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 arises tremendous vagueness and reciprocity for TMESQE. The Maclaurin symmetric mean (MSM), as a vital fusion approach, can capture the reciprocity between multiple given argument more effectually. Amount of weighted MSM (WMSM) has been presented for dealing 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 WMSM (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. Whereafter, we explore two multi-criteria decision making (MCDM) algorithms based on SVNLRWMSM and SVNLRWDMSM for dealing the TMESQE issue, along with the sensitivity analysis of various values on final ordering. Conclusively, the comparison with some existing algorithms has been conducted for showing their availability.

Keywords: Single-valued neutrosophic linguistic set; Reducibility; Idempotency; SVNLRWMSM; SVNLRWDMSM.

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, have 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

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is 788 million, accounting for 98.3 percent of the total number of Internet users. It can be seen that people’s life is more and more inclined to 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 billion, up 11.4 percent 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. Especially 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 has been 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 make tourism. The mobile e-commerce platform can control the itinerary by itself, and people begin to enjoy the convenience and fun brought 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 a lot of 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 in a disadvantaged position. 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]. Because of this, the constructing of evaluation model based on users’ experience is critical for improving both the user experience and the service quality of the company. Nevertheless, the growingly 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], has 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) which 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 TME service quality evaluation
(TMESQE). For instance, when a DM or 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, and without of limiting in the sum of three degrees. SVNNs 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 more attention and obtained certain exciting achievements [8–11]. Tian et al [12] developed some power aggregation for SVNLS in green product design selection process. Ye [13] presented the SVNL weighted arithmetic average and SVNL weighted geometric average for dealing the selection of flexible manufacturing system. Tian et al. [14,15] proposed the single-valued neutrosophic linguistic normalized weighted Bonferroni mean (SVNLNWB BM) operator for dealing 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 which can have a 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 operator [18] for solving the hotel selection.

However, it just capture the interaction among a constant number of parameters by the above aggregation operators (AOs) [12–18]. For instance, the Heronian mean (HM) operator just captures the correlation among two parameters. For boosting the elasticity of information integration, Maclaurin [19] presented the Maclaurin symmetric mean (MSM) operator which can seize the interaction among any number of parameters. Qin and Liu [20] initially combined MSM operator with intuitionistic fuzzy environment in 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 environment [21–33]. According to the research of WMSM operators in various uncertain environment, it can be easily seen two counter-intuitive issues in the following. (1) When weight information in entire parameters are same, the corresponding WMSM operators [21–33] fail to degenerate into consistent MSM operators, which is a key peculiarity of the traditional weighted operators. (2) Such kinds of WMSM operators [21–31] are out of the idempotency. That is to say, it is illogical that the weighted average value of certain selfsame aggregated parameters rely on corresponding weight values. Illuminated by reducible WMSM (RWMSM) operator and reducible weighted dual MSM (RWDMSM) operator [34], we fuse the above-mentioned operators with SVNLS for fusing single-valued neutrosophic linguistic information and dealing 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 aggregation operators (single-valued neutrosophic linguistic RWMSM (SVNLRWMSM) and single-valued neutrosophic linguistic RWDMSM (SVNLRWDMSM)) for integrating the decision preferences of DMs or experts;
(2) Present two MCDM algorithms based SVNLRWMSM and SVNLRWDMSM for dealing the TME service quality issue;

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

(4) Construct a comprehensive appraise system for TME service quality.

The remaining of the paper is listed in the following. In Sect. 2, we simply retrospect fundamental notions of SVNLS, the MSM, RWMSM, DMSM and R-WDMSM operator. In Sect. 3, the SVNLRWMSM operator and SVNLRWDMSM operator are presented with their interesting properties. In Sect. 4, two MADM algorithms based SVNLRWMSM operator and SVNLRWDMSM operator with single-valued neutrosophic linguistic number. In addition, we employ an example of TME service quality to state the feasibility of MCDM approaches by presenting the effect of the diverse argument values on final ordering of the alternatives. In Sect. 5, a comparison with certain existing MCDM algorithms is presented. Also, the characteristic comparisons of diverse SVNLAOs and various inconclusive environment are worked. Finally, Sect. 6 shows 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 $S = \{s_0, s_1, \ldots, s_l\}$ be a limited and total ordered discrete linguistic term set (LTS). The SVNLS can be denoted in the following.

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

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 named as single-valued neutrosophic linguistic number (SVNLN). For simplicity, an SVNLN is defined as $a = < s_{\theta(x)}, (T_a, I_a, F_a) >$.

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 SVNLSs and $\lambda > 0$, then operations are denoted in the following.

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

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 denoted 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

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

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

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

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

Definition 5 [21] Let $x_i$ ($i = 1, 2, \ldots, n$) be a set of nonnegative real numbers, and $k = 1, 2, \ldots, n$, then dual Maclaurin symmetric mean (DMSM) operator is denoted as

$$\text{DMSM}^{(k)}(x_1, x_2, \ldots, x_n) = \left( \frac{\sum_{1 \leq i_1 < \cdots < i_k \leq n} \prod_{j=1}^{k} w_{i_j} \prod_{j=1}^{k} x_{i_j}}{C_n^k} \right)^{1/k},$$

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

In the sake of addressing the problems of idempotency and reducibility, Shi and Xiao [34] introduced reducible weighted dual MSM (RWDMSM) and reducible weighted MSM (RWMSM).

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

$$\text{RWMSM}^{(k)}(x_1, x_2, \ldots, x_n) = \left( \frac{\sum_{1 \leq i_1 < \cdots < i_k \leq n} \prod_{j=1}^{k} w_{i_j} \prod_{j=1}^{k} x_{i_j}}{\sum_{1 \leq i_1 < \cdots < i_k \leq n} \prod_{j=1}^{k} w_{i_j}} \right)^{1/k}.$$
Definition 7 [34] Let \( x_i (i = 1, 2, \ldots, n) \) be a series of nonnegative real numbers, \( k = 1, 2, \ldots, n \), and \( W = (w_1, w_2, \ldots, w_n)^T \) with \( w_i \in [0, 1] \) and \( \sum_{i=1}^{n} w_i = 1 \), then RWDMSM operator is denoted as follows:

\[
\text{RWDMSM}(x_1, x_2, \ldots, x_n) = \frac{\prod_{1 \leq i_1 < \cdots < i_k \leq n} (\prod_{j=1}^{k} x_{i_j})^{1/k}}{1 \leq i_1 < \cdots < i_k \leq n}.
\]

3 Single-valued neutrosophic linguistic RWMSMs

3.1 Single-valued neutrosophic linguistic RWMSM operator

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

\[
\text{SVNLRWMSM}(x_1, x_2, \ldots, x_n) = \left( \prod_{1 \leq i_1 < \cdots < i_k \leq n} (\prod_{j=1}^{k} w_{i_j}) \right)^{1/k} \left( \frac{1 \leq i_1 < \cdots < i_k \leq n}{1 \leq i_1 < \cdots < i_k \leq n} \sum_{j=1}^{k} \prod_{1 \leq i_1 < \cdots < i_k \leq n} w_{i_j} \right)^{1/k}.
\]

where \( \Omega \) is the set of entire SVNLNs, then SVNLRWMSM is named single-valued neutrosophic linguistic RWMSM operator.

Based on the operational laws of SVNLNs defined in Definition 2 and Equation 6, we can obtain the aggregated result which is presented in Theorem 1.

Theorem 1 Let \( x_i =< s_{\theta(x_i)}, (T_{x_i}, I_{x_i}, F_{x_i}) > (i = 1, 2, \ldots, n) \) be a series of SVNLNs, and let \( w = (w_1, w_2, \ldots, w_n)^T \) be a weight vector that \( w_i \in [0, 1] \) and \( \sum_{i=1}^{n} w_i = 1 \), then the final result of SVNLRWMSM operator is still an SVNLN.
Proof According to the Definition 2, we can have

\[
\prod_{j=1}^{k} x_{ij} = \left\langle s, \prod_{j=1}^{k} \theta(x_{ij}) \right| \left( \prod_{j=1}^{k} T_{x_{ij}}, 1 - \prod_{j=1}^{k} (1 - I_{x_{ij}}), 1 - \prod_{j=1}^{k} (1 - F_{x_{ij}}) \right) \right\rangle
\]

and

\[
\left( \prod_{j=1}^{k} w_{ij} \right) \left( \prod_{j=1}^{k} x_{ij} \right) = \left\langle s, \prod_{j=1}^{k} \theta(x_{ij}) \right| \left( \prod_{j=1}^{k} w_{ij}, 1 - \prod_{j=1}^{k} T_{x_{ij}} \right) \left( 1 - \prod_{j=1}^{k} (1 - I_{x_{ij}}) \right) \frac{\prod_{j=1}^{k} w_{ij}}{1 - \prod_{j=1}^{k} (1 - F_{x_{ij}})} \right\rangle.
\]

Further,

\[
\sum_{1 \leq i_1 < \ldots < i_k \leq n} \left( \prod_{j=1}^{k} w_{ij} \right) \left( \prod_{j=1}^{k} x_{ij} \right) = \left\langle s, \sum_{1 \leq i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} \theta(x_{ij}) \right| \left( \prod_{j=1}^{k} w_{ij}, 1 - \prod_{i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} T_{x_{ij}} \right) \left( 1 - \prod_{i_1 < \ldots < i_k \leq n} (1 - I_{x_{ij}}) \right) \sum_{1 \leq i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} w_{ij} \right\rangle.
\]

Consequently,

\[
\left. \sum_{1 \leq i_1 < \ldots < i_k \leq n} \left( \prod_{j=1}^{k} w_{ij} \right) \left( \prod_{j=1}^{k} x_{ij} \right) \right| = \left\langle s, \sum_{1 \leq i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} \theta(x_{ij}) \right| \left( \sum_{1 \leq i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} w_{ij}, 1 - \prod_{i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} T_{x_{ij}} \right) \left( 1 - \prod_{i_1 < \ldots < i_k \leq n} (1 - I_{x_{ij}}) \right) \sum_{1 \leq i_1 < \ldots < i_k \leq n} \prod_{j=1}^{k} w_{ij} \right\rangle.
\]

In the end, we can obtain
Suppose that $\text{SVNLWMSM}^{(\theta)}(x_1, x_2, \ldots, x_n) = \left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} \left(\prod_{j=1}^{k} w_{i_j}\right) \prod_{j=1}^{k} x_{i_j}\right)^{1/k}$

$$= \left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} \left(\prod_{j=1}^{k} u_{i_j}\right) \prod_{j=1}^{k} x_{i_j}\right)^{1/k},$$

$$= \left(1 - \left(\prod_{i \in I} \left(1 - \prod_{j=1}^{k} T_{x_{i_j}}\right) \prod_{j=1}^{k} u_{i_j}\right) \prod_{j=1}^{k} x_{i_j}\right)^{1/k} \leq 1,$$

$$= \left(1 - \left(\prod_{i \in I} \left(1 - \prod_{j=1}^{k} (1 - I_{x_{i_j}})\right) \prod_{j=1}^{k} u_{i_j}\right) \prod_{j=1}^{k} x_{i_j}\right)^{1/k} \leq 1,$$

$$= \left(1 - \left(\prod_{i \in I} \left(1 - \prod_{j=1}^{k} (1 - F_{x_{i_j}})\right) \prod_{j=1}^{k} u_{i_j}\right) \prod_{j=1}^{k} x_{i_j}\right)^{1/k} \leq 1.$$

Consequently, we can consider that the aggregated results from Equation 7 is an SVNLW.

**Theorem 2 (Monotonicity)** Let $x_i (i = 1, 2, \ldots, n)$ and $x'_i (i = 1, 2, \ldots, n)$ be two sets of SVNLNs, if $x'_i = < s_{\theta(x'_i)}; T'_{x'_i}, I'_{x'_i}, F'_{x'_i} >$, $x_i = < s_{\theta(x_i)}; T_{x_i}, I_{x_i}, F_{x_i} >$, $\theta(x_i) \geq \theta(x'_i), T_{x_i} \geq T'_{x'_i}, I_{x_i} \leq I'_{x'_i}, F_{x_i} \leq F'_{x'_i}$ for $\forall i = 1, 2, \ldots, n$, then

$$\text{SVNLWMSM}^{(k)}(x_1, x_2, \ldots, x_n) \geq \text{SVNLWMSM}^{(k)}(x'_1, x'_2, \ldots, x'_n). \quad (8)$$

**Proof** Suppose that $\text{SVNLWMSM}^{(k)}(x_1, x_2, \ldots, x_n) = < s_{\theta'}; T', I', F' >$, $\text{SVNLWMSM}^{(k)}(x'_1, x'_2, \ldots, x'_n) = < s_{\theta''}; T'', I'', F'' >$. 

Since $\theta(x_i) \geq \theta(x'_i)$, we can have $\prod_{j=1}^{k} \theta(x_{ij}) \geq \prod_{j=1}^{k} \theta(x'_{ij})$.

Furthermore,
\[
s\left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} (\prod_{j=1}^{k} w_{ij}) \left(\prod_{j=1}^{k} \theta(x_{ij})\right)\right)^{1/k} \geq s\left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} (\prod_{j=1}^{k} w_{ij}) \left(\prod_{j=1}^{k} \theta(x'_{ij})\right)\right)^{1/k}
\]

Also, since $T_{x_i} \geq T'_{x'_i}$, then it can be obtained $1 - \prod_{j=1}^{k} T_{x_{ij}} \leq 1 - \prod_{j=1}^{k} T'_{x'_{ij}}$.

Further, we can achieve
\[
1 - \left(1 - \prod_{1 \leq i_1 < \cdots < i_k \leq n} \left(1 - \prod_{j=1}^{k} T_{x_{ij}}\right) \frac{1}{\prod_{j=1}^{k} w_{ij}} \right)^{1/k} \geq

1 - \left(1 - \prod_{1 \leq i_1 < \cdots < i_k \leq n} \left(1 - \prod_{j=1}^{k} T'_{x'_{ij}}\right) \frac{1}{\prod_{j=1}^{k} w_{ij}} \right)^{1/k}
\]

Consequently, $T \geq T'$.

Similarly, we can have $I \leq I', F \leq F'$.

In the end, we have $<s_{\theta}, (T, I, F) > \geq <s_{\theta'}, (T', I', F')>$.

That is to say,
\[
SVNLRWMSM^{(k)}(x_1, x_2, \cdots, x_n) \geq SVNLRWMSM^{(k)}(x'_1, x'_2, \cdots, x'_n).
\]

**Theorem 3** (Commutativity) Let $(x'_1, x'_2, \cdots, x'_n)$ be any permutation of $(x_1, x_2, \cdots, x_n)$, then
\[
SVNLRWMSM^{(k)}(x_1, x_2, \cdots, x_n) = SVNLRWMSM^{(k)}(x'_1, x'_2, \cdots, x'_n). \tag{9}
\]

**Proof**
\[
SVNLRWMSM^{(k)}(x_1, x_2, \cdots, x_n) = \left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} \left(\prod_{j=1}^{k} w_{ij}\right) \left(\prod_{j=1}^{k} x_{ij}\right)\right)^{1/k}
\]

\[
= \left(\sum_{1 \leq i_1 < \cdots < i_k \leq n} \left(\prod_{j=1}^{k} w'_{ij}\right) \left(\prod_{j=1}^{k} x'_{ij}\right)\right)^{1/k}
\]

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

**Theorem 4** (Idempotency) Let $x_i (i = 1, 2, \cdots, n)$ be a set of SVNLN s, if $x_i = x =< s_{\theta}, (T, I, F) >$ for $\forall i$, then
\[
SVNLRWMSM^{(k)}(x_1, x_2, \cdots, x_n) = x. \tag{10}
\]
Proof

\[
\text{SVNLRWMSM}^{(k)}(x_1, x_2, \ldots, x_n) = \left( \frac{1}{1/k} \sum_{1 \leq i_1 < \cdots < i_k \leq n} \left( \prod_{j=1}^{k} w_{i_j} \prod_{j=1}^{k} x_{i_j} \right) \right)^{1/k} = \left( \frac{1}{1/k} \sum_{1 \leq i_1 < \cdots < i_k \leq n} \left( \prod_{j=1}^{k} w_{i_j} \right) \right)^{1/k}
\]

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

Theorem 5 (Boundedness) Let \( x_i (i = 1, 2, \ldots, n) \) be a set of SVNLN, and \( x^+ = \langle s_{\max} \theta_i, \min T_i, \min I_i, \min F_i \rangle \), \( x^- = \langle s_{\min} \theta_i, \max T_i, \max I_i, \max F_i \rangle \) >, then

\[
x^- \leq \text{SVNLRWMSM}^{(k)}(x_1, x_2, \ldots, x_n) \leq x^+.
\]

Proof According to the idempotency and monotonicity, we can obtain

SVNLRWMSM\(^{(k)}\)(\(x_1, x_2, \ldots, x_n\)) \(\leq\) SVNLRWMSM\(^{(k)}\)(\(x^{+}, x^{+}, \ldots, x^{+}\))

and

SVNLRWMSM\(^{(k)}\)(\(x_1, x_2, \ldots, x_n\)) \(\geq\) SVNLRWMSM\(^{(k)}\)(\(x^{-}, x^{-}, \ldots, x^{-}\)).

Hence, we have \(x^- \leq \text{SVNLRWMSM}^{(k)}(x_1, x_2, \ldots, x_n) \leq x^+\).

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 SVNLA \(\text{WA} \) operator (Tan et al. [16]).

SVNLRWMSM\(^{(1)}\)(\(x_1, x_2, \ldots, x_n\)) =

\[
= \left( \sum_{i_1 \leq i_2 \leq n} w_{i_1} \theta(x_{i_1}) \prod_{1 \leq i_1 \leq n} \left( 1 - T_{x_{i_1}} \right)^{w_{i_1}} \prod_{1 \leq i_1 \leq n} I_{x_{i_1}}^{w_{i_1}} \prod_{1 \leq i_1 \leq n} F_{x_{i_1}}^{w_{i_1}} \right) = \text{SVNLWA}(x_1, x_2, \ldots, x_n)
\]

Case 2: In the event of \(k = n\), the SVNLRWMSM degenerates into an SVNLA \(\text{G} \) operator.

SVNLRWMSM\(^{(n)}\)(\(x_1, x_2, \ldots, x_n\)) =

\[
= \left( \prod_{i_1 \leq i_2 \leq n} \theta(x_{i_1}) \prod_{1 \leq i_1 \leq n} \left( 1 - T_{x_{i_1}} \right)^{1} \prod_{1 \leq i_1 \leq n} I_{x_{i_1}}^{1} \prod_{1 \leq i_1 \leq n} F_{x_{i_1}}^{1} \right) = \text{SVNLG}(x_1, x_2, \ldots, x_n)
\]
3.2 Single-valued neutrosophic linguistic RWDMSM 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 that \( w_i \in [0, 1] \) and \( \sum_{i=1}^n w_i = 1 \). The SVNLRWDMSM: \( \Omega^n \rightarrow \Omega \), an SVNLRWDMSM operator is signified in the following.

\[
\text{SVNLRWDMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \prod_{1 \leq i_1 < \cdots < i_k \leq n} \left( \frac{\sum_{j=1}^k x_{i_j}}{\sum_{j=1}^k w_{i_j}} \right)^{1/k}
\]

(12)

where \( \Omega \) is the set of entire SVNLNs, then SVNLRWDMSM is known as the single-valued neutrosophic linguistic RWDMSM operator.

Based on the operational laws of the SVNLNs defined in Definition 2 and Equation 12, we can obtain the aggregated results which is 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.

\[
\text{SVNLRWDMSM}^{(k)}(x_1, x_2, \cdots, x_n) = \left\langle s, \prod_{1 \leq i_1 < \cdots < i_k \leq n} \left( \frac{\sum_{j=1}^k x_{i_j}}{\sum_{j=1}^k w_{i_j}} \right)^{1/k} \right\rangle
\]

(13)

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 SVNLIWG operator.
\[
SVNLWDSM^{(1)}(x_1, x_2, \cdots, x_n) = \langle \sum_{i=1}^{n} \sum_{j=1}^{n} \theta_{ij} \cdot (1 - T_{ij})^{\frac{1}{w_i}} \cdot (1 - I_{ij})^{\frac{1}{w_i}} \cdot (1 - F_{ij})^{\frac{1}{w_i}} \rangle
\]

Case 2: In the event of \( k = n \), the SVNLRWDSM reduces to an SVNLA operator (Tan et al. [16]).

\[
SVNLWMSM^{(n)}(x_1, x_2, \cdots, x_n) = \langle \sum_{i=1}^{n} \sum_{j=1}^{n} \theta_{ij} \cdot (1 - T_{ij})^{\frac{1}{w_i}} \cdot (1 - I_{ij})^{\frac{1}{w_i}} \cdot (1 - F_{ij})^{\frac{1}{w_i}} \rangle = SVNLA(x_1, x_2, \cdots, x_n)
\]

Remark 2 In particular, it is vital that SVNLRWMSM or SVNLRWDSM operator cannot have the reciprocity among many given arguments while \( k = 1 \) or \( k = n \). In other words, both of them reduce into the self-governed operators such as SVNLA, SVNLG, SVNWLA and SVNWLG (Tan et al. [16]).

4 MCDM algorithms based SVNLRWMSM and SVNLRWDSM

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 signified by SVNL matrix \( P = (p_{ij})_{m \times n} = (< s_{ij}, (T_{ij}, I_{ij}, F_{ij}) >)_{m \times n} \). The evaluation values associated with the alternatives for the formalization of MCDM issues can be seen in Table 1.

[Table 1 about here.]

4.2 The MCDM method based on SVNLRWMSM or SVNLRWDSM operator

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

[Fig. 1 about here.]

In the meantime, the Algorithm 1 is given as follows:
Algorithm 1 : SVNLRWMSM or SVNLRWDMSM operator

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 Equation 14.

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

3: Use the SVNLRWMSM operator

\[
R(A_i) = < s_{\theta_{i}}, (T_i, I_i, F_i) > = SVNLRWMSM(k)(p'_{i1}, p'_{i2}, \ldots, p'_{in})
\] (15)

or Utilize the SVNLRWDMSM operator

\[
R(A_i) = < s_{\theta_{i}}, (T_i, I_i, F_i) > = SVNLRWDMSM(k)(p'_{i1}, p'_{i2}, \ldots, p'_{in})
\] (16)

to get the integrated value.

4: Compute score function \( s(R(A_i)) \) of the entire values \( R(A_i)(i = 1, 2, \ldots, m) \).

5: Choose the best alternative(s) by \( R(A_i) \).

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 and index design principles. Taking all factors into consideration, and at the same time, the relevant literature is studied to collect and sort out the previous influencing factors of user experience, tourism service and mobile e-commerce. According to these, 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.

[Table 2 about here.]

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 set \( C = (C_1(\text{Content experience}), C_2(\text{Interactivity}), C_3(\text{Security}), C_4(\text{Sensitivity}), C_5(\text{Personalization}), C_6(\text{Travel experience})) \). According to the evaluation principle of the TME service quality, we can determine that 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 \( S = \{s_0 = \text{extremely bad}, s_1 = \text{very bad}, s_2 = \text{bad}, s_3 = \text{fair}, s_4 = \text{good}, s_5 = \text{very good}, s_6 = \text{extremely good}\} \), and generate the final SVNL matrix in Table 3.

[Table 3 about here.]
Next, we employ the above developed algorithm in selecting 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:

\[
s(R(A_1)) = 4.5192, \ s(R(A_2)) = 3.7719, \ s(R(A_3)) = 3.2726, \ s(R(A_4)) = 2.6956, \ s(R(A_5)) = 2.3624.
\]

SVNLRWDMSM:

\[
s(R(A_1)) = 4.4718, \ s(R(A_2)) = 3.6676, \ s(R(A_3)) = 3.1660, \ s(R(A_4)) = 2.5831, \ s(R(A_5)) = 2.2579.
\]

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

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 Fig. 2 and Table 4, respectively. From the Fig. 2 and Table 4, some key points have been given in the following.

[Fig. 2 about here.]

[Table 4 about here.]
(1) For SVNLRWMSM, the score values of entire five tourism products are firstly monotonically increases if \( k \in [1, 5] \), and later monotonically decreases if \( k \in [5, 6] \). Moreover, it is not possessed distinguishability to find the final ranking owing to obtain the same values which vary from 2.2396 to 4.4623 with 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 entire five tourism products are firstly monotonically decreases if \( k \in [1, 5] \), and later monotonically increases if \( k \in [5, 6] \). In addition, it is very clear to find the final ranking compared with the SVNLRWMSM algorithm when \( k = 3, 4, 5 \). The final results are all ranked as \( A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5 \).

(3) The reason for the inflection point is that \( k = 1 \) is the modality of averaging operator (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 SVNLRWDMSM.

(4) The values at both ends (\( k = 1 \) and \( k = 6 \)) have an interesting case. For SVNLRWMSM, the score of five tourism products are the minimum compared with \( k = 1, 2, 3, 4, 5 \) if \( k = 6 \) (GO form). For SVNLRWDMSM, the score of five tourism products are the maximal 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, 12–18], which signify that the developed algorithms (SVNLWMSM and SVNLR-WDMSM) are feasible and reasonable for decision making issues involving SVNL information.

With respect to some SVNL AOs, only the reference [15, 18] take the reciprocity of the criteria into consideration. For better distinguish the features of existing SVNL AOs, we make a overview of them shown in Table 6. From Table 6, we can see the developed AOs are based RWMSM operators with the parameter \( k \). Therefore, the initiated AOs (SVNLWMSM and SVNLRWDMSM) are more global than some existing AOs. At the same time, they can take the interrelation of multiple criteria into consideration for dealing MCDM problems.

For a better comparison with certain MSM operators in various vague environment [20–33], we make a 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 are equivalent. In other words, it means out of the reducibility.
6 Conclusion

The dominating contributions are listed as follows:

(1) Two novel SVNL AOs are presented such as SVNLRWMSM and SVNLR-WDMSM.

(2) Certain properties (monotonicity, idempotency, boundedness, commutativity and reducibility) are explored under SVNL environment. Certain existing MSM operators in various indeterminate environment [20–33] fail to have idempotency or reducibility.

(3) Two SVNL MCDM methods based on SVNLRWMSM and SVNLRWDM are introduced. The sensitivity analysis of different $k$ on the ranking is discussed (Fig. 2 and Table 4).

(4) A synthesize appraise system of six evaluation dimensions are extracted (content experience, interactivity, security, sensitivity, personalization and travel experience), and employ it in selecting the ideal tourism product.

In the future, the SVNLRWMSM and SVNLRWDM will be applied in computational biology domain such as gene selection [35,36]. Besides, we will also put the RWM and RWMSM operators into various uncertain circumstance [37–49].

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Fig. 1: The decision making framework for employing the developed methods.  
Note: 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), Multi-criteria decision making (MCDM)
Fig. 2: The total changing trend of parameter $k$ based SVNLRWMSM.

Note: Single-valued neutrosophic linguistic reducible weighted Maclaurin symmetric mean (SVNLRWMSM)
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7. Characteristic comparisons of various indeterminate environment of MSM. ................................................................. 29
Table 1: A general SVNL MCDM matrix.

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$\ldots$</th>
<th>$C_n$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>$&lt; s_{t_11}, \langle t_{11}, i_{11}, f_{11} \rangle &gt;$</td>
<td>$&lt; s_{t_{12}}, \langle t_{12}, i_{12}, f_{12} \rangle &gt;$</td>
<td>$\ldots$</td>
<td>$&lt; s_{t_{1n}}, \langle t_{1n}, i_{1n}, f_{1n} \rangle &gt;$</td>
</tr>
<tr>
<td>$A_2$</td>
<td>$&lt; s_{t_{21}}, \langle t_{21}, i_{21}, f_{21} \rangle &gt;$</td>
<td>$&lt; s_{t_{22}}, \langle t_{22}, i_{22}, f_{22} \rangle &gt;$</td>
<td>$\ldots$</td>
<td>$&lt; s_{t_{2n}}, \langle t_{2n}, i_{2n}, f_{2n} \rangle &gt;$</td>
</tr>
<tr>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
<td>$\vdots$</td>
</tr>
<tr>
<td>$A_m$</td>
<td>$&lt; s_{t_{m1}}, \langle t_{m1}, i_{m1}, f_{m1} \rangle &gt;$</td>
<td>$&lt; s_{t_{m2}}, \langle t_{m2}, i_{m2}, f_{m2} \rangle &gt;$</td>
<td>$\ldots$</td>
<td>$&lt; s_{t_{mn}}, \langle t_{mn}, i_{mn}, f_{mn} \rangle &gt;$</td>
</tr>
</tbody>
</table>

Single-valued neutrosophic linguistic (SVNL), Multi-criteria decision making (MCDM)
Table 2: The evaluation criteria of tourism products.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Brief description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content experience ($C_1$)</td>
<td>Tourism mobile e-commerce 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, so 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.</td>
</tr>
<tr>
<td>Interactivity ($C_2$)</td>
<td>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 that users are gradually 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 six aspects: easy to learn service products, smooth operation process, good fault tolerance, timely feedback and real-time interaction.</td>
</tr>
<tr>
<td>Security ($C_3$)</td>
<td>As we all know, 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.</td>
</tr>
<tr>
<td>Sensitivity ($C_4$)</td>
<td>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, which helps 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.</td>
</tr>
<tr>
<td>Personalization ($C_5$)</td>
<td>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, so 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 diversity 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.</td>
</tr>
<tr>
<td>Travel experience ($C_6$)</td>
<td>As the key content of online travel, travel experience is of great significance. Even if customers can’t experience good e-services on the platform, 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.</td>
</tr>
</tbody>
</table>
Table 3: The SVNL matrix in Example 1.

<table>
<thead>
<tr>
<th></th>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>$s_5, (0.9, 0.1, 0.1)$</td>
<td>$s_5, (0.8, 0.1, 0.2)$</td>
<td>$s_5, (0.8, 0.2, 0.1)$</td>
</tr>
<tr>
<td>$A_2$</td>
<td>$s_5, (0.8, 0.1, 0.2)$</td>
<td>$s_5, (0.8, 0.2, 0.2)$</td>
<td>$s_4, (0.7, 0.2, 0.3)$</td>
</tr>
<tr>
<td>$A_3$</td>
<td>$s_5, (0.7, 0.1, 0.2)$</td>
<td>$s_4, (0.7, 0.2, 0.3)$</td>
<td>$s_3, (0.6, 0.2, 0.1)$</td>
</tr>
<tr>
<td>$A_4$</td>
<td>$s_5, (0.5, 0.1, 0.2)$</td>
<td>$s_4, (0.6, 0.2, 0.3)$</td>
<td>$s_3, (0.6, 0.2, 0.2)$</td>
</tr>
<tr>
<td>$A_5$</td>
<td>$s_5, (0.4, 0.1, 0.2)$</td>
<td>$s_3, (0.5, 0.2, 0.3)$</td>
<td>$s_3, (0.5, 0.2, 0.2)$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$C_4$</th>
<th>$C_5$</th>
<th>$C_6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_1$</td>
<td>$s_5, (0.9, 0.1, 0.1)$</td>
<td>$s_5, (0.8, 0.1, 0.1)$</td>
<td>$s_5, (0.8, 0.1, 0.1)$</td>
</tr>
<tr>
<td>$A_2$</td>
<td>$s_4, (0.8, 0.2, 0.2)$</td>
<td>$s_4, (0.7, 0.2, 0.1)$</td>
<td>$s_4, (0.6, 0.2, 0.1)$</td>
</tr>
<tr>
<td>$A_3$</td>
<td>$s_4, (0.8, 0.2, 0.3)$</td>
<td>$s_4, (0.6, 0.2, 0.2)$</td>
<td>$s_4, (0.6, 0.2, 0.2)$</td>
</tr>
<tr>
<td>$A_4$</td>
<td>$s_3, (0.7, 0.2, 0.3)$</td>
<td>$s_3, (0.5, 0.2, 0.1)$</td>
<td>$s_3, (0.5, 0.3, 0.1)$</td>
</tr>
<tr>
<td>$A_5$</td>
<td>$s_3, (0.6, 0.2, 0.3)$</td>
<td>$s_3, (0.4, 0.2, 0.1)$</td>
<td>$s_3, (0.4, 0.3, 0.1)$</td>
</tr>
</tbody>
</table>

Single-valued neutrosophic linguistic (SVNL)
Table 4: Ranking results of the tourism products with different $k$ by SVNLR-WDMSM algorithm.

<table>
<thead>
<tr>
<th>$k$</th>
<th>Score values</th>
<th>Ordering</th>
<th>Optimal product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$s(R(A_1)) = 4.4718$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
<td>$A_1$</td>
</tr>
<tr>
<td></td>
<td>$s(R(A_2)) = 3.6676$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$s(R(A_3)) = 3.1660$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$s(R(A_4)) = 2.5831$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$s(R(A_5)) = 2.2579$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>$s(R(A_1)) = 9.2555$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
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<td></td>
<td>$s(R(A_2)) = 7.1671$</td>
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<td>$s(R(A_3)) = 5.9762$</td>
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<tr>
<td></td>
<td>$s(R(A_4)) = 4.6179$</td>
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<tr>
<td></td>
<td>$s(R(A_5)) = 3.9624$</td>
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<tr>
<td>3</td>
<td>$s(R(A_1)) = 193.3486$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
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</tr>
<tr>
<td></td>
<td>$s(R(A_2)) = 130.0376$</td>
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<tr>
<td></td>
<td>$s(R(A_3)) = 96.3677$</td>
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</tr>
<tr>
<td></td>
<td>$s(R(A_4)) = 63.0655$</td>
<td></td>
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</tr>
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<td></td>
<td>$s(R(A_5)) = 49.5881$</td>
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<tr>
<td>4</td>
<td>$s(R(A_1)) = 2285435.1334$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
<td>$A_1$</td>
</tr>
<tr>
<td></td>
<td>$s(R(A_2)) = 10580324.2317$</td>
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<tr>
<td></td>
<td>$s(R(A_3)) = 5179747.5209$</td>
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<td></td>
<td>$s(R(A_4)) = 2041456.7743$</td>
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<td>$s(R(A_5)) = 1166101.9310$</td>
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<td>5</td>
<td>$s(R(A_1)) = 70631993944989128000000$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
<td>$A_1$</td>
</tr>
<tr>
<td></td>
<td>$s(R(A_2)) = 126354223858553260000000$</td>
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<tr>
<td></td>
<td>$s(R(A_3)) = 205841703782452300000000$</td>
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<tr>
<td></td>
<td>$s(R(A_4)) = 199406516030728930000$</td>
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<td></td>
<td>$s(R(A_5)) = 45390641943246275000$</td>
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</tr>
<tr>
<td>6</td>
<td>$s(R(A_1)) = 4.5059$</td>
<td>$A_1 &gt; A_2 &gt; A_3 &gt; A_4 &gt; A_5$</td>
<td>$A_1$</td>
</tr>
<tr>
<td></td>
<td>$s(R(A_2)) = 3.5925$</td>
<td></td>
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<tr>
<td></td>
<td>$s(R(A_3)) = 3.1862$</td>
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</tr>
<tr>
<td></td>
<td>$s(R(A_4)) = 2.5684$</td>
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</tr>
<tr>
<td></td>
<td>$s(R(A_5)) = 2.3333$</td>
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</table>

Single-valued neutrosophic linguistic reducible weighted dual Maclaurin symmetric mean (SVNLR-WDMSM)
Table 5: A comparison study in Example 1.

<table>
<thead>
<tr>
<th>Algorithms</th>
<th>Ranking</th>
<th>Optimal alternative</th>
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<tbody>
<tr>
<td>Algorithm 1: SVNLRWMSM</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<tr>
<td>Algorithm 1: SVNLRWDMSM</td>
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<td>Ye [5]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<tr>
<td>Tian et al. [15]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<td>Tian et al. [14]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<td>Wang et al. [17]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<td>Ji et al. [9]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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<td>Chen et al. [8]</td>
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<td>Tian et al. [12]</td>
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<td>Luo et al. [10]</td>
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<td>Tan et al. [16]</td>
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<td>Wang et al. [18]</td>
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<td>Wang et al. [18]</td>
<td>$A_1 \succ A_2 \succ A_3 \succ A_4 \succ A_5$</td>
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Single-valued neutrosophic linguistic reducible weighted Maclaurin symmetric mean (SVNLRWMSM), Single-valued neutrosophic linguistic reducible weighted dual Maclaurin symmetric mean (SVNLRWDMSM)
Table 6: The characteristic comparisons of various SVNL AOs.

<table>
<thead>
<tr>
<th>Aggregation operators</th>
<th>Consider interrelationships between two arguments?</th>
<th>Make the information aggregation more flexible by a parameter?</th>
<th>Consider interrelationships among multiple arguments?</th>
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<tbody>
<tr>
<td>[13]</td>
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<tr>
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<td>[16]</td>
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<tr>
<td>[16]</td>
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<tr>
<td>[16]</td>
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<td>[15]</td>
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<td>[18]</td>
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</tr>
<tr>
<td>[18]</td>
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<td>No</td>
<td>No</td>
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<tr>
<td>SVNLRWMSM</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td>SVNLRWDMSM</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</table>

Single-valued neutrosophic linguistic (SVNL), Aggregation operator (AO), Single-valued neutrosophic linguistic reducible weighted Maclaurin symmetric mean (SVNLRWMSM), Single-valued neutrosophic linguistic reducible weighted dual Maclaurin symmetric mean (SVNLRWDMMSM)
Table 7: Characteristic comparisons of various indeterminate environment of MSM.

<table>
<thead>
<tr>
<th>Sets Aggregation operators</th>
<th>SVNLS SVNLRWMSM Have the idempotency?</th>
<th>Yes</th>
<th>Yes</th>
<th>Have the reducibility?</th>
<th>Yes</th>
<th>Yes</th>
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<tbody>
<tr>
<td>SVNLS SVNLRWMSM</td>
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</table>

Maclaurin symmetric mean (MSM), single-valued neutrosophic linguistic reducible weighted MSM (SVNLRWMSM), single-valued neutrosophic linguistic reducible weighted dual MSM (SVNLRWDMSM), 2-tuple linguistic set (2TLS), Interval neutrosophic linguistic set (INLS), Intuitionistic fuzzy set (IFS), Intuitionistic linguistic set (ILS), Intuitionistic uncertain linguistic set (IULS), Linguistic intuitionistic fuzzy set (LIFS), Hesitant fuzzy linguistic set (HFLS), Hesitant fuzzy set (HFS), Pythagorean fuzzy set (PFS), q-rung orthopair fuzzy set (q-ROFS) Single-valued neutrosophic interval 2-tuple linguistic set (SVN-I2TLS), Single-valued neutrosophic linguistic set (SVNLS), Single-valued trapezoidal neutrosophic set (SVTNS), Uncertain linguistic set (ULS).