theta_{2n}}^q\right) \\ \vdots & \vdots & \vdots & \vdots \\ \overline{\ell_{m1}}^q = \left(\overline{\zeta_{m1}}^q, \overline{\eta_{m1}}^q, \overline{\theta_{m1}}^q\right) & \overline{\ell_{m2}}^q = \left(\overline{\zeta_{m2}}^q, \overline{\eta_{m2}}^q, \overline{\theta_{m2}}^q\right) & \cdots & \overline{\ell_{mn}}^q = \left(\overline{\zeta_{mn}}^q, \overline{\eta_{mn}}^q, \overline{\theta_{mn}}^q\right) \end{pmatrix}.$$

4.2. Obtaining SVN Assessment Information

In order to attain the most satisfactory scheme from the group of schemes, we first construct the expert assessment committee by inviting experts and scholars from the related fields. A mapping relation listed in Table 3, from linguistic terms to SVNN, is provided for an expert assessment committee to give their preference for the identified scheme under diverse criteria. After that, the linguistic evaluation information of pharmaceutical enterprises is achieved through the cognition preference ability and knowledge background of the experts.

Table 3. Preference ratings of pharmaceutical enterprises in view of linguistic terms.

Linguistic Term	**Abbreviation**	**SVNNs**
Very Very Low	VVL	(0.00, 0.10, 0.10)
Very Low	VL	(0.10, 0.90, 0.90)
Low	L	(0.30, 0.75, 0.70)
Moderately Low	ML	(0.40, 0.65, 0.60)
Middle	M	(0.50, 0.50, 0.50)
Moderately High	MH	(0.60, 0.35, 0.40)
High	H	(0.70, 0.25, 0.30)
Very High	VH	(0.80, 0.15, 0.20)
Very Very High	VVH	(0.90, 0.10, 0.10)
Extremely High	EH	(1.00, 0.00, 0.00)

After obtain the linguistic assessment information of pharmaceutical enterprises, we further get the SVN evaluation matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n}$ through transforming the preference provided from the expert committee.

4.3. Obtaining the Fused SVN Assessment Information

In this subsection, the similarity measure-based expert weight determination algorithm and SVN Einstein weighted averaging operator are employed to acquire the aggregated SVN assessment matrix. First, the expert weight stands for the importance degree and familiarity of the expert with the decision issues, so the expert weight in the proposed method is determined by similarity-based approach objectively. The core of this weight identification technique is consider the consistency between the expert assessment matrix and the ideal matrix, namely, the higher the consistency with the ideal matrix, the expert should be given a higher weight. In such a situation, motivated by the thought of the TOPSIS method, the SVN distance measure and SVN Einstein weighted averaging operator are utilized to ascertain the importance of expert. Then, based on the weight information of the expert, the SVN Einstein weighted averaging operator is used to attain the fused SVN group assessment matrix. Lastly, the normalized SVN group assessment matrix is identified through transforming the cost criteria to benefit criteria.

First, based on the SVNS assessment matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n}$ from the expert E_q, we can compute the mean of experts assessment value for pharmaceutical enterprises $\mathcal{A}_k$ under the criteria $\mathcal{C}_t$ as below:

$$\widetilde{\widetilde{\ell_{kt}}} = \frac{1}{Q}\sum_{q=1}^{Q}\overline{\ell_{kt}}^q \tag{9}$$
$$= \left(\frac{\prod_{q=1}^{Q}\left(1+\overline{\zeta_{kt}}^q\right)^{\frac{1}{Q}} - \prod_{q=1}^{Q}\left(1-\overline{\zeta_{kt}}^q\right)^{\frac{1}{Q}}}{\prod_{q=1}^{Q}\left(1+\overline{\zeta_{kt}}^q\right)^{\frac{1}{Q}} + \prod_{q=1}^{Q}\left(1-\overline{\zeta_{kt}}^q\right)^{\frac{1}{Q}}}, \frac{2\prod_{q=1}^{Q}(\overline{\eta_{kt}}^q)^{\frac{1}{Q}}}{\prod_{q=1}^{Q}(2-\overline{\eta_{kt}}^q)^{\frac{1}{Q}} + \prod_{q=1}^{Q}(\overline{\eta_{kt}}^q)^{\frac{1}{Q}}}, \frac{2\prod_{q=1}^{Q}\left(\overline{\theta_{kt}}^q\right)^{\frac{1}{Q}}}{\prod_{q=1}^{Q}\left(2-\overline{\theta_{kt}}^q\right)^{\frac{1}{Q}} + \prod_{q=1}^{Q}\left(\overline{\theta_{kt}}^q\right)^{\frac{1}{Q}}} \right).$$

In light of the similarity measure determination method based on the distance measure, the similarity measure between $\overline{\ell_{kt}}^q$ and $\tilde{f}_{kt}$ is worked out as follows:

$$S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) = 1 - \frac{D\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)}{\sum_{q=1}^{Q} D\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)} \tag{10}$$

where $D\left(f_{kt}^q, \tilde{f}_{kt}\right)$ is the distance measure between $\overline{\ell_{kt}}^q$ and $\tilde{f}_{kt}$, which can be calculated by:

$$D\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) = \sqrt{\frac{1}{3}\left(\left|\overline{\zeta_{kt}}^q - \widetilde{\widetilde{\zeta_{kt}}}\right|^2 + \left|\overline{\eta_{kt}}^q - \widetilde{\widetilde{\eta_{kt}}}\right|^2 + \left|\overline{\theta_{kt}}^q - \widetilde{\widetilde{\theta_{kt}}}\right|^2\right)}. \tag{11}$$

Then, inspired by the TOPSIS approach, the positive and negative ideal similarity measure are, respectively, calculated by the following formulation:

$$S^+\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) = \left(g_{kt}^+\right)_{m\times n},\ g_{kt}^+ = \frac{1}{Q}\sum_{q=1}^{Q} S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right), \tag{12}$$

$$S^-\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) = \left(g_{kt}^-\right)_{m\times n},\ g_{kt}^- = \frac{1}{Q}\min_{1\le q\le Q}\left\{S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)\right\}. \tag{13}$$

The importance degree ε_q of each expert could be ascertained as follows:

$$\varepsilon_q = \frac{\sqrt{\sum_{k=1}^{m}\sum_{t=1}^{n}\left(S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) - S^-\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)\right)^2}}{\sqrt{\sum_{k=1}^{m}\sum_{t=1}^{n}\left(S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) - S^-\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)\right)^2} + \sqrt{\sum_{k=1}^{m}\sum_{t=1}^{n}\left(S\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right) - S^+\left(\overline{\ell_{kt}}^q, \widetilde{\widetilde{\ell_{kt}}}\right)\right)^2}} \tag{14}$$

Furthermore, based on the weight of experts ε_q and the expert assessment matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n}$, the aggregated assessment matrix $\overline{\ell} = \left(\overline{\ell_{kt}}\right)_{m\times n}$ can be obtained by the following formulation:

$$\overline{\ell_{kt}} = SVNEWA\left(\overline{\ell_{kt}}^1, \overline{\ell_{kt}}^2, \cdots, \overline{\ell_{kt}}^Q\right) = \varepsilon_1 f_{kt}^1 \oplus \varepsilon_2 f_{kt}^2 \oplus \oplus \varepsilon_Q f_{kt}^Q \tag{15}$$
$$= \left(\frac{\prod_{q=1}^{Q}\left(1+\overline{\zeta_{kt}}^q\right)^{\varepsilon_q} - \prod_{q=1}^{Q}\left(1-\overline{\zeta_{kt}}^q\right)^{\varepsilon_q}}{\prod_{q=1}^{Q}\left(1+\overline{\zeta_{kt}}^q\right)^{\varepsilon_q} + \prod_{q=1}^{Q}\left(1-\overline{\zeta_{kt}}^q\right)^{\varepsilon_q}}, \frac{2\prod_{q=1}^{Q}(\overline{\eta_{kt}}^q)^{\varepsilon_q}}{\prod_{q=1}^{Q}(2-\overline{\eta_{kt}}^q)^{\varepsilon_q} + \prod_{q=1}^{Q}(\overline{\eta_{kt}}^q)^{\varepsilon_q}}, \frac{2\prod_{q=1}^{Q}\left(\overline{\theta_{kt}}^q\right)^{\varepsilon_q}}{\prod_{q=1}^{Q}\left(2-\overline{\theta_{kt}}^q\right)^{\varepsilon_q} + \prod_{q=1}^{Q}\left(\overline{\theta_{kt}}^q\right)^{\varepsilon_q}} \right).$$

Ultimately, considering that different kinds of criteria will lead the irrational consequence in the same decision problem, e should normalize the decision data to a unified form. In this research, we achieve the normalized assessment matrix $\ell = (\ell_{kt})_{m\times n}$ through shifting the cost criteria into benefit criteria. It can be conducted by the following formulation:

$$\ell_{kt} = (\zeta_{kt}, \eta_{kt}, \theta_{kt}) = \begin{cases} \left(\overline{\zeta_{kt}}, \overline{\eta_{kt}}, \overline{\theta_{kt}}\right), & C_t \text{ is benefit criterion;} \\ \left(\overline{\theta_{kt}}, 1-\overline{\eta_{kt}}, \overline{\zeta_{kt}}\right), & C_t \text{ is cost criterion.} \end{cases} \tag{16}$$

4.4. The Determination of Assessment Criteria Weight

In order to ascertain the importance of criteria during in the course of decision analysis, this subsection suggests a combinative weight determination model through taking the BWM approach and CRITIC method into account, which considers the influence of subjective preference and objective information simultaneously. The detailed computation process of combinative weight is expounded as below.

Subjective weight calculation by BWM .The BWM algorithm proposed by Rezaei [49] is a famous technique to pairwise determine the subjective weight of the criteria. This subsection will utilize the BWM to ascertain the subjective weight of criteria to fully show experts' subjective preference.

Firstly, we identify the best criterion (the most important criterion) $\mathcal{C}_B$ and worst criterion (the last important criterion) $\mathcal{C}_W$ after the discussion of the expert committee.

Then, we further ascertain the preference including the the best criterion $\mathcal{C}_B$ to other criteria and other criteria to the worst criterion $\mathcal{C}_W$ based on the scale 1 to 9. The Best-to-others comparative vector is signified as $T_B = (x_{B1}, x_{B2}, \cdots, x_{Bn})$, where x_{Bt} stands for the preference of the best criteria compared to other criteria. In the same manner, other-to-Worst comparative vector is signified as $T_W = (x_{1W}, x_{2W}, \cdots, x_{nW})$, where x_{tw} stands for the preference of other criteria compared to the worst criteria. Note that $x_{BB} = x_{WW} = 1$.

Furthermore, the subjective weight of criteria $(\omega_1^{sub}, \omega_2^{sub}, \cdots, \omega_n^{sub})^T$ obtained by BWM method will meet the condition that $\omega_B^{sub}/\omega_t^{sub} = x_{Bt}$ and $\omega_t^{sub}/\omega_W^{sub} = x_{tW}$ hold for every pair of $\omega_B^{sub}/\omega_t^{sub}$ and $\omega_t^{sub}/\omega_W^{sub}$, respectively. Hence, we shall minimize the maximum absolute differences $\left|\frac{\omega_B^{sub}}{\omega_t^{sub}} - x_{Bt}\right|$ and $\left|\frac{\omega_t^{sub}}{\omega_W^{sub}} - x_{tW}\right|$ for all t, and the model can be attained as below:

$$\min \max_{1 \le t \le n} \left\{ \left| \frac{\omega_B^{sub}}{\omega_t^{sub}} - x_{Bt} \right|, \left| \frac{\omega_t^{sub}}{\omega_W^{sub}} - x_{tW} \right| \right\} \tag{17}$$
$$s.t \quad \begin{cases} \sum\limits_{t=1}^{n} \omega_t = 1 \\ \omega_t \ge 0. \end{cases}$$

Next, we shift the model in Equation (17) into a linear programming model as follows:

$$\min \xi \tag{18}$$
$$s.t \quad \begin{cases} \left| \frac{\omega_B^{sub}}{\omega_t^{sub}} - x_{Bt} \right| \le \xi \\ \left| \frac{\omega_t^{sub}}{\omega_W^{sub}} - x_{tW} \right| \le \xi \\ \sum\limits_{t=1}^{n} \omega_t = 1 \\ \omega_t \ge 0. \end{cases}$$

Finally, we can attain the subjective weight vector $(\omega_1^{sub}, \omega_2^{sub}, \cdots, \omega_n^{sub})^T$ of criteria with the help of LINGO software and the consistency coefficient ξ of the comparison. It is known that the comparison system exhibit a high level of consistency if the consistency coefficient ξ closer to zero.

Objective weight calculation by the CRITIC method. The objective weight computed based on the provided practical decision data is important for the decision analysis process. In this part, we extend the CRITIC [50] method to SVN environment on the basis of the presented score function for determining the objective weight of the criteria.

First, we identify the correlation coefficient matrix of criteria based on the score function and the normalized group assessment matrix $\ell = (\ell_{kt})_{m \times n}$. Assume that $\Gamma = \left(\delta_{tt'}\right)_{m \times n}$

denote the correlation coefficient matrix, where $\beta_{tt'}$ stands for the correlation coefficient between the tth criteria and t'th criteria:

$$\delta_{tt'} = \frac{\sum_{k=1}^{m}\left(\mathcal{S}(\ell_{kt}) - \sum_{k=1}^{m}\frac{\mathcal{S}(\ell_{kt})}{m}\right)\left(\mathcal{S}(\ell_{tt'}) - \sum_{k=1}^{m}\frac{\mathcal{S}(\ell_{tt'})}{m}\right)}{\sqrt{\sum_{k=1}^{m}\left(\mathcal{S}(\ell_{kt}) - \sum_{k=1}^{m}\frac{\mathcal{S}(\ell_{kt})}{m}\right)^2}\sqrt{\sum_{k=1}^{m}\left(\mathcal{S}(\ell_{tt'}) - \sum_{k=1}^{m}\frac{\mathcal{S}(\ell_{tt'})}{m}\right)^2}}. \tag{19}$$

Then, we calculate the standard deviations of criteria with the following equation:

$$\sigma_t = \sqrt{\frac{\sum_{k=1}^{m}\left(\mathcal{S}(\ell_{kt}) - \frac{\sum_{k=1}^{m}\mathcal{S}(\ell_{kt})}{m}\right)^2}{m}}\ t = 1, 2, \cdots, n. \tag{20}$$

Next, we estimate the quantity of information of every criteria C_t via the following equation

$$\varsigma_t = \sigma_t \sum_{t'=1}^{n}\left(1 - \delta_{tt'}\right). \tag{21}$$

Finally, we compute the objective weight of each criterion with the following equation:

$$\omega_t^{obj} = \frac{\varsigma_t}{\sum_{j=1}^{n}\varsigma_t}. \tag{22}$$

Ascertain the combined weight of the criteria. Based on the BWM approach and SVN-CRITIC method, the synthesize weight ω_t of criterion C_t can be identified with the following formula:

$$\omega_t = \frac{\left(\omega_t^{obj}\right)^{\alpha}\left(\omega_t^{sub}\right)^{\beta}}{\sum_{t=1}^{n}\left(\omega_t^{obj}\right)^{\alpha}\left(\omega_t^{sub}\right)^{\beta}},\ t = 1, 2, \cdots, n. \tag{23}$$

in which α and β are the preference parameter of the subjective weight and objective weight, respectively, and satisfy $\alpha + \beta = 1$. From the formulation, we can easily obtain that if $\alpha = 1$, ω_t is degenerated as objective weight ω_t^{sub}, and if $\beta = 1$, ω_t is degenerated as objective weight ω_t^{obj}. Decision experts can freely adjust the parameter according to their knowledge experience and actual application condition.

4.5. Ranking by Utilizing the Proposed SVN Regret Theory-MARCOS Approach

This subsection will put forward a novel extension of the MARCOS approach based on the regret theory under an SVN environment to consider the psychological behavioral of expert during the process of decision analysis. In addition, considering that the influence between the perceived utility values of pharmaceutical enterprises under different criteria, the Heronian mean operator is utilized to characterize the interrelationship between perceived utility values under two different criteria of the same pharmaceutical enterprise.

(1) Deduce the utility matrix of the pharmaceutical enterprise. The utility matrix $V = (\nu_{kt})_{m\times n}$ of pharmaceutical enterprise can be calculated based on the presented SVN score function:

$$\nu_{kt} = \left(\mathcal{S}(\ell_{kt})\right)^{\vartheta}, \tag{24}$$

where $\mathcal{S}(\ell_{kt})$ is the score value of group assessment information and can be computed by $\mathcal{S}(\ell_{kt}) = \zeta_{kt} - \theta_{kt} + \frac{3e^{\zeta_{kt}-\eta_{kt}-\theta_{kt}}}{4-\zeta_{kt}-\eta_{kt}-\theta_{kt}}$, ν_{kt} is the utility value of pharmaceutical enterprise under diverse criteria, and $\vartheta(\vartheta \in [0,1])$ signifies the risk aversion of expert and is determined by the risk preference of expert.

(2) Determine the positive ideal point vector. Considering the principle of determining the ideal pharmaceutical enterprise, the positive ideal point vector denoted as $\{\ell_1^*, \ell_2^*, \cdots, \ell_n^*\}$ and positive ideal point under the criteria $\mathcal{C}_t$ is computed by the following formula:

$$\ell_t^* = \max_{1 \le k \le m} (\ell_{kt}), t = 1, 2, \cdots, n. \tag{25}$$

(3) Attain the regret matrix of the pharmaceutical enterprise. By comparing it with the positive ideal point of the criteria, the regret matrix of a pharmaceutical enterprise can be identified by:

$$\Re_{kt} = 1 - e^{-\gamma(\nu_{kt} - \nu_t^*)}, \tag{26}$$

where $\Re_{kt}$ is the regret value of pharmaceutical enterprise $\mathcal{A}_k$ with respect to criteria $\mathcal{C}_t$. ν_t^* is the utility value of ideal point ℓ_t^* and $\gamma \in [0, \infty]$ signifies the risk aversion of the decision maker.

(4) Compute the perceived utility matrix of pharmaceutical enterprise. In light of Definition 8, we construct the perceived utility valued matrix $U = (u_{kt})_{m \times n}$ based on the original utility value and regret value of the pharmaceutical enterprise:

$$u_{kt} = \nu_{kt} + \Re_{kt}, \tag{27}$$

where u_{kt} is the perceived utility value of the pharmaceutical enterprise $\mathcal{A}_k$ under the criteria $\mathcal{C}_t$.

(5) Construct the extended perceived utility matrix. Considering that the classical MARCOS method ignores the psychological feature of expert in selecting the optimal pharmaceutical enterprise, we build the MARCOS-based on regret theory to enhance the practicability of the MARCOS algorithm. For every criterion, we first determine the anti-ideal (AID) and the ideal (ID), where AID and ID denote the negative and oppositive solution, respectively:

$$AID = \left\{ arg \min_{1 \le t \le n} \mathcal{S}(u_{kt}) \right\}, \tag{28}$$

$$ID = \left\{ arg \max_{1 \le t \le n} \mathcal{S}(u_{kt}) \right\}. \tag{29}$$

Then, we add the outcomes of AID and ID to the perceived utility matrix to form an extended perceived utility matrix $\hat{U} = (\hat{u}_{kt})_{(m+2) \times n}$, displayed as below:

$$\hat{U} = (\hat{u}_{kt})_{(m+2)\times n} = \begin{pmatrix} u_{k1}^{AID} & u_{k2}^{AID} & \cdots & u_{kn}^{AID} \\ u_{11} & u_{12} & \cdots & u_{1n} \\ u_{21} & u_{22} & \cdots & u_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ u_{m1} & u_{m2} & \cdots & u_{mn} \\ u_{k1}^{ID} & u_{k2}^{ID} & \cdots & u_{kn}^{ID} \end{pmatrix} \tag{30}$$

(6) During the procedure of the decision analysis, the interrelationship among the assessment criteria is momentous for acquiring more reasonable decision outcomes. Hence,

the comprehensive perceived utility value M_k of pharmaceutical enterprise $\mathcal{A}_k$ under all criteria is determined by using the weighted Heronian mean operator:

$$M_k = \left(\frac{2}{n(n+1)} \sum_{t=1}^{n} \sum_{j=t}^{n} (\omega_t \hat{u}_{kt})^{\phi} \left(\omega_j \hat{u}_{kj} \right)^{\varphi} \right)^{\frac{1}{\phi+\varphi}}. \tag{31}$$

where ω_t is the weight of the criterion j and ϕ and φ are the preference parameters.

(7) After obtaining the comprehensive perceived utility value of the pharmaceutical enterprise, the utility degrees of the pharmaceutical enterprise $\mathcal{A}_k$ are worked out with the following formula:

$$P_k^- = \frac{M_k}{M_{AID}}, \tag{32}$$

$$P_k^+ = \frac{M_k}{M_{ID}}. \tag{33}$$

(8) We further calculate the utility functions $f(P_k)$ of pharmaceutical enterprise $\mathcal{A}_k$ on the basis of the following equation:

$$f(P_k) = \frac{P_k^+ + P_k^-}{1 + \frac{1-f\left(P_k^+\right)}{f\left(P_k^+\right)} + \frac{1-f\left(P_k^-\right)}{f\left(P_k^-\right)}}. \tag{34}$$

where $f\left(P_k^-\right)$ and $f\left(P_k^-\right)$ indicate the utility function of anti-ideal and ideal point, respectively, which can be computed by $f\left(P_k^-\right) = \frac{P_k^+}{P_k^+ + P_k^-}, f\left(P_k^+\right) = \frac{P_k^-}{P_k^+ + P_k^-}$.

(9) Pharmaceutical enterprise ranking. The most satisfactory pharmaceutical enterprise can be determined by the utility functions of the pharmaceutical enterprise. The larger the utility function of the pharmaceutical enterprise, the better the pharmaceutical enterprise.

4.6. The Decision Procedures of the Propounded Approach

As discussed above, the proposed SVN regret theory-MARCOS method including four phases can be summed into thirteen steps and exhibited as follows.

Suppose that a MCGDM problem involves m pharmaceutical enterprises denoted as $\mathcal{A} = \{\mathcal{A}_k | k = 1, 2, \cdots, m\}$ and n criteria denoted as $\mathcal{C} = \{\mathcal{C}_t | t = 1, 2, \cdots, n\}$ whose goal is to select the best scheme under the criteria by the group of expert $E = \{E_q | t = 1, 2, \cdots, Q\}$. We will use the proposed regret theory-based SVN-MARCOS method to deal with the MCGDM problem and obtain the optimal pharmaceutical enterprise.

Step 1 : Achieving the SVN assessment information. The experts are invited to take part in the assessment and provide their viewpoints with the linguistic terms displayed in Table 3. Then, the SVN assessment matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q \right)_{m \times n}$ can be attained through transforming the linguistic assessments into SVNNs.

Step 2: Determining the expert weight information. The weight of expert ε_q is computed by the aid of Equations (9)–(14).

Step 3: Obtaining the normalized SVN group assessment matrix. First, the SVN group assessment matrix $\overline{\ell} = \left(\overline{\ell_{kt}} \right)_{m \times n}$ is determined by SVNEWA operators displayed in Equation (15). Then, the normalized SVN group assessment matrix $\ell = (\ell_{kt})_{m \times n}$ is ascertained through Equation (16).

Step 4: Identifying the criteria weight information. The subjective weight ω_t^{sub} of the criteria can be computed by the BWM method according to Equations (17) and (18). Next, the objective weight ω_t^{obj} of the criteria can be worked out by the SVN-CRITIC method by means of Equations (19)–(22). Ultimately, the synthesize weight ω_t of the criteria is acquired, drawing support from Equation (23).

Step 5: Deducing the utility matrix of pharmaceutical enterprise. The utility matrix $V = (v_{kt})_{m\times n}$ of the pharmaceutical enterprise is obtained using Equation (24).

Step 6: Determining positive ideal point vector. The positive ideal point under the criteria $\mathcal{C}_t$ is computed with the aid of Equation (25).

Step 7: Attaining the regret matrix of the pharmaceutical enterprise. The regret matrix of the pharmaceutical enterprise can be identified with Equation (26).

Step 8: Achieving the perceived utility matrix of pharmaceutical enterprise. We construct the perceived utility valued matrix $U = (u_{kt})_{m\times n}$ with Equation (27).

Step 9: Construct the extended perceived utility matrix. The extended perceived utility matrix $U = (u_{kt})_{(m+2)\times n}$ is formed with Equations (28)–(30).

Step 10: Obtaining the comprehensive perceived utility value pharmaceutical enterprise. The comprehensive perceived utility value of the pharmaceutical enterprise $\mathcal{A}_k$ is obtained with the help of Equation (31).

Step 11: Computing the utility degrees of the pharmaceutical enterprise. The utility degrees of the pharmaceutical enterprise $\mathcal{A}_k$ are worked out using Equations (32) and (33).

Step 12: Computing the utility function of the pharmaceutical enterprise. The utility function of the pharmaceutical enterprise $\mathcal{A}_k$ can be figured out with the aid of Equation (34).

Step 13: Ranking pharmaceutical enterprises. The order of pharmaceutical enterprises can be determined by the values of the utility function in descending order. That is, the best pharmaceutical enterprise is the one with the biggest utility function value.

In light of the mentioned decision procedures, a visual flowchart of the developed SVN regret theory-MARCOS group decision methodology is displayed in Figure 2.

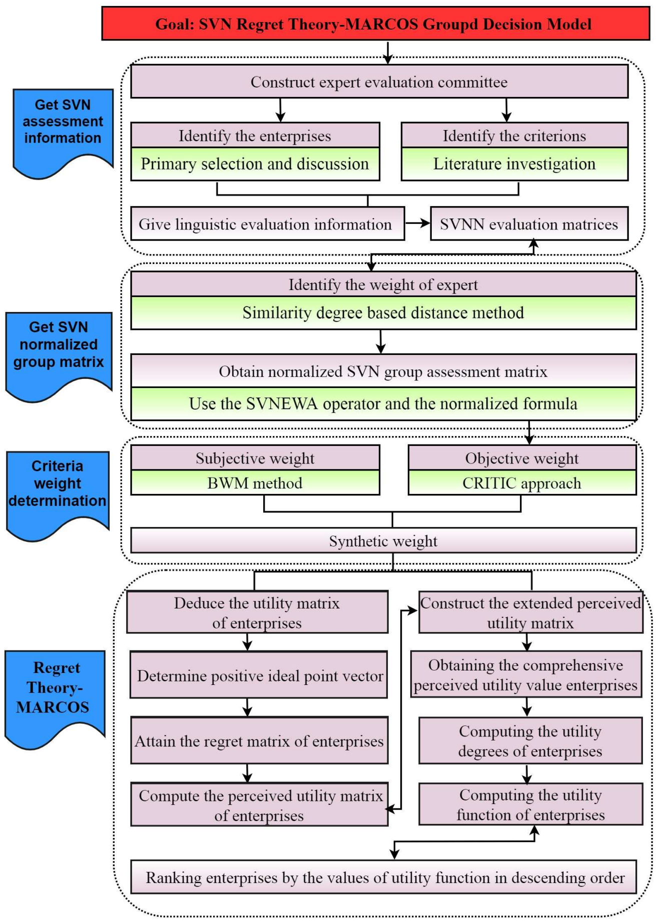

Figure 2. The SVN regret theory-MARCOS group decision framework.

5. Illustrate Example

This section utilizes the introduced SVN regret theory-MARCOS group decision method for assessing and selecting a satisfactory pharmaceutical enterprises who have a SHQDA to confirm the feasibility and practicability of the proposed group decision framework. Furthermore, the sensitivity analysis and contrast study are also implemented to exhibit the stability and superiority separately.

5.1. Background Introduction

The sudden spread of COVID-19 has brought numerous challenges to human production life, economic development and public health defense. At present, scientists domestically and abroad are devoted to the research and development of new crown pneumonia drugs and have achieved some significant results. In order to further mitigate the epidemic, it is of great importance to choose pharmaceutical enterprises with sustainable and high-quality development capability for drug production and environmental protection. The pharmaceutical management department of a city will choose pharmaceutical enterprises to produce drugs from the perspective of sustainable and high-quality development. After preliminary qualification examination and screening, six enterprises denoted as $\mathcal{A} = \{\mathcal{A}_1, \mathcal{A}_2, \cdots, \mathcal{A}_6\}$ in the region are selected as candidate enterprises for the evaluation committee to select the best pharmaceutical enterprises under different evaluation criteria. First, the The Pharmaceutical Administration Department invited four experts $E = \{E_1, E_2, E_3, E_4\}$ from the fields of drug research and development, production management and sustainable economic development to form an evaluation committee. Secondly, seven evaluation criteria $\mathcal{C} = \{\mathcal{C}_1, \mathcal{C}_2, \cdots, \mathcal{C}_7\}$ are determined as the comprehensive evaluation criteria after the collective discussion of the evaluation committee and the investigation of existing literature [1]. The corresponding illustration of the evaluation criteria are shown in Table 4.

Table 4. Depictions of the criteria for pharmaceutical enterprises ranking.

Criteria	Description	Type
Effective supply ability ($\mathcal{C}_1$)	This refers to the enterprise's supply capacity of raw materials and instrument and equipment consumables involved in the product production process. It is embodied in whether the supply materials of main products are sufficient, whether the mechanical materials consumed by equipment are sufficient and whether the necessities required by employees in the production process are sufficient.	Benefit
Scientific and technological innovation ability ($\mathcal{C}_2$)	This refers to the ability of enterprises to continuously innovate and develop new products by paying attention to social development and citizens' needs in the process of product research and development. It is reflected in the number of international professional papers published in the research and development process, the number of patent projects and the amount of funds for achievement transformation.	Benefit
Transnational cooperation ability ($\mathcal{C}_3$)	This refers to the ability of enterprises to cooperate with enterprises in other countries to achieve mutual benefit and win-win results in order to accelerate the diversified development of industries. It is comprehensively evaluated from the aspects of the number of cooperation between enterprises and foreign enterprises, the extent of geographical coverage, benefits and so on.	Benefit
Efficient operation ability ($\mathcal{C}_4$)	This refers to the ability of an enterprise to maximize benefits through resource integration and process optimization by using limited resources, personnel and equipment in the production process. It is embodied by the level of personnel scheduling, the ability of resource optimization and integration and the ability of emergency light in production process optimization.	Benefit
market development ability ($\mathcal{C}_5$)	This refers to the level at which an enterprise sells its products through various ways and strategies in product sales. It is specifically reflected in the sales scope of the product market, product sales channels and product sales to comprehensively evaluate the market development ability of the enterprise.	Benefit
Green development ability ($\mathcal{C}_6$)	This refers to the ability of enterprises to follow the concept of green development in the production process and ensure environmental safety while developing the economy. It is specifically reflected in the level of pollutant emissions, the amount of energy consumed and whether there is complete environmental protection equipment and pollutant treatment equipment.	Benefit
Social contribution ability ($\mathcal{C}_7$)	This refers to the overall impact and comprehensive benefits brought by enterprises to society in the process of production. It is embodied in production safety management, ensuring the harmonious development of society and ensuring the legitimate rights and interests of employees in the production process.	Benefit

5.2. Decision Analysis

Due to the uncertainty and complexity of the assessment environment, the expert weight and criterion weight in the assessment process are completely unknown, and experts need to provide comparative preferences between the criteria to determine the subjective weight of the criteria. Based on the evaluation information provided by experts, this section applies the proposed group decision-making method to rank the six pharmaceutical enterprises in the region and select the best pharmaceutical enterprises. The specific decision-making steps and results are as follows.

Step 1: By mean of the linguistic terms listed in Table 3, four experts give their judgements and viewpoint of the pharmaceutical enterprises under the criteria listed in Table 5. Then, SVN assessment matrices $\overline{\ell}^q = \left(\overline{\ell_{kt}}^q\right)_{m\times n} (q = 1, 2, 3, 4)$ can be attained and displayed in Appendix A (Table A1).

Table 5. SVN assessment matrices provided by experts.

Expert	Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
E^1	$\mathcal{A}_1$	VH	H	VH	VH	VH	M	MH
	$\mathcal{A}_2$	MH	VL	VH	MH	VH	H	MH
	$\mathcal{A}_3$	H	ML	H	ML	VVH	H	ML
	$\mathcal{A}_4$	H	VH	M	H	VH	M	MH
	$\mathcal{A}_5$	M	MH	ML	VVH	MH	VVH	M
	$\mathcal{A}_6$	MH	M	MH	VVH	H	VH	ML
E^2	$\mathcal{A}_1$	MH	MH	VH	H	VH	MH	MH
	$\mathcal{A}_2$	MH	H	VH	MH	MH	H	ML
	$\mathcal{A}_3$	M	L	VH	H	MH	MH	M
	$\mathcal{A}_4$	VH	VL	MH	VVH	M	VVH	ML
	$\mathcal{A}_5$	VH	H	VH	H	MH	VH	M
	$\mathcal{A}_6$	H	VH	M	VH	VVH	VH	MH
E^3	$\mathcal{A}_1$	M	M	MH	ML	L	M	VL
	$\mathcal{A}_2$	MH	H	M	M	VH	ML	M
	$\mathcal{A}_3$	M	VH	ML	H	H	MH	MH
	$\mathcal{A}_4$	VVH	H	M	VH	VH	M	ML
	$\mathcal{A}_5$	M	VH	ML	MH	H	VH	MH
	$\mathcal{A}_6$	MH	H	VH	H	M	H	M
E^4	$\mathcal{A}_1$	MH	M	L	H	H	VH	VH
	$\mathcal{A}_2$	H	ML	ML	MH	MH	VH	MH
	$\mathcal{A}_3$	VH	L	M	H	MH	VH	M
	$\mathcal{A}_4$	VH	M	ML	MH	VVH	MH	M
	$\mathcal{A}_5$	MH	ML	MH	VH	VH	M	VH
	$\mathcal{A}_6$	MH	M	M	VVH	VH	VH	VVH

Step 2: By the aid of Equations (9)–(14), the weight of expert $\varepsilon_q (q = 1, 2, 3, 4)$ is attained as: $\varepsilon_1 = 0.2619, \varepsilon_2 = 0.2605, \varepsilon_3 = 0.2139, \varepsilon_4 = 0.2637$.

Step 3: Based on the SVNEWA operators displayed in Equation (15), the SVN group assessment matrix $\overline{\ell} = \left(\overline{\ell_{kt}}\right)_{m\times n}$ is determined and listed in Appendix A (Table A2). Furthermore, we omit the normalization process in this problem because all considered criteria are benefit type, namely, $\ell = (\ell_{kt})_{m\times n} = \overline{\ell} = \left(\overline{\ell_{kt}}\right)_{m\times n}$.

Step 4: In this step, we use the BWM and CRITIC method to determine the subjective and objective weight of the criteria, respectively. After a discussion by the evaluation committee, the criteria $\mathcal{C}_6$ and $\mathcal{C}_3$ are ascertained as the best criteria and worst criteria, respectively. Furthermore, the assessment committee provides the preference of criteria $\mathcal{C}_6$ compared to other criteria and other criteria compared to the worst criteria $\mathcal{C}_3$, which are displayed in Table 6.

Table 6. Pairwise comparison of the best criteria and worst criteria with other criteria.

Best-others criteria	x_{61}	x_{62}	x_{63}	x_{64}	x_{65}	x_{66}	x_{67}
	2	2	8	3	2	1	3
Others-worst criteria	x_{13}	x_{23}	x_{33}	x_{43}	x_{53}	x_{63}	x_{73}
	2	3	1	2	4	8	5

By means of the following model, the subjective weight of the criteria can be ascertained:

$$\min \xi$$
$$s.t \begin{cases} \left|\frac{\omega_6^{sub}}{\omega_1^{sub}} - 2\right| \le \xi, \left|\frac{\omega_6^{sub}}{\omega_2^{sub}} - 2\right| \le \xi, \left|\frac{\omega_6^{sub}}{\omega_3^{sub}} - 8\right| \le \xi, \\ \left|\frac{\omega_6^{sub}}{\omega_4^{sub}} - 3\right| \le \xi, \left|\frac{\omega_6^{sub}}{\omega_5^{sub}} - 2\right| \le \xi, \left|\frac{\omega_6^{sub}}{\omega_7^{sub}} - 3\right| \le \xi, \\ \left|\frac{\omega_1^{sub}}{\omega_3^{sub}} - 2\right| \le \xi, \left|\frac{\omega_2^{sub}}{\omega_3^{sub}} - 3\right| \le \xi, \left|\frac{\omega_4^{sub}}{\omega_3^{sub}} - 2\right| \le \xi, \\ \left|\frac{\omega_5^{sub}}{\omega_3^{sub}} - 4\right| \le \xi, \left|\frac{\omega_7^{sub}}{\omega_3^{sub}} - 5\right| \le \xi, \\ \sum_{t=1}^{n} \omega_t = 1 \\ \omega_t \ge 0. \end{cases}$$

By means of Equations (17) and (18), the subjective weights ω_t^{sub} of the criteria are identified as: $\omega_1^{sub} = 0.1523, \omega_2^{sub} = 0.1015, \omega_3^{sub} = 0.0761, \omega_4^{sub} = 0.1523, \omega_5^{sub} = 0.0761$, $\omega_6^{sub} = 0.3807, \omega_7^{sub} = 0.0609$. Furthermore, $\xi = 0.2284$, $CR = 0.0511$. The objective weights ω_t^{obj} of the criteria are computed through Equations (19)–(22) and listed as: $\omega_1^{obj} = 0.1753$, $\omega_2^{obj} = 0.0930, \omega_3^{obj} = 0.1469, \omega_4^{obj} = 0.1540, \omega_5^{obj} = 0.0733, \omega_6^{obj} = 0.2731, \omega_7^{obj} = 0.0844$. Furthermore, the synthesize weight ω_t based on Equation (23) is figured out as $\omega_1 = 0.1653$, $\omega_2 = 0.0983, \omega_3 = 0.1070, \omega_4 = 0.1550, \omega_5 = 0.0756, \omega_6 = 0.3263, \omega_7 = 0.0726$.

Step 5: The utility matrix $V = (\nu_{kt})_{m\times n}$ of the pharmaceutical enterprise is calculated by Equation (24) and placed in Table 7. Here, ϑ is assigned as 0.88.

Table 7. The utility matrix $V = (\nu_{kt})_{m\times n}$ of the pharmaceutical enterprise.

Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
$\mathcal{A}_1$	1.3357	1.0841	1.2734	1.4851	1.5695	1.2406	1.1030
$\mathcal{A}_2$	1.2664	0.7668	1.4114	1.0695	1.6129	1.4861	0.8779
$\mathcal{A}_3$	1.3521	0.6423	1.2800	1.2875	1.7007	1.5209	0.7511
$\mathcal{A}_4$	2.0643	1.0232	0.7695	1.8939	1.9400	1.5450	0.6954
$\mathcal{A}_5$	1.2373	1.2963	1.0810	2.0988	1.5017	1.4295	1.2231
$\mathcal{A}_6$	1.2650	1.3100	1.1717	2.1126	1.8697	1.9497	1.3784

Step 6: The ideal point under the criteria $\mathcal{C}_t$ computed based on Equation (25) is determined as:

$$\ell^* = \left\{ \begin{array}{c} (0.8069, 0.1579, 0.1931), (0.6413, 0.3227, 0.3587), (0.6658, 0.2986, 0.3342), \\ (0.8168, 0.1511, 0.1832), (0.7834, 0.1893, 0.2166), (0.7815, 0.1677, 0.2185), \\ (0.6625, 0.3341, 0.3375) \end{array} \right\}$$

Here, ϑ is assigned as 0.88.

Step 7: Using Equation (26), the regret matrix of pharmaceutical enterprise can be identified, and placed in Table 8, γ is fitted as 0.3.

Table 8. The regret matrix of pharmaceutical enterprises.

Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
$\mathcal{A}_1$	−0.2443	−0.0701	−0.0423	−0.2071	−0.1176	−0.2371	−0.0861
$\mathcal{A}_2$	−0.2705	−0.1770	0.0000	−0.3674	−0.1031	−0.1492	−0.1620
$\mathcal{A}_3$	−0.2382	−0.2218	−0.0402	−0.2808	−0.0744	−0.1373	−0.2071
$\mathcal{A}_4$	0.0000	−0.0898	−0.2124	−0.0678	0.0000	−0.1291	−0.2274
$\mathcal{A}_5$	−0.2816	−0.0041	−0.1042	−0.0041	−0.1405	−0.1689	−0.0477
$\mathcal{A}_6$	−0.2710	0.0000	−0.0746	0.0000	−0.0213	0.0000	0.0000

Step 8: Utilizing Equation (27), the perceived utility valued matrix $U = (u_{kt})_{m\times n}$ can be attained, as exhibited in Table 9 .

Table 9. The perceived utility valued matrix of pharmaceutical enterprises.

Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
$\mathcal{A}_1$	1.0915	1.0140	1.2311	1.2780	1.4520	1.0035	1.0168
$\mathcal{A}_2$	0.9959	0.5898	1.4114	0.7021	1.5098	1.3368	0.7158
$\mathcal{A}_3$	1.1139	0.4206	1.2397	1.0066	1.6262	1.3836	0.5440
$\mathcal{A}_4$	2.0643	0.9334	0.5571	1.8261	1.9400	1.4158	0.4680
$\mathcal{A}_5$	0.9558	1.2921	0.9768	2.0947	1.3612	1.2605	1.1754
$\mathcal{A}_6$	0.9940	1.3100	1.0972	2.1126	1.8483	1.9497	1.3784

Step 9: The extended perceived utility matrix $U = (u_{kt})_{(m+2)\times n}$ is formed by using Equations (28)–(30), as shown in Table 10.

Table 10. The extended perceived utility matrix of pharmaceutical enterprises.

Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
AID	0.9558	0.4206	0.5571	0.7021	1.3612	1.0035	0.4680
$\mathcal{A}_1$	1.0915	1.0140	1.2311	1.2780	1.4520	1.0035	1.0168
$\mathcal{A}_2$	0.9959	0.5898	1.4114	0.7021	1.5098	1.3368	0.7158
$\mathcal{A}_3$	1.1139	0.4206	1.2397	1.0066	1.6262	1.3836	0.5440
$\mathcal{A}_4$	2.0643	0.9334	0.5571	1.8261	1.9400	1.4158	0.4680
$\mathcal{A}_5$	0.9558	1.2921	0.9768	2.0947	1.3612	1.2605	1.1754
$\mathcal{A}_6$	0.9940	1.3100	1.0972	2.1126	1.8483	1.9497	1.3784
ID	2.0643	1.0140	1.4114	1.8261	1.9400	1.4158	1.0168

Step 10: Utilizing Equation (31), the comprehensive perceived utility values of pharmaceutical enterprise $\mathcal{A}_k$ are calculated as $\mathcal{A}_1 = 0.1844, \mathcal{A}_2 = 0.2111, \mathcal{A}_3 = 0.2206,$ $\mathcal{A}_4 = 0.2620$, $\mathcal{A}_5 = 0.2310, \mathcal{A}_6 = 0.3127$; ϕ and φ are set as $\phi = \varphi = 2$.

Step 11: Using Equations (32) and (33), the utility degrees of pharmaceutical enterprises $\mathcal{A}_k$ are as below:

$$P_1^- = 1.1402,\ P_2^- = 1.3055,\ P_3^- = 1.3640,\ P_4^- = 1.6198,\ P_5^- = 1.4285,\ P_6^- = 1.9336,$$
$$P_1^+ = 0.6890,\ P_2^+ = 0.7889,\ P_3^+ = 0.8243,\ P_4^+ = 0.9789,\ P_5^+ = 0.8633,\ P_6^+ = 1.1685.$$

Step 12: The utility function of pharmaceutical enterprise $\mathcal{A}_k$ can be worked out by Equation (34), displayed as:

$$f(P_1) = 0.5613,\ f(P_2) = 0.6426,\ f(P_3) = 0.6715,$$
$$f(P_4) = 0.7974,\ f(P_5) = 0.7032,\ f(P_6) = 0.9518.$$

Step 13: Based on the value of utility function of pharmaceutical enterprise, we can obtain the order relation of pharmaceutical enterprise as $\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$; thus, the best pharmaceutical enterprise is $\mathcal{A}_6$.

5.3. Sensitivity Analysis

This section will conduct a sensitivity discussion to analyze the impact of different variables on the ranking of pharmaceutical enterprises. In the calculation process of the evaluation model of pharmaceutical enterprises from the perspective of sustainable and high-quality development, different prioritization results of pharmaceutical enterprises will be attained by setting diverse variables or parameters, which will affect the decision making of pharmaceutical management departments under different criteria. As a consequence, it is necessary to analyze the impact of different variables and parameters on the final ranking results. In this paper, the presented SVNS regret theory-MARCOS method involves the following three variables, different types of criteria weight, the preference parameters α, β in the comprehensive weight and the parameters ϕ, φ in Heronian mean operator. Based on the determination of those parameters, the sensitivity analysis is carried out by taking different parameter values. A detailed analysis will be implemented as follows.

Different types of weight analyses. In the proposed SVNS regret-MARCOS method, in order to enhance the feasibility of the advanced method in this paper, the combined weight of criteria is employed to acquire a more accurate rank of pharmaceutical enterprises. Considering the influence produced by different types of criteria weights, we apply different kinds of weights to recompute the mentioned empirical results; the corresponding results are displayed in Table 11 and Figure 3 ($\phi = \varphi = 2$). From Table 11, it can be found that the ranks of pharmaceutical enterprises obtained by different kinds of weight is basically consistent, and the most satisfactory pharmaceutical enterprise is $\mathcal{A}_6$, which further illustrates the stability of the propounded approach in this paper. Next, we further discuss the decision results derived by the different comprehensive weight based on setting diverse parameters α and β.

Table 11. The impact of different weight types for the ultimate decision results.

Weight Type	Ranking Values						Sorting
	$f(P_1)$	$f(P_2)$	$f(P_3)$	$f(P_4)$	$f(P_5)$	$f(P_6)$	
Objective weight	0.5566	0.6651	0.6949	0.7938	0.7047	0.9895	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
Subjective weight	0.5717	0.6244	0.6474	0.7949	0.6970	0.9022	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
Combinative weight	0.5613	0.6426	0.6715	0.7974	0.7032	0.9518	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
Equal weight	0.6184	0.5865	0.6015	0.7813	0.7220	0.8430	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$

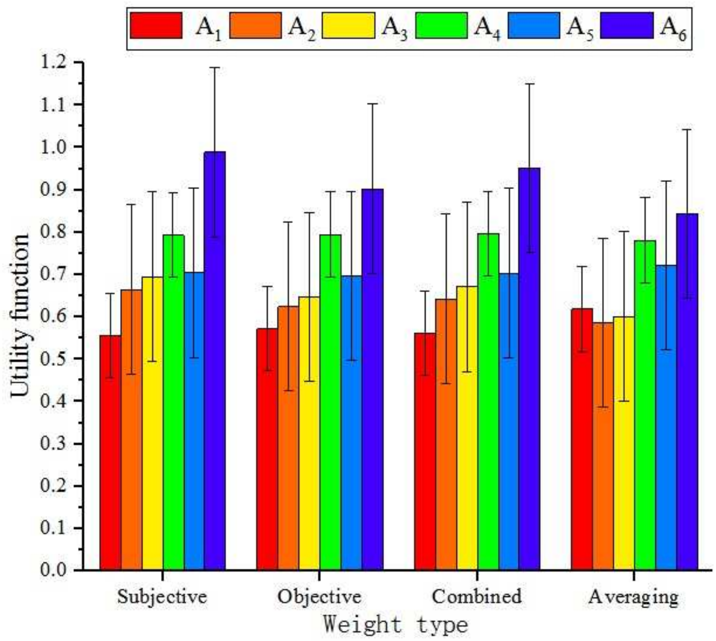

Figure 3. Decision results obtained by different types of weight.

Combined weight analysis based on different preference parameters. In the proposed SVNS regret-MARCOS method, an adjustable combined weight model using two preference parameters α and β is employed for experts to select appropriate criteria weights. The parameters α and β can be regarded as the importance of subjective weight and objective weight. In the process of dealing with different practical decision problems, experts determine the criteria weight according to the subjectivity of the experts and the objectivity of the decision data; hence, selecting a suitable preference to determine the final weight is important for experts to acquire a more reasonable decision result. Based on the range of α and β, we take the values of α from 0 to 1 and obtain the homologous utility functions and ranks of pharmaceutical enterprise, which are shown in Table 12 and Figure 4. Based on Table 12, we can observe that no matter how the α value changes, the sorting of the rank of pharmaceutical enterprises is always $\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$. Accordingly, the proposed SVNS regret-MARCOS method is stable under different weights combination. Therefore, the presented SVNS regret-MARCOS method can provide a more stable decision outcome for selecting the optimal pharmaceutical enterprise.

Table 12. The ultimate decision results obtained by different parameters α and β.

α	β	Ranking Values						Rank
		$f(P_1)$	$f(P_2)$	$f(P_3)$	$f(P_4)$	$f(P_5)$	$f(P_6)$	
0.1	0.9	0.5689	0.6270	0.6519	0.7962	0.6987	0.9130	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.2	0.8	0.5665	0.6303	0.6566	0.7970	0.7001	0.9234	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.3	0.7	0.5645	0.6341	0.6615	0.7975	0.7014	0.9333	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.4	0.6	0.5627	0.6383	0.6665	0.7976	0.7024	0.9428	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.5	0.5	0.5613	0.6426	0.6715	0.7974	0.7032	0.9518	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.6	0.4	0.5600	0.6472	0.6764	0.7970	0.7038	0.9604	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.7	0.3	0.5590	0.6517	0.6813	0.7964	0.7043	0.9684	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.8	0.2	0.5581	0.6563	0.6860	0.7956	0.7045	0.9759	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
0.9	0.1	0.5573	0.6607	0.6906	0.7948	0.7047	0.9830	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
1.0	0	0.5566	0.6651	0.6949	0.7938	0.7047	0.9895	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$

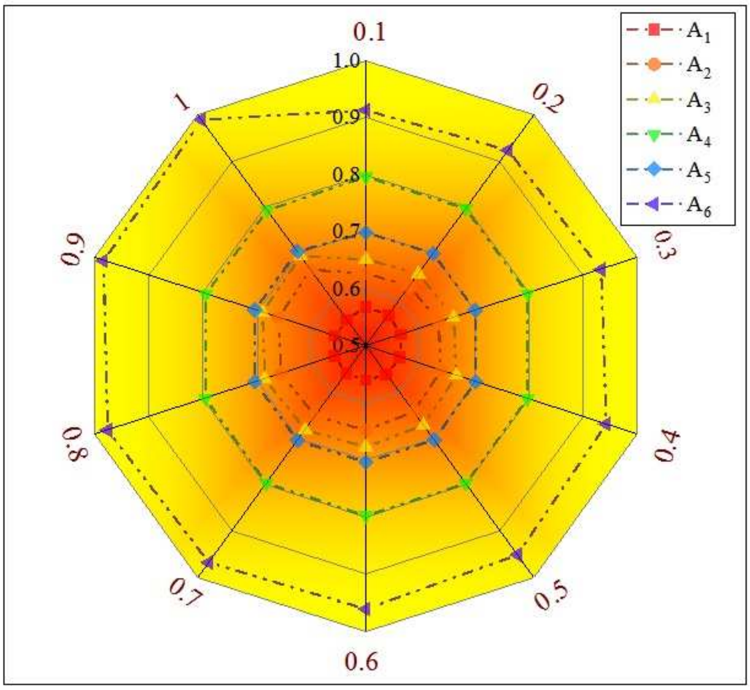

Figure 4. The ultimate decision results obtained with different parameters α and β.

Comprehensive perceived utility value analysis based on different parameters in Heronian mean. In the suggested SVNS regret-MARCOS approach, we determine the comprehensive perceived utility value of pharmaceutical enterprises by utilizing the Heronian mean operator to consider the interrelationship of the perceived utility values under the criteria. The preference parameters ϕ and φ can flexibly control the information fusion procedure and attain a more rational comprehensive perceived utility value of the pharmaceutical enterprise. We set diverse values of ϕ and φ and obtain the corresponding comprehensive perceived utility values listed in Table 13. As seen in Table 13, the final ranks of the pharmaceutical enterprise is relatively stable for different parameter values of ϕ and φ, the best option is always the sixth pharmaceutical enterprise.

Table 13. The ultimate decision results obtained by different parameters α and β.

ϕ	φ	Ranking Values						Rank
		$f(P_1)$	$f(P_2)$	$f(P_3)$	$f(P_4)$	$f(P_5)$	$f(P_6)$	
1	1	0.6003	0.5937	0.6184	0.7733	0.7100	0.8831	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_1 \succ \mathcal{A}_2$
1	2	0.5768	0.6389	0.6677	0.7874	0.7123	0.9478	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
1	5	0.5556	0.6972	0.7240	0.7803	0.7021	1.0201	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
2	1	0.5718	0.6027	0.6295	0.7958	0.6983	0.8963	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
2	2	0.5613	0.6426	0.6715	0.7974	0.7032	0.9518	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
2	5	0.5516	0.6927	0.7201	0.7857	0.6994	1.0158	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
5	5	0.5438	0.7145	0.7399	0.7807	0.6966	1.0446	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$
5	10	0.5458	0.7210	0.7465	0.7773	0.6929	1.0532	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$

5.4. Comparison Study

This subsection will implement a comparison study by utilizing the extant SVNS decision approaches to cope with the mentioned pharmaceutical enterprise assessment problem to further verify the efficiency and rationality of the advanced SVNS regret-MARCOS approach. By means of a literature overview, we can find that the existing decision approaches for SVN main include aggregation-based methods and the improvement of classical decision methods. Hence, the comparison utilizes the following methods to finish the comparison analysis, involving SVN weighted averaging and geometric operator [12], SVN Einstein averaging and geometric operator [12], SVN-WSM [25], SVN-WPM [25], SVN-WASPAS [25] and SVN-TOPSIS [17]. In order to guarantee the rationality of the comparison process, we utilize the combined weight determined to solve the numerical by the mentioned SVN approaches in this paper; the ranking value and rank are displayed in Table 14.

Table 14. The impact of different weight types for the ultimate decision results.

Approaches	Ranking Values						Sorting
	$\mathcal{A}_1$	$\mathcal{A}_2$	$\mathcal{A}_3$	$\mathcal{A}_4$	$\mathcal{A}_5$	$\mathcal{A}_6$	
SVNWA operator [12]	0.7974	0.7925	0.8027	0.8691	0.8445	0.9011	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_1 \succ \mathcal{A}_2$
SVNWG operator [12]	0.7939	0.7796	0.7842	0.8359	0.8303	0.8849	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$
SVNEWA operator [12]	0.7969	0.7908	0.8004	0.8655	0.8427	0.8994	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_1 \succ \mathcal{A}_2$
SVNEWG operator [12]	0.8642	0.8521	0.8539	0.8934	0.8846	0.9167	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$
SVN-WSM [25]	0.3178	0.3110	0.3249	0.4347	0.3917	0.5042	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_1 \succ \mathcal{A}_2$
SVN-WPM [25]	0.3122	0.2907	0.2942	0.3733	0.3679	0.4693	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$
SVN-WASPAS [25]	0.3150	0.3008	0.3096	0.4040	0.3798	0.4867	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_1 \succ \mathcal{A}_3 \succ \mathcal{A}_2$
SVN-TOPSIS [17]	0.0409	0.1022	0.1445	0.3659	0.2122	0.5299	$\mathcal{A}_6 \succ \mathcal{A}_4 \succ \mathcal{A}_5 \succ \mathcal{A}_3 \succ \mathcal{A}_2 \succ \mathcal{A}_1$

Efficiency analysis. It can be seen from Table 15 that the results of ranking pharmaceutical enterprise by the proffered SVN regret theory-MARCOS approach are basically consistent with the previous SVN decision method [12,17,25]. The most satisfactory pharmaceutical enterprise determined by the SVNWA and SVNWG operator, SVNEWA and SVNEWG operator, SVN-WSM method, SVN-WPM method, SVN-WASPAS method, SVN-TOPSIS method and the method suggested in this paper is the sixth pharmaceutical enterprise. Hence, the validity and applicability of the designed SVN regret theory-MARCOS approach are verified. Furthermore, we provide a detailed discussion of the existing SVN approach and highlight the merits of the presented approach.

Further analysis. For the extant SVNS decision approaches mentioned in this paper, the SVNWA operator, SVNWG operator, SVNEWA operator and SVNEWG operator are all aggregation-based decision methods, which obtain the ranks of pharmaceutical enterprise by aggregating the preference value of each pharmaceutical enterprise under different criteria. However, although those methods can obtain the rank values of pharmaceutical enterprises rapidly, those methods fail to consider the objective weight determination and the psychological behavioral of decision makers. Furthermore, the SVN-WSM method, SVN-WPM method, SVN-WASPAS method and SVN-TOPSIS method are determined by the final rank values of pharmaceutical enterprises on the basis of the utility theory, which states that experts are completely rational in the decision-making process. Obviously, this assumption will lead to unreasonable decision outcomes, owing to the complicated of realistic decision settings. Nevertheless, the propounded not only considers the combined weight of criteria by BWM and CRITIC methods but also takes the psychological preference of experts into consideration in assessment of the pharmaceutical enterprise, which effectively conquer the defect derived from the previous SVN decision methodology.

By the aid of the aforementioned comparison analysis, we further derive the conspicuous characteristics of these compared approaches according to the main characteristics of the MCGDM process, which are exhibited in Table 15. As seen in Table 15, we analyze the important feature of every method to further highlight the unique superiority of the developed method in this paper. In light of the above discussion, several advantages of the introduced SVNS regret theory-MARCOS approach are outlined as below:

✠ The proposed SVNS regret theory-MARCOS approach can effectively cope with the practical uncertain assessment problems when the criteria weight and expert weight are all complete unknown.
✠ The suggested method is built by an innovative SVNS score function, which further provides more credible outcome than other existing score functions.
✠ The weight information of the assessment criteria takes the subjective preference and actual decision information simultaneously into account, which further enhances the reliability and credibility of the ranks in dealing with complex assessment problems.
✠ The propounded SVNS regret theory-MARCOS method takes both the advantages of regret theory and MARCOS method, which comprehensively considers the psychological preference of experts and the utility function theory of decision information to attain a more credible and robust decision outcomes.

Table 15. Characteristic comparison between the propounded methods and other SVN decision approaches.

Methods	Calculation of Experts Weight	Criteria Weight	Ranking Algorithm	Consider Expert Psychological Factor
SVNWA operator [12]	Subjective	Subjective	aggregation	NO
SVNWG operator [12]	Subjective	Subjective	aggregation	NO
SVNEWA operator [12]	Subjective	Subjective	aggregation	NO
SVNEWG operator [12]	Subjective	Subjective	aggregation	NO
SVN-WSM method [25]	Subjective	Combined weight	WSM	NO
SVN-WPM method [25]	Subjective	Combined weight	WPM	NO
SVN-WASPAS method [25]	Subjective	Combined weight	WASPAS	NO
SVN-TOPSIS method [17]	Subjective	Subjective	TOPSIS	NO
SVN regret theory-MARCOS method	Objective	Combined weight	MARCOS	YES

6. Conclusions

The ability of sustainable and high-quality development is one of the important indicators for pharmaceutical enterprises to win the core competitiveness under the background of green economic development. Evaluating pharmaceutical enterprises from the perspective of sustainable and high-quality development can provide valuable guidance strategies for pharmaceutical management departments in formulating development plans and rectification of pharmaceutical enterprises. In this paper, a hybrid assessment framework integrating regret theory, MARCOS method and Heronian mean operator under SVNS environment is constructed to cope with the pharmaceutical enterprises assessment problem with uncertainty. The proposed assessment framework can attain more reasonable and credible decision outcomes for experts by comprehensive considering the uncertainty, psychological impact of experts and intrinsic relevance in the course of assessment. First, we present a new SVNS score function to strengthen the validity and rationality of the SVNN comparison. Then, we determine the criteria weight by aggregating the BWM and improved SVN-CRITIC method using the proposed score function. Afterwards, we propound a hybrid assessment framework through aggregating the regret theory, MARCOS method and Heronian mean operator under a single-valued neutrosophic context. Furthermore, the case illustrates the applicability and feasibility of the presented assessment framework. Finally, the comparison and sensitivity study demonstrate the stability, superiority and rationality of the developed method. The proposed uncertain assessment framework possesses the following merits in dealing with the pharmaceutical enterprises' assessment problem: (1) it can fully express the cognition preference of expert by considering three angles, including truth-membership, indeterminacy-membership and falsity-membership; (2) it can take into account the psychological behavioral factors of evaluators in the process of assessment; (3) it can validly settle the uncertain assessment issues when the weight information is completely unknown because of the ambiguity and indeterminacy of assessment environment; (4) it also considers the interrelation of diverse criteria and the comparison with anti-ideal and ideal solutions in the course of the assessment.

The investigation possesses several limitations when implementing the decision analysis. The criteria in this study are attained with the help of expert consultation and a literature research, which cannot guarantee that all criteria are considered. Thus, a comprehensive assessment index systems should be established by means of various aspects. Moreover, owing to the conflict and inconsistency of criteria, the interrelationship among the considered criteria should be considered in the course of expert information aggregation. Furthermore, we also had to take into account the consensus-reaching process of experts to achieve more robust and rational decision outcomes.

In the future, we will go on to develop the construction of uncertain assessment framework for addressing complex uncertain assessment issues. First, some novel decision models, namely the Simple Weighted Sum-Product method and MULTIMOOSRAL approach, can be constructed on the basis of the proposed score function. Additionally, we can introduce more decision models by combining the behavioral decision theories and decision algorithms to analyze the psychological cognition behavioral of expert. Moreover, we also employ the introduced assessment framework to address other realistic decision problems, such as renewable energy project management [51], food waste treatment technology selection [52] and a selection of desalination technology [53].

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Abbreviations

The following abbreviations displayed as below:

Full Name	Abbreviation
Sustainable and High-Quality Development Ability	SHQDA
Measurement Alternatives and Ranking based on the COmpromise Solution	MARCOS
Multi Criteria Group Decision-Making	MCGDM
Single-Valued Neutrosophic Set	SVNS
Single-Valued Neutrosophic Number	SVNN
CRiteria Importance Through Intercriteria Correlation	CRITIC
Best and Worst Method	BWM
Intuitionistic Fuzzy Set	IFS
Single-Valued Neutrosophic	SVN
Multi objective optimization based on the ratio analysis with the full multiplicative form	MULTIMOORA
Technique for Order Preference by Similarity to an Ideal Solution	TOPSIS
VIse KriterijumsaOptimiz acija I Kompromisno Resenje	VIKOR
Mixed Aggregation by COmprehensive Normalization Technique	MACONT
Weighted Aggregated Sum Product ASsessment	WASPAS
LINear programming technique for Multidimensional Analysis of Preference	LINMAP
Single-Valued Neutrosophic weighted averaging operator	SVNWA
Single-Valued Neutrosophic geometric operator	SVNWG
Single-Valued Neutrosophic Einstein weighted averaging operator	SVNEWA
Single-Valued Neutrosophic Einstein geometric operator	SVNEWG

Appendix A

Table A1. SVN assessment matrices provided by experts.

Expert	Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
E^1	$\mathcal{A}_1$	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.90, 0.10, 0.10)	(0.80, 0.15, 0.20)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.70, 0.25, 0.30)
	$\mathcal{A}_2$	(0.60, 0.35, 0.40)	(0.10, 0.90, 0.90)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)
	$\mathcal{A}_3$	(0.70, 0.25, 0.30)	(0.40, 0.65, 0.60)	(0.70, 0.25, 0.30)	(0.40, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.70, 0.25, 0.30)	(0.40, 0.65, 0.60)
	$\mathcal{A}_4$	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)
	$\mathcal{A}_5$	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.90, 0.10, 0.10)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)	(0.50, 0.50, 0.50)
	$\mathcal{A}_6$	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)
E^2	$\mathcal{A}_1$	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)
	$\mathcal{A}_2$	(0.60, 0.35, 0.40)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.70, 0.25, 0.30)	(0.40, 0.65, 0.60)
	$\mathcal{A}_3$	(0.50, 0.50, 0.50)	(0.30, 0.75, 0.70)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)
	$\mathcal{A}_4$	(0.80, 0.15, 0.20)	(0.10, 0.90, 0.90)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)	(0.50, 0.50, 0.50)	(0.90, 0.10, 0.10)	(0.40, 0.65, 0.60)
	$\mathcal{A}_5$	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)
	$\mathcal{A}_6$	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)	(0.90, 0.10, 0.10)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)
E^3	$\mathcal{A}_1$	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.30, 0.75, 0.70)	(0.50, 0.50, 0.50)	(0.10, 0.90, 0.90)
	$\mathcal{A}_2$	(0.60, 0.35, 0.40)	(0.70, 0.25, 0.30)	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)	(0.10, 0.90, 0.90)
	$\mathcal{A}_3$	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)	(0.70, 0.25, 0.30)	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)
	$\mathcal{A}_4$	(0.90, 0.10, 0.10)	(0.70, 0.25, 0.30)	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.40, 0.65, 0.60)
	$\mathcal{A}_5$	(0.10, 0.90, 0.90)	(0.80, 0.15, 0.20)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)
	$\mathcal{A}_6$	(0.60, 0.35, 0.40)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.50, 0.50, 0.50)	(0.70, 0.25, 0.30)	(0.10, 0.90, 0.90)
E^4	$\mathcal{A}_1$	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)	(0.30, 0.75, 0.70)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)	(0.70, 0.25, 0.30)	(0.80, 0.15, 0.20)
	$\mathcal{A}_2$	(0.70, 0.25, 0.30)	(0.40, 0.65, 0.60)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.60, 0.35, 0.40)
	$\mathcal{A}_3$	(0.80, 0.15, 0.20)	(0.30, 0.75, 0.70)	(0.50, 0.50, 0.50)	(0.70, 0.25, 0.30)	(0.60, 0.35, 0.40)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)
	$\mathcal{A}_4$	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)
	$\mathcal{A}_5$	(0.60, 0.35, 0.40)	(0.40, 0.65, 0.60)	(0.60, 0.35, 0.40)	(0.90, 0.10, 0.10)	(0.80, 0.15, 0.20)	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)
	$\mathcal{A}_6$	(0.60, 0.35, 0.40)	(0.50, 0.50, 0.50)	(0.50, 0.50, 0.50)	(0.80, 0.15, 0.20)	(0.80, 0.15, 0.20)	(0.80, 0.15, 0.20)	(0.90, 0.10, 0.10)

Table A2. SVN group assessment matrix.

Pharmaceutical Enterprises	$\mathcal{C}_1$	$\mathcal{C}_2$	$\mathcal{C}_3$	$\mathcal{C}_4$	$\mathcal{C}_5$	$\mathcal{C}_6$	$\mathcal{C}_7$
$\mathcal{A}_1$	(0.6461, 0.3074, 0.3539)	(0.5850, 0.3836, 0.4150)	(0.6328, 0.3350, 0.3672)	(0.6821, 0.2754,0.3179)	(0.7008, 0.2524, 0.2992)	(0.6241, 0.3390, 0.3759)	(0.5871, 0.3603, 0.4129)
$\mathcal{A}_2$	(0.6286, 0.3209, 0.3714)	(0.5001, 0.4743, 0.4999)	(0.6658, 0.2986, 0.3342)	(0.5799, 0.3788,0.4201)	(0.7094, 0.2367, 0.2906)	(0.6823, 0.2752, 0.3177)	(0.5315, 0.4487, 0.4685)
$\mathcal{A}_3$	(0.6512, 0.3107, 0.3488)	(0.4685, 0.5392, 0.5315)	(0.6344, 0.3331, 0.3656)	(0.6358, 0.3283,0.3642)	(0.7327, 0.2384, 0.2673)	(0.6888, 0.2585, 0.3112)	(0.4984, 0.4999, 0.5016)
$\mathcal{A}_4$	(0.8069, 0.1579, 0.1931)	(0.5678, 0.3905, 0.4322)	(0.5032, 0.4923, 0.4968)	(0.7733, 0.1954,0.2267)	(0.7834, 0.1893, 0.2166)	(0.6990, 0.2796, 0.3010)	(0.4834, 0.5213, 0.5166)
$\mathcal{A}_5$	(0.6233, 0.3399, 0.3767)	(0.6376, 0.3241, 0.3624)	(0.5853, 0.3921, 0.4147)	(0.8171, 0.1685,0.1829)	(0.6844, 0.2628, 0.3156)	(0.6695, 0.2913, 0.3305)	(0.6200, 0.3450, 0.3800)
$\mathcal{A}_6$	(0.6282, 0.3213, 0.3718)	(0.6413, 0.3227, 0.3587)	(0.6072, 0.3591, 0.3928)	(0.8168, 0.1511,0.1832)	(0.7690, 0.2042, 0.2310)	(0.7815, 0.1677, 0.2185)	(0.6625, 0.3341, 0.3375)

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