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Single-valued neutrosophic linguistic reducible weighted MSM for tourism mobile e-commerce service quality evaluation

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Abstract. The Tourism Mobile E-commerce Service Quality Evaluation (TMESQE) is of great concern to enterprises for enriching the service content of the enterprise and improving its market competitiveness. The key issue is the tremendous vagueness and reciprocity for TMESQE. The Maclaurin Symmetric Mean (MSM), as a vital fusion approach, can capture the reciprocity between multiple given arguments more effectually. Amount of Weighted MSM (WMSM) has been presented for dealing with various neutrosophic information integration issues because the arguments are hourly interoperable. However, these kinds of WMSM operators are out of the reducibility or idempotency. To handle two problems above, we introduce Single-Valued Neutrosophic Linguistic Reducible Weighted MSM (SVNLRWMSM) operator and Single-Valued Neutrosophic Linguistic Reducible Weighted Dual MSM (SVNLRWDMSM) operator. In the meantime, the diverting properties and certain peculiar cases of developed operators are discussed. Therefore, we explore two Multi-Criteria Decision-Making (MCDM) algorithm based on SVNLRWMSM and SVNLRWDMSM for dealing with the TMESQE issue, along with the sensitivity analysis of various values on final ordering. Conclusively, the comparison of some existing algorithms has been conducted for showing their availability.

1. Introduction

The rapid development of mobile communication technology and Internet Technology provides a favorable environment for mobile e-commerce applications in people's lives and in various industries. In recent years, the number of mobile users, including smartphones, has explosively increased by the 42nd China Internet network development statistics report [1]. The number of Internet users in China is 802 million till June 2018, among which the number of mobile Internet users is 788 million, accounting for 98.3% of the total number of Internet users. It can be seen that people's life is more and more inclined to using mobile. Moreover, under the background of rapid economic development and continuous improvement of residents' consumption level in China, tourism has gradually become a popular leisure and entertainment mode, and the scale of tourism consumption in China is increasing year by year. The China tourism academy released the tourism economic data report for the first half of 2018, which showed that the number of domestic tourists reached 2.826

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billion, up by 11.4% from the same period last year [2]. Tourism consumers are also increasingly diversified and self-service in their demands for tourism. They begin to choose tourism products according to their own preferences, time, cost, and other factors. In particular, in the context of mobile e-commerce, information access is more convenient and the individualization of tourism groups becomes more prominent. Under these two backgrounds, mobile e-commerce is widely used in combination with the tourism industry due to its unique advantages such as timeliness, convenience, and personalization. The all-round development of Tourism Mobile E-commerce (TME) has become an inevitable trend. The use of TME runs through the whole process of tourism. Users can complete travel route planning, accommodation, and catering reservations before tourism, obtain real-time tourism information, and formulate or change tourism modes and tourism and end of tourism at any time to ensure tourism. The mobile e-commerce platform can control the itinerary by itself, and people begin to enjoy the convenience and fun provided by the TME.

Due to the close cooperation between mobile e-commerce and tourism in recent years, the tourism market in these years is dominated by the expansion of TME. More and more companies join in this big market. In the fierce competition environment, service quality problems begin to appear frequently. According to the complaint platform of people's tourism website 3.15, there are many complaints from tourism consumers about the service of the TME platform. For example, there is a big gap between the description on the Internet and the tourism products provided; there is a problem with the ticket refund and alteration on the website; and the service commitment of fraudulent marketing activities cannot be fulfilled. The emergence of these problems has a negative impact on users' experience and feelings, reduces users' satisfaction, and puts tourism service enterprises at a disadvantage. Compared to the conventional e-commerce service, the mobile e-commerce service of tourism has more unstable factors and higher requirements on service quality [3,4]. Therefore, the construction of the evaluation model based on user experience is critical to improving both the user experience and the service quality of the company. Nevertheless, the increasingly intricate decision-making environments and indecisive Decision Maker (DM) have trouble in presenting preference information with uncertain information when solving the above Multi-Criteria Decision-Making (MCDM) issues.

Single-Valued Neutrosophic Linguistic Set (SVNLS), initiatively conceived by Ye [5], is perceived as a more underlying measure for depicting the indeterminacy of quantitative and qualitative evaluation information, which is a generalization of materialization Neutrosophic Set (NS) [6] (named Single- Valued Neutrosophic Set (SVNS) [7]). It constitutes a linguistic portion (qualitative) and a fuzzy portion (quantitative) where the fuzzy portion is employed in describing the confidence degree of linguistic value in the linguistic portion. SVNLS is an effective instrument for presenting preference information in the Tourism Mobile E-commerce Service Quality Evaluation (TMESQE). For instance, when a DM or an expert is required to evaluate a TME company, she or he offers a qualitative assessment (e.g., the TME product is excellent) in place of a numerical scale. Moreover, the degree of which she or he considers as the evaluation is true ranges between 0 and 1 such as 0.6. The degree of which she or he considers as the evaluation is false ranges between 0 and 1, such as 0.3. The degree of which she or he does not ascertain about the evaluation is a decimal between 0 and 1, such as 0.4. In addition, these three degrees are independent of each other, without limitation in the sum of three degrees. SVNSs can describe information with respect to the reliance of the evaluation faultlessly and SVNLSs can present the evaluations in TME company selection triumphantly. Up to now, SVNLS has attracted much attention and obtained certain exciting achievements [8–11]. Tian et al. [12] developed some power aggregation for SVNLS in the green product design selection process. Ye [13] presented the SVNL weighted arithmetic average and SVNL weighted geometric average for dealing with the selection of flexible manufacturing system. Tian et al. [14,15] proposed the Single-Valued Neutrosophic Linguistic Normalized Weighted Bonferroni Mean (SVNLNWBM) operator for dealing with the issue of investment appraisal project selection, which can seize the relevancy of given arguments. Tan et al. [16] presented the generalized form of the SVNL aggregation operators with greater flexibility in employing the complex real problems. Wang et al. [17] combined Single-valued Neutrosophic Cloud (SNC) notion with the neutrosophic linguistic Maclaurin Symmetric Mean (MSM) operator [18] for solving the hotel selection.

However, it just captures the interaction among a constant number of parameters using the above Aggregation Operators (AOs) [12–18]. For instance, the Heronian Mean (HM) operator only captures the correlation between two parameters. For boosting the elasticity of information integration, Maclaurin [19] presented the MSM operator that can seize the interaction among any number of parameters. Qin and Liu [20] initially combined MSM operator with intuitionistic fuzzy environment in an uncertain field and initiated the weighted intuitionistic fuzzy MSM for aggregating decision evaluation information. At present, there are many generalizations of MSM operators by employing them in different indeterminate environments [21–

33]. According to the research of Weighted MSM (WMSM) operators in various uncertain environments, two counter-intuitive issues can be easily seen in the following: (1) When weight information in entire parameters is the same, the corresponding WMSM operators [21–33] fail to degenerate into consistent MSM operators, representing a key peculiarity of the traditional weighted operators; and (2) Such kinds of WMSM operators [21–31] are out of idempotency. That is to say, it is illogical that the weighted average value of certain selfsame aggregated parameters relies on corresponding weight values. Illuminated by Reducible WMSM (RWMSM) operator and Reducible Weighted Dual MSM (RWDMSM) operator [34], we combine the above-mentioned operators with SVNLS for fusing single-valued neutrosophic linguistic information and dealing with the corresponding MCDM issues by considering the virtues of both.

The above discussion comes down to the main four targets in the following:

1. Introduce two new kinds of AOs (Single-Valued Neutrosophic Linguistic Reducible Weighted MSM (SVNLRWMSM) and Single-Valued Neutrosophic Linguistic Reducible Weighted Dual MSM (SVNL-RWDMSM)) for integrating the decision preferences of DMs or experts;

2. Present two MCDM algorithm based on SVNLR-WMSM and SVNLRWDMSM for dealing with the TME service quality issue;

3. Discuss the sensitivity analysis of different parameter values on the conclusive ranking;

4. Construct a comprehensive appraisal system for TME service quality.

The remaining part of the paper is listed in the following. In Section 2, we simply present fundamental notions of SVNLS, MSM, RWMSM, Dual Maclaurin Symmetric Mean (DMSM), and RWDMSM operators. In Section 3, the SVNLRWMSM and SVNLRWDMSM operators are presented with their interesting properties. In Section 4, two MADM algorithms based on SVNLRWMSM operator and SVNLRWDMSM operator are given with a Single- Valued Neutrosophic Linguistic Number (SVNLN). In addition, we employ an example of TME service quality to state the feasibility of MCDM approaches by presenting the effect of diverse argument values on final ordering of the alternatives. In Section 5, a comparison with certain existing MCDM algorithms is presented. Also, the characteristic comparisons of diverse SVNL AOs and various inconclusive environment are made. Finally, Section 6 offers the conclusive remarks.

2. Preliminaries

2.1. Single-Valued Neutrosophic Linguistic Set (SVNLS)

Definition 1 [5]. Let X be the universe of discourse, with a crowd of elements in X signified by x. Let $S = \{s_0, s_1, ..., s_l\}$ be a limited and total ordered discrete Linguistic Term Set (LTS). The SVNLS can be denoted in the following:

$$A = \{< s_{\theta(x)}, (T_A(x), I_A(x), F_A(x)) >| \ x \in X\}, \quad (1)$$

where $x \in X, s_{\theta(x)} \in S, T_A(x) \in [0,1], I_A(x) \in [0,1]$, and $F_A(x) \in [0,1]$. The $T_A(x)$, $I_A(x)$ and $F_A(x)$ are the truth-membership, indeterminate-membership, and false-membership of x in X to $s_{\theta(x)}$, respectively. In addition, $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 1$ exists for any $x \in X$. Moreover, $a =< s_{\theta(x)}, (T_A(x), I_A(x), F_A(x)) >$ is called Single-Valued Neutrosophic Linguistic Number (SVNLN). For simplicity, an SVNLN is defined as $a =< s_{\theta(a)}, (T_a, I_a, F_a) >$.

Definition 2 [5]. Let $x =< s_{\theta(x)}, (T_x, I_x, F_x) >$ and $y =< s_{\theta(y)}, (T_y, I_y, F_y) >$ be two SVNLNs and $\lambda > 0$; then, operations are shown in the following:

1. $x^c =< s_{l-\theta(x)}, (F_x, 1 - I_x, T_x) >$;
2. $x \oplus y =< s_{\theta(x)+\theta(y)}, (T_x + T_y - T_x * T_y, I_x * I_y, F_x * F_y) >$;
3. $x \otimes y =< s_{\theta(x)\theta(y)}, (T_x * T_y, I_x + I_y - I_x * I_y, F_x + F_y - F_x * F_y) >$;
4. $\lambda x =< s_{\lambda\theta(x)}, (1 - (1 - T_x)^\lambda, (I_x)^\lambda, (F_x)^\lambda) >$;
5. $x^\lambda =< s_{\theta^\lambda(x)}, ((T_x)^\lambda, 1-(1-I_x)^\lambda, 1-(1-F_x)^\lambda) >$.

Definition 3 [12]. Let $x =< s_{\theta(x)}, (T_x, I_x, F_x) >$ be an SVNLN. Then, the score function $s(x)$, the accuracy function $a(x)$, and the certainty function $c(x)$ are suggested in the following:

1. $s(x) = \theta(x)(T_x + 2 - I_x - F_x)$;
2. $a(x) = \theta(x)(T_x - F_x)$;
3. $c(x) = \theta(x)T_x$.

For any two SVNLNs x, y:

1. When $s(x) > s(y)$, then $x \succ y$;
2. When $s(x) = s(y)$ and $a(x) > a(y)$, then $x \succ y$;
3. When $s(x) = s(y)$ and $a(x) = a(y)$;
   If $c(x) > c(y)$, then $x \succ y$;
   If $c(x) = c(y)$, then $x \sim y$.

2.2. Reducible Weighted Maclaurin Symmetric Means (RWMSM)

The MSM, developed by Maclaurin [19], can acquire the reciprocity among multiple given arguments more efficaciously. For now, the MSM is used for integrating vague evaluation information.

Definition 4 [19]. Let $x_i (i = 1, 2, \cdots, n)$ be a set of nonnegative real numbers, and $k = 1, 2, \cdots, n$. Then, MSM operator is signified as follows:

$$\mathrm{MSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left(\frac{\sum_{1 \le i_1 < \cdots < i_k \le n} \prod_{j=1}^{k} x_{i_j}}{C_n^k} \right)^{1/k}, \tag{2}$$

where $(i_1, i_2, \cdots, i_k)$ is ergodic for all the k-permutations of $(1, 2, \cdots, n)$ and C_n^k is the binomial coefficient meeting $C_n^k = \frac{n!}{k!(n-k)!}$.

Definition 5 [21]. Let $x_i (i = 1, 2, \cdots, n)$ be a set of nonnegative real numbers and $k = 1, 2, \cdots, n$; then, DMSM operator is suggested as follows:

$$\mathrm{DMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left(\frac{\sum_{1 \le i_1 < \cdots < i_k \le n} \prod_{j=1}^{k} x_{i_j}}{C_n^k} \right)^{1/k}, \tag{3}$$

where $(i_1, i_2, \cdots, i_k)$ is ergodic for all the k-permutations of $(1, 2, \cdots, n)$ and C_n^k is the binomial coefficient meeting $C_n^k = \frac{n!}{k!(n-k)!}$.

In the sake of addressing the problems of idempotency and reducibility, Shi and Xiao [34] introduced RWDMSM and RWMSM.

Definition 6 [34]. Let $x_i (i = 1, 2, \cdots, n)$ be a series of nonnegative real numbers, $k = 1, 2, \cdots, n$, and $W = (w_1, w_2, \cdots, w_n)^T$ with $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$. Then, the RWMSM operator is suggested in the following:

$$\mathrm{RWMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left(\frac{\sum\limits_{1 \le i_1 < \cdots < i_k \le n} \left(\prod_{j=1}^{k} w_{i_j} \right) \left(\prod_{j=1}^{k} x_{i_j} \right)}{\sum\limits_{1 \le i_1 < \cdots < i_k \le n} \prod_{j=1}^{k} w_{i_j}} \right)^{1/k}. \tag{4}$$

Definition 7 [34]. Let $x_i (i = 1, 2, \cdots, n)$ be a series of nonnegative real numbers, $k = 1, 2, \cdots, n$, and $W = (w_1, w_2, \cdots, w_n)^T$ with $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$; then, RWDMSM operator is given as follows:

$$\mathrm{RWDMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \frac{\prod\limits_{1 \le i_1 < \cdots < i_k \le n} \left(\sum_{j=1}^{k} x_{i_j} \right)^{\frac{\sum_{j=1}^{k} w_{i_j}}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}}}{k}. \tag{5}$$

3. Single-valued Neutrosophic Linguistic Reducible Weighted MSMs (SVNLRWMSMs)

3.1. SVNLRWMSM operator

Definition 8. Let $x_i =< s_{\theta(x_i)}, (T_{x_i}, I_{x_i}, F_{x_i}) >$ $(i = 1, 2, \cdots, n)$ be a set of SVNLNs and let $W = (w_1, w_2, \cdots, w_n)^T$ be a weight vector where $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$. The SVNLRWMSM, $\Omega^n \to \Omega$: an SVNLRWMSM operator is given as follows:

$$\mathrm{SVNLRWMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left(\frac{\sum\limits_{1 \le i_1 < \cdots < i_k \le n} \left(\prod_{j=1}^{k} w_{i_j} \right) \left(\prod_{j=1}^{k} x_{i_j} \right)}{\sum\limits_{1 \le i_1 < \cdots < i_k \le n} \prod_{j=1}^{k} w_{i_j}} \right)^{1/k}, \tag{6}$$

where Ω is the set of entire SVNLNs and then, SVNL-RWMSM is named the Single-Valued Neutrosophic Linguistic RWMSM operator.

Based on the operational laws of SVNLNs defined in Definition 2 and Eq. (6), we can obtain the aggregated result presented in Theorem 1.

Theorem 1. *Let $x_i =< s_{\theta(x_i)}, (T_{x_i}, I_{x_i}, F_{x_i}) >$ $(i = 1, 2, \cdots, n)$ be a series of SVNLNs and let $W = (w_1, w_2, \cdots, w_n)^T$ be a weight vector where $w_i \in [0, 1]$ and $\sum_{i=1}^{n} w_i = 1$; then, the final result of SVNLRWMSM operator is still an SVNLN.*

Eq. (7) is shown in Box I.

Proof. According to Definition 2, we can have:

$$\prod_{j=1}^{k} x_{i_j} = \left\langle s_{\prod_{j=1}^{k} \theta(x_{i_j})}, \left(\prod_{j=1}^{k} T_{x_{i_j}}, 1 - \prod_{j=1}^{k} (1 - I_{x_{i_j}}), 1 - \prod_{j=1}^{k} (1 - F_{x_{i_j}}) \right) \right\rangle,$$

and:

$$\left(\prod_{j=1}^{k} w_{i_j} \right) \left(\prod_{j=1}^{k} x_{i_j} \right) = \left\langle s_{\left(\prod_{j=1}^{k} w_{i_j} \right) \left(\prod_{j=1}^{k} \theta(x_{i_j}) \right)}, \left(1 - \left(1 - \prod_{j=1}^{k} T_{x_{i_j}} \right)^{\prod_{j=1}^{k} w_{i_j}}, \left(1 - \prod_{j=1}^{k} (1 - I_{x_{i_j}}) \right)^{\prod_{j=1}^{k} w_{i_j}}, \right.\right.$$

$$\text{SVNLRWMSM}^{(k)}(x_1, x_2, \cdots, x_n) =$$

$$\left\langle s_{\left(\frac{\sum_{1\le i_1<\cdots<i_k\le n}\left(\prod_{j=1}^{k} w_{i_j}\right)\left(\prod_{j=1}^{k}\theta(x_{i_j})\right)}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k} w_{i_j}}\right)^{1/k}},\right.$$

$$\left(\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k} T_{x_{i_j}}\right)^{\prod_{j=1}^{k} w_{i_j}}\right)^{\frac{1}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k} w_{i_j}}}\right)^{1/k},\right.$$

$$1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-I_{x_{i_j}})\right)^{\prod_{j=1}^{k} w_{i_j}}\right)^{\frac{1}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k} w_{i_j}}}\right)^{1/k},$$

$$\left.\left.1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod_{j=1}^{k} w_{i_j}}\right)^{\frac{1}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k} w_{i_j}}}\right)^{1/k}\right)\right\rangle. \tag{7}$$

Box I

$$\left.\left.\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod_{j=1}^{k} w_{i_j}}\right)\right\rangle.$$

Further:

$$\sum_{1\le i_1<\cdots<i_k\le n}\left(\prod_{j=1}^{k} w_{i_j}\right)\left(\prod_{j=1}^{k} x_{i_j}\right)$$

$$=\left\langle s_{\sum_{1\le i_1<\cdots<i_k\le n}\left(\prod_{j=1}^{k} w_{i_j}\right)\left(\prod_{j=1}^{k}\theta(x_{i_j})\right)},\right.$$

$$\left(1-\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k} T_{x_{i_j}}\right)^{\prod_{j=1}^{k} w_{i_j}},\right.$$

$$\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-I_{x_{i_j}})\right)^{\prod_{j=1}^{k} w_{i_j}},$$

$$\left.\left.\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod_{j=1}^{k} w_{i_j}}\right)\right\rangle.$$

Consequently, the equation shown in Box II is obtained.

In the end, we can obtain the equation shown in Box III, then we can know that Eq. (7) is right. Here the equation shown in Box IV can be easily obtained.

Consequently, we can consider that the aggregated result from Eq. (7) is an SVNLN.

Theorem 2 (Monotonicity). *Let $x_i (i = 1, 2, \cdots, n)$ and $x'_i (i = 1, 2, \cdots, n)$ be two sets of SVNLNs; if $x'_i = < s_{\theta(x'_i)}, (T_{x'_i}, I_{x'_i}, F_{x'_i}) >$, $x_i = < s_{\theta(x_i)}, (T_{x_i}, I_{x_i}, F_{x_i}) >$, $\theta(x_i) \ge \theta(x'_i), T_{x_i} \ge T_{x'_i}, I_{x_i} \le I_{x'_i}, F_{x_i} \le F_{x'_i}$ for $\forall i = 1, 2, \cdots, n$, then:*

$$\text{SVNLRWMSM}^{(k)}(x_1, x_2, \cdots, x_n) \ge \text{SVNLRWMSM}^{(k)}(x'_1, x'_2, \cdots, x'_n). \tag{8}$$

Proof. Suppose that:

$$\text{SVNLRWMSM}^{(k)}(x_1, x_2, \cdots, x_n) =< s_\theta, (T, I, F) >,$$

$$\text{SVNLRWMSM}^{(k)}(x'_1, x'_2, \cdots, x'_n) =< s_{\theta'}, (T', I', F') >.$$

Since $\theta(x_i) \ge \theta(x'_i)$, we can have $\prod_{j=1}^{k}\theta(x_{i_j}) \ge$

$$\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}x_{i_j}\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}=\left\langle s_{\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}\theta(x_{i_j})\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}},\right.$$

$$\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}T_{x_{i_j}}\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right),$$

$$\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-I_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}},$$

$$\left.\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)\right\rangle.$$

Box II

$\prod\limits_{j=1}^{k}\theta(x'_{i_j})$. Furthermore, we have:

$$s_{\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}heta(x_{i_j})\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}\right)^{1/k}}\ge$$

$$s_{\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}\theta(x'_{i_j})\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}\right)^{1/k}}.$$

Also, since $T_{x_i}\ge T'_{x_i}$, it can be obtained that:

$$1-\prod_{j=1}^{k}T_{x_{i_j}}\le 1-\prod_{j=1}^{k}T_{x'_{i_j}}.$$

Further, we can achieve the equation shown in Box V.

Consequently, $T\ge T'$. Similarly, we can have $I\le I'$ and $F\le F'$. In the end, we have $<s_\theta,(T,I,F)>\ge<s_{\theta'},(T',I',F')>$. That is to say:

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)\ge$$
$$\mathrm{SVNLRWMSM}^{(k)}(x'_1,x'_2,\cdots,x'_n).$$

Theorem 3 (Commutativity). *Let $(x'_1,x'_2,\cdots,x'_n)$ be any permutation of $(x_1,x_2,\cdots,x_n)$, then:*

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)=$$
$$\mathrm{SVNLRWMSM}^{(k)}(x'_1,x'_2,\cdots,x'_n). \tag{9}$$

Proof:

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)=$$

$$\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}x_{i_j}\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}\right)^{1/k}$$

$$=\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}x_{i_j}\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w'_{i_j}}\right)^{1/k}$$

$$=\mathrm{SVNLRWMSM}^{(k)}(x'_1,x'_2,\cdots,x'_n).$$

Theorem 4 (Idempotency). *Let $x_i(i=1,2,\cdots,n)$ be a set of SVNLNs; if $x_i=x=<s_\theta,(T,I,F)>$ for $\forall i$, then:*

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)=x. \tag{10}$$

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)=\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}x_{i_j}\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}\right)^{1/k}$$

$$=\left\langle s_{\left(\frac{\sum\limits_{1\le i_1<\cdots<i_k\le n}\left(\prod\limits_{j=1}^{k}w_{i_j}\right)\left(\prod\limits_{j=1}^{k}\theta(x_{i_j})\right)}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}\right)^{1/k}},\right.$$

$$\left(\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}T_{x_{i_j}}\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k},\right.$$

$$1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-I_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k},$$

$$\left.\left.1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k}\right)\right\rangle.$$

Box III

$$0\le\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}T_{x_{i_j}}\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k}\le 1,$$

$$0\le 1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-I_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k}\le 1,$$

$$0\le 1-\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}(1-F_{x_{i_j}})\right)^{\prod\limits_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum\limits_{1\le i_1<\cdots<i_k\le n}\prod\limits_{j=1}^{k}w_{i_j}}}\right)^{1/k}\le 1.$$

Box IV

$$\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}T_{x_{i_j}}\right)^{\prod_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}}\right)^{1/k}\ge$$

$$\left(1-\left(\prod_{1\le i_1<\cdots<i_k\le n}\left(1-\prod_{j=1}^{k}T_{x'_{i_j}}\right)^{\prod_{j=1}^{k}w_{i_j}}\right)^{\frac{1}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}}\right)^{1/k}.$$

Box V

Proof:

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)$$

$$=\left(\frac{\sum_{1\le i_1<\cdots<i_k\le n}\left(\prod_{j=1}^{k}w_{i_j}\right)\left(\prod_{j=1}^{k}x_{i_j}\right)}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}\right)^{1/k}$$

$$=\left(\frac{\sum_{1\le i_1<\cdots<i_k\le n}\left(\prod_{j=1}^{k}w_{i_j}\right)\left(\prod_{j=1}^{k}x\right)}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}\right)^{1/k}$$

$$=\left(\frac{x^k\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}{\sum_{1\le i_1<\cdots<i_k\le n}\prod_{j=1}^{k}w_{i_j}}\right)^{1/k}=x.$$

Theorem 5 (Boundedness). *Let $x_i(i=1,2,\cdots,n)$ be a set of SVNLNs, and:*

$$x^+=<s_{\max_{i=1}^n\theta_i},(\max_{i=1}^nT_i,\min_{i=1}^nI_i,\min_{i=1}^nF_i)>,$$

$$x^-=<s_{\min_{i=1}^n\theta_i},(\min_{i=1}^nT_i,\max_{i=1}^nI_i,\max_{i=1}^nF_i)>,$$

then:

$$x^-\le\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)\le x^+.\quad(11)$$

Proof. According to the idempotency and monotonicity, we can obtain:

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)\le$$
$$\mathrm{SVNLRWMSM}^{(k)}(x^+,x^+,\cdots,x^+)\quad\text{and}$$

$$\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)\ge$$
$$\mathrm{SVNLRWMSM}^{(k)}(x^-,x^-,\cdots,x^-).$$

Hence, we have:

$$x^-\le\mathrm{SVNLRWMSM}^{(k)}(x_1,x_2,\cdots,x_n)\le x^+.$$

Next, we discuss two particular cases of the SVNLRWMSM by regulating the argument k:

Case 1: In the event of $k=1$, the SVNLRWMSM degenerates into an SVNLWA operator [16].

$$\mathrm{SVNLRWMSM}^{(1)}(x_1,x_2,\cdots,x_n)$$

$$=\left\langle s_{\sum_{1\le i_1\le n}w_i\theta(x_{i_1})},\left(1-\prod_{1\le i_1\le n}(1-T_{x_{i_1}})^{w_{i_1}},\prod_{1\le i_1\le n}I_{x_{i_1}}^{w_{i_1}},\prod_{1\le i_1\le n}F_{x_{i_1}}^{w_{i_1}}\right)\right\rangle$$

$$=\mathrm{SVNLWA}(x_1,x_2,\cdots,x_n).$$

Case 2: In the event of $k=n$, the SVNLRWMSM degenerates into an Single-Valued Neutrosophic Linguistic Geometric (SVNLG) operator.

$$\mathrm{SVNLRWMSM}^{(n)}(x_1,x_2,\cdots,x_n)=$$

$$=\left\langle s_{\prod_{j=1}^{n}\theta^{\frac{1}{n}}(x_{i_j})},\left(1-\prod_{1\le i_1\le n}(1-T_{x_{i_1}})^{\frac{1}{n}},\prod_{1\le i_1\le n}I_{x_{i_1}}^{\frac{1}{n}},\prod_{1\le i_1\le n}F_{x_{i_1}}^{\frac{1}{n}}\right)\right\rangle$$

$$=\mathrm{SVNLG}(x_1,x_2,\cdots,x_n).$$

3.2. SVNLRWDMSM operator

Definition 9. Let $x_i=<s_{\theta(x_i)},(T_{x_i},I_{x_i},F_{x_i})>$ $(i=1,2,\cdots,n)$ be a set of SVNLNs and let $W=$

$(w_1, w_2, \cdots, w_n)^T$ be the weight vector in which $w_i \in [0,1]$ and $\sum_{i=1}^n w_i = 1$. The SVNLRWDMSM, $\Omega^n \to \Omega$; an SVNLRWDMSM operator is suggested in the following:

$$\mathrm{SVNLRWDMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \frac{\prod\limits_{1 \le i_1 < \cdots < i_k \le n} \left(\sum\limits_{j=1}^{k} x_{i_j} \right)^{\frac{\sum_{j=1}^{k} w_{i_j}}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}}}{k}, \tag{12}$$

where Ω is the set of entire SVNLNs and then, SVNL-RWDMSM is known as the single-valued neutrosophic linguistic RWDMSM operator.

Based on the operational laws of the SVNLNs defined in Definition 2 and Eq. (12), we can obtain the aggregated results shown in Theorem 6.

Theorem 6. *Let $x_i =< s_{\theta(x_i)}, (T_{x_i}, I_{x_i}, F_{x_i}) >$ $(i = 1, 2, \cdots, n)$ be a set of SVNLNs, and let $W = (w_1, w_2, \cdots, w_n)^T$ be the weight vector with $w_i \in [0,1]$ and $\sum_{i=1}^n w_i = 1$; then, the result of SVNLRWDMSM operator is notwithstanding an SVNLN.*

Eq. (13) is shown in Box VI.

Remark 1. The SVNLRWDMSM operator also owns the monotonicity, idempotency, boundedness, and commutativity.

Later, we discuss some particular cases of the SVNLRWDMSM by regulating the argument k.

Case 1: In the event of $k = 1$, the SVNLRWDMSM reduces to an SVNLWG operator.

$$\mathrm{SVNLRWDMSM}^{(1)}(x_1, x_2, \cdots, x_n)$$

$$=< s_{\prod\limits_{1 \le i_1 \le n} \theta^{w_{i_j}}(x_{i_j})}, \Bigg(\prod_{1 \le i_1 \le n} T_{x_{i_j}}^{w_{i_j}},$$

$$\prod_{1 \le i_1 \le n} 1 - (1 - I_{x_{i_j}})^{w_{i_j}},$$

$$\prod_{1 \le i_1 \le n} 1 - (1 - F_{x_{i_j}})^{w_{i_j}} \Bigg) >$$

$$= \mathrm{SVNLWG}(x_1, x_2, \cdots, x_n).$$

Case 2: In the event of $k = n$, the SVNLRWDMSM

$$\mathrm{SVNLRWDMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left\langle s_{\frac{\prod\limits_{1 \le i_1 < \cdots < i_k \le n} \left(\sum_{j=1}^{k} \theta(x_{i_j}) \right)^{\frac{\sum_{j=1}^{k} w_{i_j}}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}}}{k}}, \right.$$

$$\left(1 - \left(1 - \left(\prod_{1 \le i_1 < \cdots < i_k \le n} \left(1 - \prod_{j=1}^{k} (1 - T_{x_{i_j}}) \right)^{\sum_{j=1}^{k} w_{i_j}} \right)^{\frac{1}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}} \right)^{1/k} \right),$$

$$\left(1 - \left(\prod_{1 \le i_1 < \cdots < i_k \le n} \left(1 - \prod_{j=1}^{k} I_{x_{i_j}} \right)^{\sum_{j=1}^{k} w_{i_j}} \right)^{\frac{1}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}} \right)^{1/k},$$

$$\left. \left(1 - \left(\prod_{1 \le i_1 < \cdots < i_k \le n} \left(1 - \prod_{j=1}^{k} F_{x_{i_j}} \right)^{\sum_{j=1}^{k} w_{i_j}} \right)^{\frac{1}{\sum_{1 \le i_1 < \cdots < i_k \le n} \sum_{j=1}^{k} w_{i_j}}} \right)^{1/k} \right) \right\rangle. \tag{13}$$

Box VI

reduces to an SVNLA operator [16].

$$\text{SVNLRWMSM}^{(n)}(x_1, x_2, \cdots, x_n) =$$

$$= \left\langle s_{\sum_{j=1}^{n} \frac{\theta(x_{i_j})}{n}}, \left(1 - \prod_{1 \le i_1 \le n} (1 - T_{x_{i_1}})^{\frac{1}{n}}, \prod_{1 \le i_1 \le n} I_{x_{i_1}}^{\frac{1}{n}}, \prod_{1 \le i_1 \le n} F_{x_{i_1}}^{\frac{1}{n}}\right)\right\rangle$$

$$= \text{SVNLA}(x_1, x_2, \cdots, x_n)$$

Remark 2. In particular, it is vital that SVNLR-WMSM or SVNLRWDMSM operator cannot have the reciprocity among many given arguments while $k = 1$ or $k = n$. In other words, both of them are reduced into the self-governed operators such as SVNLA, SVNLG, SVNWLA, and SVNWLG [16].

4. MCDM algorithms based on SVNLRWMSM and SVNLRWDMSM

4.1. Description of the MCDM problems

Suppose that $A = \{A_1, A_2, \cdots, A_m\}$ be a set of alternatives, $C = \{C_1, C_2, \cdots, C_n\}$ be a set of n criteria, and $W = \{w_1, w_2, \cdots, w_n\}$ be the weight vector assigned to the attributes by the DMs with the normal constraints $w_j \in [0, 1], \sum_{j=1}^{n} w_j = 1$. Assume that the whole evaluation information of the alternatives with respect to criteria is suggested by SVNL matrix $P = (p_{ij})_{m \times n} = (< s_{\theta_{ij}}, (T_{ij}, I_{ij}, F_{ij}) >)_{m \times n}$. The evaluation values associated with the alternatives for the formalization of MCDM issues are given in Table 1.

4.2. The MCDM method based on SVNLRWMSM or SVNLRWDMSM operator

In order to make a decision, the decision-making framework for employing the proposed methods is presented in Figure 1.

In the meantime, Algorithm 1 is given for SVNL-RWMSM or SVNLRWDMSM operator.

4.3. A case of TMESQE

In determining the TMESQE indicators, the literature research method is mainly adopted and the index system is constructed by summarizing relevant research results and combining practical investigation with index design principles. Upon taking all factors into consideration, the relevant literature is studied to

Table 1. A general Single-Valued Neutrosophic Linguistic (SVNL) Multi-Criteria Decision Making (MCDM) matrix.

	C_1	C_2	$\cdots$	C_n
A_1	$< s_{\theta_{11}}, (T_{11}, I_{11}, F_{11}) >$	$< s_{\theta_{12}}, (T_{12}, I_{12}, F_{12}) >$	$\cdots$	$< s_{\theta_{1n}}, (T_{1n}, I_{1n}, F_{1n}) >$
A_2	$< s_{\theta_{21}}, (T_{21}, I_{21}, F_{21}) >$	$< s_{\theta_{22}}, (T_{22}, I_{22}, F_{22}) >$	$\cdots$	$< s_{\theta_{2n}}, (T_{2n}, I_{2n}, F_{2n}) >$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
A_m	$< s_{\theta_{m1}}, (T_{m1}, I_{m1}, F_{m1}) >$	$< s_{\theta_{m2}}, (T_{m2}, I_{m2}, F_{m2}) >$	$\cdots$	$< s_{\theta_{mn}}, (T_{mn}, I_{mn}, F_{mn}) >$

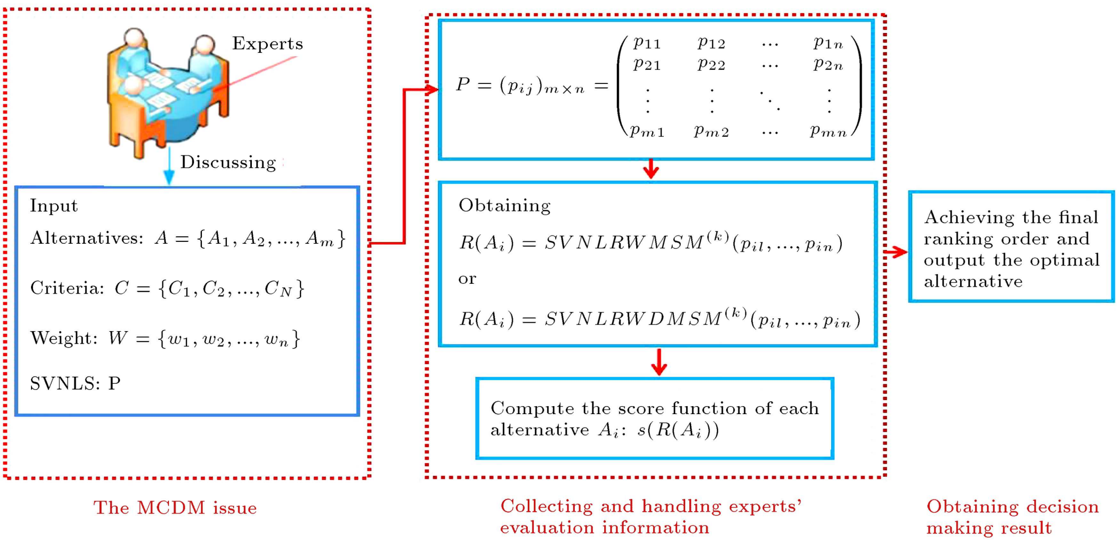

Figure 1. The decision-making framework for employing the developed methods. Single-Valued Neutrosophic Linguistic Set: SVNLS; Single-Valued Neutrosophic Linguistic Reducible Weighted Maclaurin Symmetric Mean: SVNLRWMSM; Single-Valued Neutrosophic Linguistic Reducible Weighted Dual Maclaurin Symmetric Mean: SVNLRWDMSM; and Multi-Criteria Decision-Making: MCDM.

1: Select the given attributes and alternatives, and obtain the SVNL matrix $P=(p_{ij})_{m\times n}$ which is presented in Table 1.
2: Switch matrix $P=(p_{ij})_{m\times n}$ into a normalized SVNL matrix $P'=(p'_{ij})_{n\times m}$ by Eq. (14).

$$p'_{ij}=\begin{cases}< s_{\theta_{ij}},(T_{ij},I_{ij},F_{ij})>, & C_j \text{ is benefit criteria},\\ < s_{l-\theta_{ij}},(F_{ij},1-I_{ij},T_{ij})>, & C_j \text{ is cost criteria}.\end{cases} \tag{14}$$

3: Use the SVNLRWMSM operator

$$R(A_i)=< s_{\theta_i},(T_i,I_i,F_i)>=\text{SVNLRWMSM}^{(k)}(p'_{i1},p'_{i2},\cdots,p'_{in}), \tag{15}$$

or utilize the SVNLRWDMSM operator

$$R(A_i)=< s_{\theta_i},(T_i,\hat{I}_i,F_i)>=\text{SVNLRWDMSM}^{(k)}(p'_{i1},p'_{i2},\cdots,p'_{in}) \tag{16}$$

to get the integrated value.
4: Compute score function $s(R(A_i))$ of the entire values $R(A_i)(i=1,2,\cdots,m)$.
5: Choose the best alternative(s) by $R(A_i)$.

Algorithm 1. SVNLRWMSM or SVNLRWDMSM operator.

collect and sort out the previous influencing factors of user experience, tourism service, and mobile e-commerce. According to the above, six evaluation dimensions are extracted, which are content experience, interactivity, security, sensitivity, personalization, and travel experience.

A preliminary evaluation index system of TME service quality level is built. Six preliminary criteria $(C_1,C_2,C_3,\ C_4,C_5,C_6)$ are established in the evaluation index system related to tourism products. The detailed description of each criterion is given in Table 2.

Example 1. Suppose that there are five influential tourism products $A=\{A_1,A_2,A_3,A_4,A_5\}$ to be considered. The experts choose the highly representative attribute sets:

- $C=\{C_1$(Content experience);
- C_2 (Interactivity);
- C_3 (Security);
- C_4 (Sensitivity);
- C_5 (Personalization);
- and C_6 (Travel experience)$\}$.

According to the evaluation principle of the TME service quality, we can determine that the whole criteria are benefit criteria. Moreover, the weight information given by experts is $w=(0.2,0.3,0.1,0.1,0.1,0.2)$. The experts assess these tourism products by SVNLNs under the LTS $S=\{s_0=$ extremely bad, $s_1=$ very bad, $s_2=$ bad, $s_3=$ fair, $s_4=$ good, $s_5=$ very good, and $s_6=$ extremely good$\}$ and generate the final SVNL matrix in Table 3.

Next, we employ the above developed algorithm in selecting the most popular tourism product under SVNL text.

Step 1: Select the attributes and alternatives and achieve the SVNL matrix $P=(p_{ij})_{5\times 6}$ which is presented in Table 3.

Step 2: No transformation is needed because entire criteria are beneficial criteria.

Step 3: Utilize the SVNLRWMSM$^{(1)}$ operator to integrate the decision value as follows:

$$R(A_1)=< s_{5.2000},(0.8375,0.1072,0.1231)>,$$

$$R(A_2)=< s_{4.7000},(0.7509,0.1741,0.1692)>,$$

$$R(A_3)=< s_{4.3000},(0.6768,0.1741,0.2195)>,$$

$$R(A_4)=< s_{3.7000},(0.5655,0.1888,0.1911)>,$$

$$R(A_5)=< s_{3.4000},(0.4644,0.1888,0.1911)>,$$

or utilize SVNLRWDMSM$^{(1)}$ operator to integrate the decision value as follows:

$$R(A_1)=< s_{5.1857},(0.8288,0.1105,0.1312)>,$$

$$R(A_2)=< s_{4.6382},(0.7354,0.1809,0.1822)>,$$

$$R(A_3)=< s_{4.2149},(0.6670,0.1809,0.2326)>,$$

$$R(A_4)=< s_{3.6222},(0.5562,0.2025,0.2143)>,$$

$$R(A_5)=< s_{3.3227},(0.4554,0.2025,0.2143)>.$$

Step 4: Calculate the score function $s(R(A_i))$ of the entire values $R(A_i)(i=1,2,3,4,5)$ as follows:

SVNLRWMSM:

$$s(R(A_1))=4.5192,\qquad s(R(A_2))=3.7719,$$

$$s(R(A_3))=3.2726,\qquad s(R(A_4))=2.6956,$$

$$s(R(A_5))=2.3624.$$

Table 2. The evaluation criteria of tourism products.

Criteria	Brief description
Content experience (C_1)	TME has very rich service functions. Users can query tourism information, payment, booking and sharing experience through the service platform on mobile devices. All the service functions of TME are designed on the basis of content; thus, the quality of service content is closely related to the quality of user experience. By sorting out the literature, the content perception from five aspects, including complete and comprehensive services, true and accurate information content, novel and timely information content, easy to understand in information and concise and orderly information content.
Interactivity (C_2)	The real purpose of user experience is to get information content, and the main means is to use interaction, which can ensure the smooth process of user's content experience. The interaction behavior appears in the whole process of user experience. The interaction process between users and products is the learning process in which users are gradually becoming familiar with service products. Each step of user expansion of service products can be regarded as the communication and interaction with service products. Interactivity can be reflected in the following five aspects: easy to learn service products, smooth operation process, good fault tolerance, timely feedback and real-time interaction.
Security (C_3)	As is known, the basic principle of mobile online travel is absolute safety. For example, when booking and paying for tickets or tickets for scenic spots, some users will also consider the validity and security of the transaction and worry about whether their bank and private information will be leaked. Therefore, before providing the service, travel mobile e-commerce service operators should solve the security problems that consumers are worried about and guarantee that they can enjoy the best service. Security can be reflected in four aspects: payment security, transaction validity, protection of rights and interests, and data information security.
Sensitivity (C_4)	Sensitivity experience refers to the feelings generated by consumers in hearing, touch, vision and psychology when they use the product or enjoy the service. When the TME platform provides various services for consumers, users can have a perception of the price and appearance of service products. In addition to enhancing the pleasure of browsing, good user experience can also enhance the interactive experience of users and service products, helping the company establish a good brand image. It can be reflected in four aspects: beautiful interface, reasonable layout, brand, reputation image, service price, trust degree and credit degree.
Personalization (C_5)	Different users have different demands and expectations for service information. Even the functional preferences and interaction behaviors of the same service product may have different requirements due to individual differences; thus, the experiential experience in the service process will be different. When providing mobile tourism services for users, individual differences should be taken into account, including the differences between different individuals in their hobbies and content needs. Based on this, the function of online travel service is adjusted to meet the diverse standards of different users. It can be reflected in four aspects: conforming to user habits, meeting user preferences and expectations, upgrading and updating of service products, and emotional perception of users.
Travel experience (C_6)	As the key content of online travel, travel experience is of great significance. Even if customers cannot experience good e-services on the platform and if they can create perfect practical experience for users, the overall service quality will be highly evaluated. It is reflected as follows: real product information description, service attitude, etiquette in place, and service emergency remedy.

Table 3. The Single-Valued Neutrosophic Linguistic (SVNL) matrix in Example 1.

	C_1	C_2	C_3
A_1	$< s_6, (0.9, 0.1, 0.1) >$	$< s_5, (0.8, 0.1, 0.2) >$	$< s_5, (0.8, 0.2, 0.1) >$
A_2	$< s_6, (0.8, 0.1, 0.2) >$	$< s_5, (0.8, 0.2, 0.2) >$	$< s_4, (0.7, 0.2, 0.3) >$
A_3	$< s_6, (0.7, 0.1, 0.2) >$	$< s_4, (0.7, 0.2, 0.3) >$	$< s_3, (0.6, 0.2, 0.1) >$
A_4	$< s_5, (0.5, 0.1, 0.2) >$	$< s_4, (0.6, 0.2, 0.3) >$	$< s_3, (0.6, 0.2, 0.2) >$
A_5	$< s_5, (0.4, 0.1, 0.2) >$	$< s_3, (0.5, 0.2, 0.3) >$	$< s_3, (0.5, 0.2, 0.2) >$
	C_4	C_5	C_6
A_1	$< s_5, (0.9, 0.1, 0.1) >$	$< s_5, (0.8, 0.1, 0.1) >$	$< s_5, (0.8, 0.1, 0.1) >$
A_2	$< s_4, (0.8, 0.2, 0.2) >$	$< s_4, (0.7, 0.2, 0.1) >$	$< s_4, (0.6, 0.2, 0.1) >$
A_3	$< s_4, (0.8, 0.2, 0.3) >$	$< s_4, (0.6, 0.2, 0.2) >$	$< s_4, (0.6, 0.2, 0.2) >$
A_4	$< s_3, (0.7, 0.2, 0.3) >$	$< s_3, (0.5, 0.2, 0.1) >$	$< s_3, (0.5, 0.3, 0.1) >$
A_5	$< s_3, (0.6, 0.2, 0.3) >$	$< s_3, (0.4, 0.2, 0.1) >$	$< s_3, (0.4, 0.3, 0.1) >$

SVNLRWDMSM:

$$s(R(A_1)) = 4.4718, \qquad s(R(A_2)) = 3.6676,$$

$$s(R(A_3)) = 3.1660, \qquad s(R(A_4)) = 2.5831,$$

$$s(R(A_5)) = 2.2579.$$

Step 5: According to the above score function $s(R(A_i))(i = 1, 2, 3, 4, 5)$, we can achieve the ranking of the tourism products as $A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$.

4.4. Sensitivity analysis

For discussing the sensitivity of the parameters k of score values, an experiment (Example 1) was constructed by taking various values of $k(k = 1, 2, 3, 4, 5, 6)$.

According to the SVNLRWMSM operator and SVNLRWDMSM operator, the final score values of five tourism products are shown in Figure 2 and Table 4, respectively. From Figure 2 and Table 4, some key points are given in the following:

1. For SVNLRWMSM, the score values of the entire five tourism products are monotonically increasing first if $k \in [1, 5]$ and later monotonically decreasing if $k \in [5, 6]$. Moreover, it is not difficult to determine the final ranking owing to the same values obtained that vary from 2.2396 to 4.4623 with a diverse value of 2.22 when $k = 6$. The final ranking results are all ranked as:

$$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5.$$

2. For SVNLRWDMSM, the score values of the entire five tourism products are firstly monotonically decreasing if $k \in [1, 5]$ and later monotonically increasing if $k \in [5, 6]$. In addition, it is very clear to determine the final ranking compared with the SVNLRWMSM algorithm when $k = 3, 4, 5$. The final results are all ranked as follows:

$$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5.$$

3. The reason for the inflection point is that $k = 1$ is the modality of AO firstly and $k = 6$ is the modality of Geometric Operator (GO) at the end for SVNLRWMSM. Homoplastically, it experiences the transformation from GO to AO for SVNLR-WDMSM.

4. The values at both ends ($k = 1$ and $k = 6$) have an interesting case. For SVNLRWMSM, the score of five tourism products is the minimum compared with $k = 1, 2, 3, 4, 5$ if $k = 6$ (GO form). For

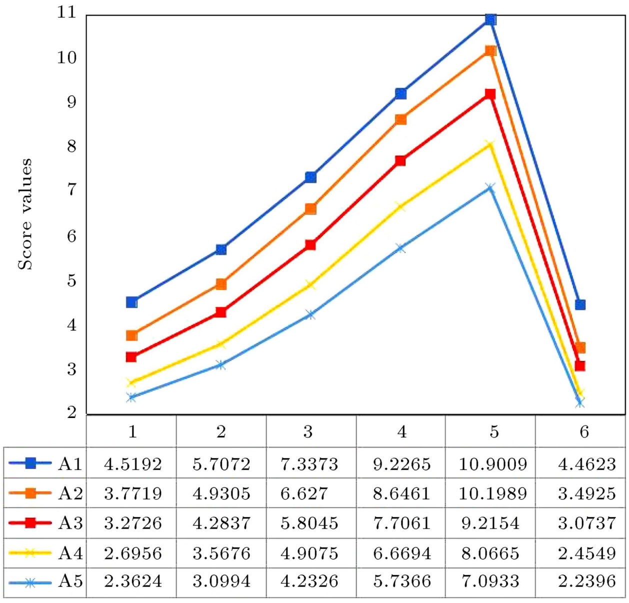

Figure 2. The total changing trend of parameter k based on Single-Valued Neutrosophic Linguistic Reducible Weighted MSM (SVNLRWMSM).

Table 4. Ranking results of the tourism products with different k's by Single-Valued Neutrosophic Linguistic Reducible Weighted Dual MSM (SVNLRWDMSM) algorithm.

k	Score values	Ordering	Optimal product
$k=1$	$s(R(A_1))=4.4718$ $s(R(A_2))=3.6676$ $s(R(A_3))=3.1660$ $s(R(A_4))=2.5831$ $s(R(A_5))=2.2579$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
$k=2$	$s(R(A_1))=9.2555$ $s(R(A_2))=7.1671$ $s(R(A_3))=5.9762$ $s(R(A_4))=4.6179$ $s(R(A_5))=3.9624$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
$k=3$	$s(R(A_1))=193.3486$ $s(R(A_2))=130.0276$ $s(R(A_3))=96.3677$ $s(R(A_4))=63.0655$ $s(R(A_5))=49.5881$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
$k=4$	$s(R(A_1))=23854335.1334$ $s(R(A_2))=10580324.2317$ $s(R(A_3))=5179747.5209$ $s(R(A_4))=2014156.7743$ $s(R(A_5))=1166101.9310$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
$k=5$	$s(R(A_1))=7063199394498912800000$ $s(R(A_2))=1263542238585532600000$ $s(R(A_3))=205841703782452300000$ $s(R(A_4))=19940651603072893000$ $s(R(A_5))=4539064194324627500$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
$k=6$	$s(R(A_1))=4.5059$ $s(R(A_2))=3.5925$ $s(R(A_3))=3.1862$ $s(R(A_4))=2.5683$ $s(R(A_5))=2.3333$	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1

SVNLRWDMSM, the score of five tourism products is at a maximum compared with $k=1,2,3,4,5$ if $k=6$ (AO form).

5. Comparative analysis

In the following, some existing decision-making methods [5,8,9,12–18] with their final decision-making results and their characteristics are explored in detail.

Remark 3. Based on Table 5, we can find that the developed algorithms have achieved the identical ordering results with the existing methods [5,8,9,12,14–18], suggesting that the developed algorithms (SVNLRWMSM and SVNLRWDMSM) are feasible and reasonable for decision-making issues involving SVNL information.

With respect to some SVNL AOs, only the references [15,18] took the reciprocity of the criteria into consideration. To better distinguish the features of existing SVNL AOs, we make an overview of them shown in Table 6. According to Table 6, the developed AOs are based on RWMSM operators with the parameter k. Therefore, the initiated AOs (SVNLRWMSM and SVNLRWDMSM) are more global than some existing

Table 5. A comparison study in Example 1.

Algorithms	Ranking	Optimal alternative
Algorithm 1: SVNLRWMSM[a]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Algorithm 1: SVNLRWDMSM[b]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Ye [5]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Tian et al. [15]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Tian et al. [14]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Wang et al. [17]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Ji et al. [9]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Chen el al. [8]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Tian et al. [12]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Luo et al. [10]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Tan et al. [16]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Wang et al. [18]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Wang et al. [18]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1
Wang et al. [18]	$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$	A_1

[a]SVNLRWMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted Maclaurin Symmetric Mean;
[b]SVNLRWDMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted Dual Maclaurin Symmetric Mean.

Table 6. The characteristic comparisons of various Single-Valued Neutrosophic Linguistic (SVNL) Aggregation Operator (AO).

Aggregation operators	Consider interrelationships between two arguments?	Make the information aggregation more flexible by a parameter?	Consider interrelationships among multiple arguments?
[13]	No	No	No
[13]	No	No	No
[17]	No	No	No
[16]	No	Yes	No
[16]	No	Yes	No
[16]	No	Yes	No
[15]	Yes	No	No
[18]	Yes	No	No
[18]	Yes	No	No
[18]	Yes	No	No
SVNLRWMSM[a]	Yes	Yes	Yes
SVNLRWDMSM[b]	Yes	Yes	Yes

[a]SVNLRWMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted Maclaurin Symmetric Mean;
[b]SVNLRWDMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted Dual Maclaurin Symmetric Mean.

AOs. At the same time, they can take the interrelation of multiple criteria into consideration for dealing with MCDM problems.

For a better comparison with certain MSM operators in various vague environments [20–33], we make an overview of them given in Table 7.

From Table 7, some existing WMSM operators do not have the idempotency. In addition, the WMSM fails to reduce the MSM when their weights information is equivalent. In other words, it means out of reducibility.

6. Conclusion

The dominating contributions are listed as follows:

1. Two novel SVNL AOs including Single-Valued Neutrosophic Linguistic Reducible Weighted MSM (SVNLRWMSM) and Single-Valued Neutrosophic Linguistic Reducible Weighted Dual MSM (SVNLRWDMSM) are presented;
2. Certain properties (monotonicity, idempotency, boundedness, commutativity, and reducibility) are

Table 7. Characteristic comparisons of various indeterminate environments of Maclaurin Symmetric Mean (MSM).

Sets	Aggregation operators	Have the idempotency?	Have the reducibility?
SVNLS	SVNLRWMSM	Yes	Yes
SVNLS	SVNLRWDMSM	Yes	Yes
IFS	[20]	No	No
ULS	[21]	No	No
ILS	[22]	No	No
IULS	[22]	No	No
LIFS	[23]	No	No
LIFS	[23]	No	No
PFS	[24]	No	No
HFLS	[25]	No	No
PFS	[26]	No	No
q-ROFS	[26]	Yes	No
q-ROFS	[26]	Yes	No
q-ROFS	[33]	Yes	No
HFS	[27]	No	No
SVTNS	[28]	No	No
INLS	[29]	No	No
SVNI2TLS	[30]	No	No
2TLS	[31]	No	No

Note: SVNLRWMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted MSM,
SVNLRWDMSM: Single-Valued Neutrosophic Linguistic Reducible Weighted Dual MSM,
2TLS: 2-Tuple Linguistic Set, INLS: Interval Neutrosophic Linguistic Set, IFS: Intuitionistic Fuzzy Set,
ILS: Intuitionistic Linguistic Set, IULS: Intuitionistic Uncertain Linguistic Set,
LIFS: Linguistic Intuitionistic Fuzzy Set, HFLS: Hesitant Fuzzy Linguistic Set, HFS: Hesitant Fuzzy Set,
PFS: Pythagorean Fuzzy Set, q-ROFS: q-rung Orthopair Fuzzy Set, SVN-I2TLS: Single-Valued
Neutrosophic Interval 2-Tuple Linguistic Set, SVNLS: Single-Valued Neutrosophic Linguistic Set,
SVTNS: Single-Valued Trapezoidal Neutrosophic Set, ULS: Uncertain Linguistic Set.

explored under SVNL environment. Certain existing Maclaurin Symmetric Mean (MSM) operators in various indeterminate environments [20–33] fail to have idempotency or reducibility;

3. Two SVNL Multi-Criteria Decision-Making (MCDM) methods based on SVNLRWMSM and SVNLRWDMSM are introduced. The sensitivity analysis of different k's on the ranking is discussed (Figure 2 and Table 4);
4. A synthesized appraisal system of six evaluation dimensions is extracted (content experience, interactivity, security, sensitivity, personalization, and travel experience) and it is employed to select the ideal tourism product.

In the future, the SVNLRWMSM and SVNLR-WDMSM are applied in computational biology domain such as gene selection [35,36]. Besides, we will also put the Reducible Weighted Dual MSM (RWDMSM) and Reducible WMSM (RWMSM) operators into various uncertain circumstances [37–49].

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