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PSS Evaluation Based on Vague Assessment Big Data: Hybrid Model of Multi-Weight Combination and Improved TOPSIS by Relative Entropy

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Abstract
Driven by the vague assessment big data, a product service system (PSS) evaluation method is developed based on a hybrid model of multi-weight combination and improved TOPSIS by relative entropy. The index values of PSS alternatives are solved by the integration of the stakeholders' vague assessment comments presented in the form of trapezoidal fuzzy numbers. Multi-weight combination method is proposed for index weight solving of PSS evaluation decision-making. An improved TOPSIS by relative entropy (RE) is presented to overcome the shortcomings of traditional TOPSIS and related modified TOPSIS and then PSS alternatives are evaluated. A PSS evaluation case in a printer company is given to test and verify the proposed model. The RE closeness of seven PSS alternatives are 0.3940, 0.5147, 0.7913, 0.3719, 0.2403, 0.4959, and 0.6332 and the one with the highest RE closeness is selected as the best alternative. The results of comparison examples show that the presented model can compensate for the shortcomings of existing traditional methods.

Keywords
Big Data, E Product-Service System, Evaluation Decision-Making, Index System, Multi-Weight Combination, Relative Entropy, TOPSIS

1. Introduction

As manufacturing enterprises gradually shift their business focus from providing industrial products to offering a combination of products and services, and rely on services to enhance profitability, business models or strategies focused on solutions are becoming mainstream. This transformation, which is from selling products and basic services to selling solutions or product service systems (PSSs), is regarded as service-oriented. Many manufacturing enterprises view service-oriented services as an important way to create customer value, improve customer satisfaction, generate differentiated competitive advantages, improve business performance, and promote economic development. PSS [1], as an emerging concept of maintaining product functionality for customers, has appeared. It can optimize resource utilization and improve enterprise competitiveness [2,3]. Scheme evaluation is a key part of the PSS design and development course [4,5], and the rationality of the evaluation results directly influences the success or failure of the design. Due to the subjectivity and uncertainty of services, PSS scheme evaluation is a typical mixed multi-attribute decision-making problem. Under the era of big data, the application of big

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data methods [6,7] in decision-making processes also can provide support for the optimization of PSS evaluation decisions.

Due to the complexity of PSS evaluation problems, traditional methods [8-10] are powerless to make PSS evaluation decisions, which is mainly reflected as following aspects:

1) The process of selecting the indexes in the establishment of the PSS evaluation index system is subjective. The comprehensiveness of indexes is also low.
2) When calculating the index weights, subjective or objective weighting methods are always adopted separately, which has certain limitations.
3) The convenient calculation method for index values is lacked. In response to these shortcomings in existing research, this article proposes a PSS evaluation method based on big data, which is a hybrid model of multi weight combination and improved TOPSIS by relative entropy (RE).

2. Holistic Framework

The holistic framework of PSS evaluation based on big data is shown in Fig. 1.

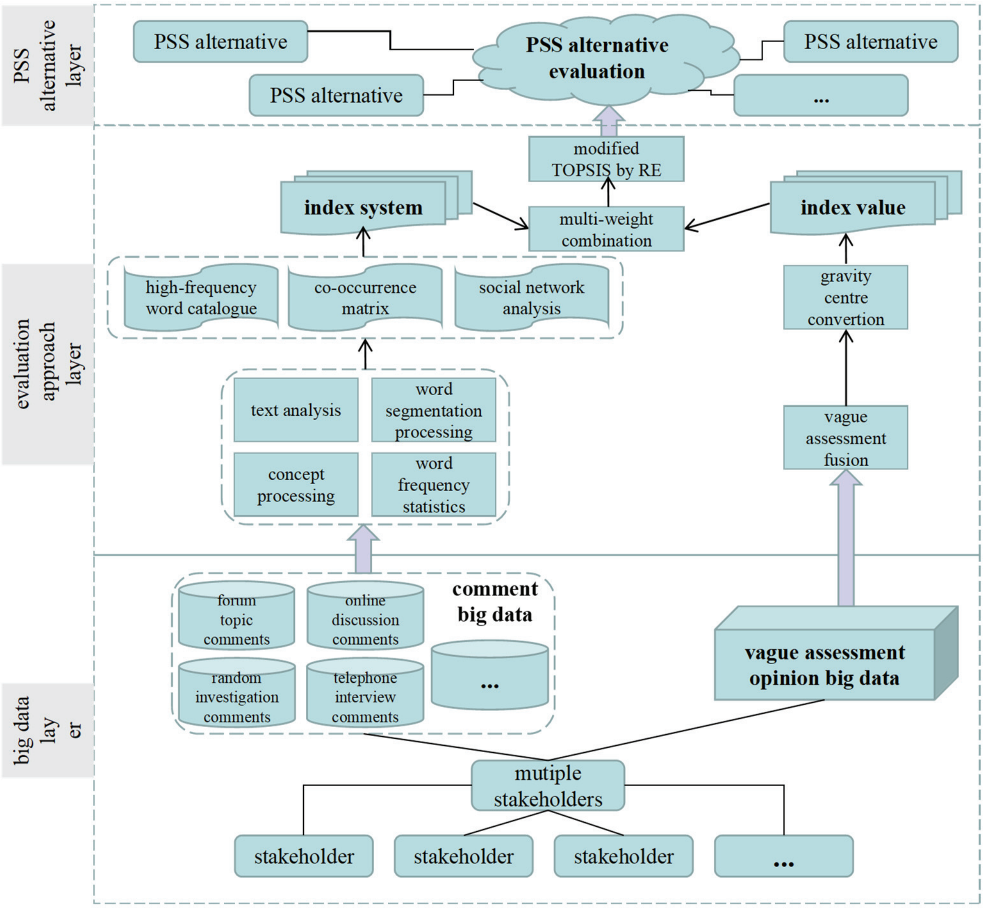

Fig. 1. Holistic framework.

The holistic framework is divided into three layers which are big data layer, evaluation approach layer and PSS alternative layer. The business logic within and between the three layers of the holistic framework is shown in Fig. 1.

3. Index System

The opinions of stakeholders on PSS evaluation decisions mainly exist in forums, online discussions, user comments, and other channels. Using web crawlers can obtain these big data. This article uses text analysis to conceptualize and segment these big data, and conducts word frequency statistics. The words which have no actual meaning or clear direction need to be excluded in order to obtain a true high-frequency word directory. The relative relationship between two high-frequency words is generally represented by their co-occurrence matrix. In a co-occurrence matrix, if the matrix value of is larger, the correlation between two high-frequency words is stronger. Based on the analysis of high-frequency words, its semantic network diagram can be obtained through social network analysis. The semantic network diagram example of high-frequency words is shown in Fig. 2.

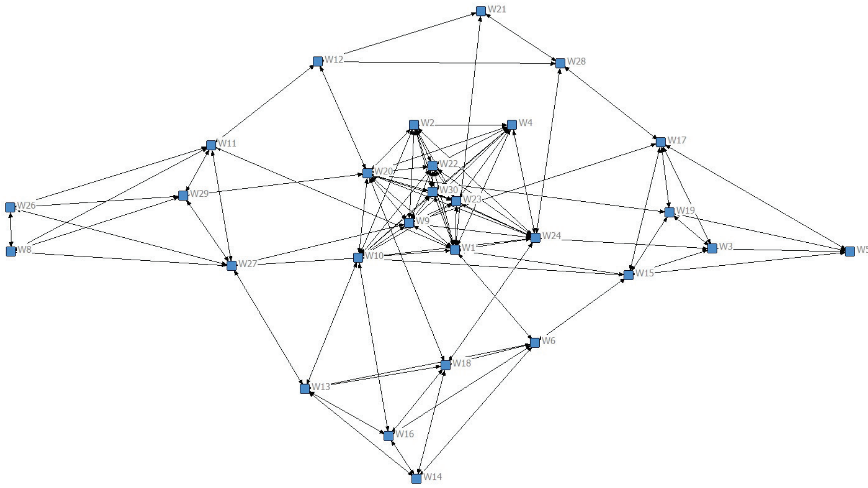

Fig. 2. The semantic network diagram example of high-frequency words.

According to Fig. 2, this article classifies high-frequency words based on logical relationships and interrelationships. The obtained category is the secondary index for PSS evaluation. Finally, this article reclassifies the secondary indicators and obtains the primary indicators. A tree shaped and multi-level PSS evaluation decision index system has been constructed, as shown in Table 1.

In Table 1, there are 6 first-level index and 19 second-level index. Here, I_1 means customer expectation degree, I_2 means customer acceptance degree, I_3 means system convenience degree, I_4 means service quality degree, I_5 means product quality degree, I_6 means degree of employment opportunities provided, I_7 means profit ability degree, I_8 means employee working environment, I_9 means service cost degree of providing PSS, I_{10} means service positioning degree, I_{11} means market size degree, I_{12} means investment cost degree, I_{13} means relationship with competitors, I_{14} means government financial support degree, I_{15} means support degree of government laws and regulations, I_{16} means user health and safety assurance degree, I_{17} means CO_2 emission degree, I_{18} means harmful substance emission degree, and I_{19} means resource consumption degree.

Table 1. Index system

First-level index (perspective)	Second-level index (connotation)
Customer	I_1
	I_2
	I_3
	I_4
	I_5
Business	I_6
	I_7
	I_8
	I_9
Vendor	I_{10}
	I_{11}
	I_{12}
Society	I_{13}
	I_{14}
	I_{15}
	I_{16}
Environment	I_{17}
	I_{18}
	I_{19}

4. Index Value Determination

There are p PSS schemes and q stakeholders. The evaluation value (TFN) of scheme s ($1 \leq s \leq p$) given by stakeholder r ($1 \leq r \leq q$) on index I_i is $\tilde{x}_{s,i}^r = (a_{s,i}^r, b_{s,i}^r, c_{s,i}^r, d_{s,i}^r)$. Then, the integrated value of all stakeholders can be solved as follows:

$$\tilde{x}_{s,i} = \left(a_{s,i}, b_{s,i}, c_{s,i}, d_{s,i}\right) = \left(\sum_{r=1}^{q} a_{s,i}^r / q \, , b_{s,i} = \sum_{r=1}^{q} b_{s,i}^r / q \, , c_{s,i} = \sum_{r=1}^{q} c_{s,i}^r / q \, , d_{s,i} = \sum_{r=1}^{q} d_{s,i}^r / q\right). \quad (1)$$

While calculating the index value of scheme s on index I_i, the index value is evaluated by four stakeholders. The vague comments contain nine level scales: extremely good (L_1), strongly good (L_2), obviously good (L_3), slightly good (L_4), middle (L_5), slightly bad (L_6), obviously bad (L_7), strongly bad (L_8) and extremely bad (L_9). The four stakeholders evaluated the index value using a vague comment as shown in Table 2.

Table 2. Stakeholder assessments of scheme s on index I_i

Alternative	Index	Stakeholders			
		1	2	3	4
s	I_i	L_2	L_6	L_4	L_3

The fuzzy values corresponding to the vague comments of four stakeholders are $\tilde{x}_{s,i}^1$ = (7/3,3,17/3,9), $\tilde{x}_{s,i}^2$ = (3/7,7/13,9/11,1), $\tilde{x}_{s,i}^3$ = (1,11/9,13/7,7/3), and $\tilde{x}_{s,i}^4$ = (3/2,13/7,3,4). Then the group decision evaluation value is obtained as $\tilde{x}_{s,i} = (a_{s,i}, b_{s,i}, c_{s,i}, d_{s,i})$, here $a_{s,i}$ = (7/3+3/7+1+3/2)/4=1.3155, $b_{s,i}$=

(3+7/13+11/9+13/7)/4=1.6545, $c_{s,i}$ = (17/3+9/11+13/7+3)/4=2.8355, and $d_{s,i}$ = (9+1+7/3+4)/4=4.0833.

By the gravity center formula of TFN, the real number form of $\tilde{x}_{s,i}$ is obtained as follows:

$$x_{s,i} = \frac{\left(c_{s,i}^2 + c_{s,i}d_{s,i} + d_{s,i}^2\right) - \left(a_{s,i}^2 + a_{s,i}b_{s,i} + b_{s,i}^2\right)}{3\left(c_{s,i} + d_{s,i} - a_{s,i} - b_{s,i}\right)} \tag{2}$$

For $\tilde{x}_{s,i}$ = (1.3155, 1.6545, 2.8355, 4.0833), its corresponded real number is $x_{s,i}$ = 2.5026.

5. PSS Scheme Alternative Evaluation

5.1 Multi-Weight Combination

A single weighting method often leads to unstable evaluation results. In order to make the weighting of evaluation indexed more fair, scientific and reasonable, a multi-weight combination approach was developed, as shown in Fig. 3.

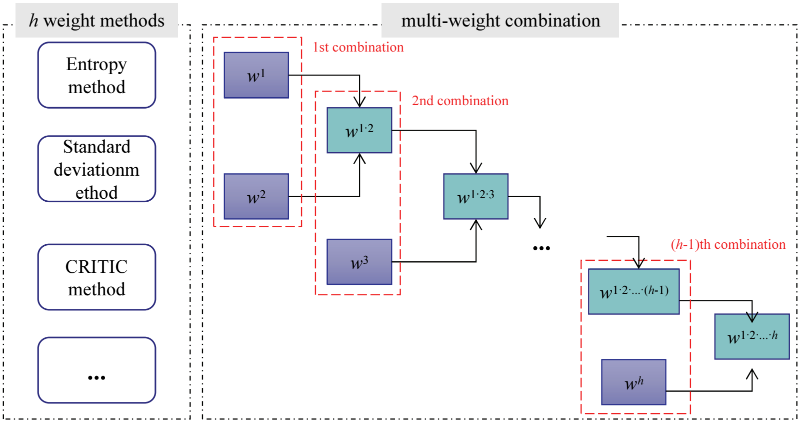

Fig. 3. The multi-weight combination process.

By h different weighting methods, the weight vectors are obtained are as follows:

$$\begin{gathered} w^1 = [w_1^1, w_2^1, \ldots, w_N^1]^{\mathrm{T}} \\ w^2 = [w_1^2, w_2^2, \ldots, w_N^2]^{\mathrm{T}} \\ \cdots \\ w^h = [w_1^h, w_2^h, \ldots, w_N^h]^T \end{gathered} \tag{3}$$

In the multi-weight combination process, there are $h-1$ combination operations. In the first combination operation (w^1 and w^2), the combination weight vector $w^{1\cdot 2}$ is shown as follows.

$$w^{1\cdot 2} = \tau_1 w^1 + \tau_2 w^2 \tag{4}$$

where $\tau_1$and τ_2 are the combination coefficients corresponding to w^1 and w^2, and $\tau_1 \geq 0$, $\tau_2 \geq 0$, $\tau_1 + \tau_2 = 1$.

The total weight contribution discrepancy (TWCD) of w^1 and w^2 is defined as follows.

$$TWCD^{1\cdot 2} = \sum_{s=1}^{p} \sum_{i=1}^{N} \left(\tau_1 w_i^1 x_{s,i} - \tau_2 w_i^2 x_{s,i}\right)^2 \tag{5}$$

Therefore, a multi-weight combination approach is built to make the weight contributions of w^1 and w^2 balanced, which is as following.

$$\min TWCD^{1\cdot 2} \text{ s.t. } \tau_1 \geq 0, \tau_2 \geq 0, \tau_1 + \tau_2 = 1 \tag{6}$$

Two combination coefficients are obtained as follows:

$$\begin{cases} \tau_1 = \dfrac{\sum_{s=1}^{p} \sum_{i=1}^{N} (x_{s,i})^2 w_i^2 (w_i^1 + w_i^2)}{\sum_{s=1}^{p} \sum_{i=1}^{N} (x_{s,i})^2 (w_i^1 + w_i^2)} \\ \tau_2 = 1 - \tau_1 \end{cases}. \tag{7}$$

Then $w^{1\cdot 2}$ and w^3 are combined and their combination weight is $w^{1\cdot 2\cdot 3}$. At last the combination weight vector is obtained as follows.

$$w^{1\cdot 2\cdot \ldots \cdot h} = [w_1^{1\cdot 2\cdot \ldots \cdot h}, w_2^{1\cdot 2\cdot \ldots \cdot h}, \ldots, w_N^{1\cdot 2\cdot \ldots \cdot h}]^{\mathrm{T}}. \tag{8}$$

5.2 Improved TOPSIS by RE

Between two *n*-dimensional uncertainty systems $\theta^A = (\theta_1^A, \theta_2^A, \ldots, \theta_n^A)$ and $\theta^B = (\theta_1^B, \theta_2^B, \ldots, \theta_n^B)$, the difference degree can be expressed by RE [11-13] as follows:

$$RE^{A,B} = \sum_{k=1}^{n} \left[\theta_k^A \log \frac{\theta_k^A}{\theta_k^B} + (1 - \theta_k^A) \log \frac{1-\theta_k^A}{1-\theta_k^B}\right], \tag{9}$$

where θ_k^A and θ_k^B are the occurrence chance of uncertain state k in systems θ^A and θ^B.

RE has two features: (1) $RE^{A,B} \geq 0$, (2) only if $A = B$, $RE^{A,B} = 0$.

According to the calculation in the previous text, the index value matrix is $X = \left[x_{s,i}\right]_{p\times N}$, and the weight vector is $w^{1\cdot 2\cdot \ldots \cdot h}$. Then the weighted index value matrix can be solved as $T = \left[t_{s,i}\right]_{p\times N}$, where $t_{s,i} = w_i^{1\cdot 2\cdot \ldots \cdot h} t_{s,i}$. The positive and negative ideal point (PIP and NIP) can be solved as:

$$\begin{aligned} T^+ &= [t_1^+, t_2^+, \ldots, t_i^+, \ldots, t_N^+] \\ T^- &= [t_1^-, t_2^-, \ldots, t_i^-, \ldots, t_N^-] \end{aligned} \tag{10}$$

where $t_i^+ = \max\{t_{1,i}, t_{2,i}, \ldots, t_{p,i}\}$ and $t_i^- = \min\{t_{1,i}, t_{2,i}, \ldots, t_{p,i}\}$.

The index value of PSS scheme *s* is solved as $T^s = \left[t_{s,1}, t_{s,2}, \ldots, t_{s,i}, \ldots, t_{s,N}\right]$. Then the RE from T^s to PIP T^+ is calculated as:

$$RE^{s,+} = \sum_{i=1}^{N} \left[t_{s,i} \log \frac{t_{s,i}}{t_i^+} + \left(1 - t_{s,i}\right) \log \frac{1-t_{s,i}}{1-t_i^+}\right]. \tag{11}$$

The RE from T^s to NIP T^- is calculated as:

$$RE^{s,-} = \sum_{i=1}^{N} \left[t_{s,i} \log \frac{t_{s,i}}{t_i^-} + \left(1 - t_{s,i}\right) \log \frac{1-t_{s,i}}{1-t_i^-}\right]. \tag{12}$$

For PSS scheme s, the RE closeness is calculated as:

$$\varphi^s = \frac{RE^{s,-}}{RE^{s,+}+RE^{s,-}}. \quad (13)$$

Here RE closeness φ^s has three characteristics: (1) if $T^s = T^+$, $\varphi^s = 1$; (2) if $T^s = T^-$, $\varphi^s = 0$; (3) if $T^- \neq T^s \neq T^+$ and $T^s \to T^+$, $\varphi^s \to 1$.

6. Case Study

Here shows a PSS evaluation case in a printer company. It is assumed that there are seven PSS schemes (P1, P2, P3, P4, P5, P6 and P7), and there are 60 persons in the stakeholder group, namely PSS customers (12 persons), customer demand analysts (12 persons), PSS entrepreneurs (12 persons), social and environmental researchers (12 persons) and PSS design engineers (12 persons).

Taking the performance of PSS scheme P1 on index I_1 as an example, six stakeholders thinks L_1, one stakeholder thinks L_2, eight stakeholders think L_3, fifteen stakeholders think L_4, six stakeholder thinks L_5, fourteen stakeholders think L_6, three stakeholders think L_7, no stakeholder thinks L_8 and seven stakeholders think L_9. The fuzzy opinion of P1 on the19 indexes is counted as shown in Table 3.

Then the index value of P1 in TFN form is solved and then we convert it to the real number form as follows (Tables 4 and 5).

By the same way, the index values of other six PSS schemes can be obtained (Table 6).

By entropy approach, CRITIC method and standard deviation approach, the corresponding weight vectors are obtained as w^1, w^2 and w^3, respectively. Based on multi-weight combination, the combination weight vector $w^{1\text{•}2\text{•}3}$ is obtained as shown in Table 7.

Table 3. The vague assessment opinion of P1

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}
L_1	6	8	2	1	2	11	7	14	9	12	18	3	0	5	4	0	8	9	3
L_2	1	1	25	8	0	13	2	1	5	2	4	1	9	5	5	4	0	11	1
L_3	8	19	12	14	2	1	7	5	0	0	11	1	8	5	4	1	1	9	2
L_4	15	18	10	15	11	1	11	8	19	5	2	17	1	9	11	16	4	4	2
L_5	6	11	3	1	0	0	10	6	15	5	6	7	9	12	6	25	0	1	3
L_6	14	1	4	2	24	8	2	3	7	9	0	4	0	1	18	1	10	0	9
L_7	3	0	0	2	8	10	3	5	3	16	8	10	5	1	7	1	24	14	1
L_8	0	0	2	0	4	0	1	16	1	5	2	7	11	2	0	9	5	4	37
L_9	7	2	2	17	9	16	17	2	1	6	9	10	17	20	5	3	8	8	2

Table 4. The index value of P1 (indexes I_1–I_{10})

	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}
TFN index value	(1.1144, 1.4251, 2.1972, 2.6042)	(1.5414, 1.9563, 3.0044, 3.5250)	(1.6582, 2.1095, 3.6922, 5.3782)	(1.0485, 1.3105, 2.1817, 3.0375)	(0.5955, 0.7631, 1.1882, 1.5272)	(1.4090, 1.8972, 3.2046, 4.1556)	(1.1296, 1.4376, 2.2058, 2.5974)	(1.4062, 1.8954, 2.9726, 3.2921)	(1.4273, 1.8213, 2.7912, 3.2919)	(1.0425, 1.3423, 2.1913, 2.7971)
Index value	1.8377	2.5095	3.2510	1.9139	1.0238	2.6803	1.8448	2.3877	2.3357	2.0851

Table 5. The index value of P1 (indexes I_{11}–I_{19})

	I_{11}	I_{12}	I_{13}	I_{14}	I_{15}	I_{16}	I_{17}	I_{18}	I_{19}
TFN index value	(1.8176, 2.4482, 3.8991, 4.4629)	(0.7656, 0.9578, 1.4499, 1.8528)	(0.7894, 0.9596, 1.5869, 2.3466)	(1.0548, 1.3178, 2.0433, 2.5226)	(1.0114, 1.2853, 2.0357, 2.6403)	(0.8974, 1.0201, 1.4211, 1.8240)	(0.8205, 1.1206, 1.7769, 2.2579)	(1.4167, 1.8811, 3.1508, 4.1841)	(0.5129, 0.6848, 1.0995, 1.3087)
Index value	3.1553	1.2631	1.4415	1.7407	1.7534	1.2999	1.4996	2.6757	0.9025

Table 6. The index value matrix of the seven PSS schemes

	P1	P2	P3	P4	P5	P6	P7
I_1	1.8377	2.0960	1.3680	2.0768	2.1789	2.4512	2.8612
I_2	2.5095	1.9084	2.0972	3.4547	1.1940	2.8081	2.5544
I_3	3.2510	1.8617	1.7617	3.4818	2.2323	1.5178	2.6705
I_4	1.9139	1.1522	2.1484	1.5011	1.7576	2.5402	3.0975
I_5	1.0238	1.9017	3.3874	1.0867	1.5675	1.4738	1.4145
I_6	2.6803	3.2090	3.6591	1.0073	1.8991	2.1903	1.8695
I_7	1.8448	1.8344	2.4879	2.8215	2.6038	2.3443	2.5583
I_8	2.3877	1.9092	1.6164	1.5494	1.9171	1.5251	1.2640
I_9	2.3357	1.5742	3.4707	1.2064	1.8004	1.8400	2.0063
I_{10}	2.0851	2.2272	1.6969	3.5012	1.4373	3.1232	1.6266
I_{11}	3.1553	3.0206	2.0623	1.3925	2.5138	2.9287	2.9647
I_{12}	1.2631	1.5374	1.8932	2.2962	1.9658	2.0283	2.6907
I_{13}	1.4415	1.8200	1.5309	1.4309	2.0325	1.7764	3.1508
I_{14}	1.7407	2.4359	3.4073	2.4599	0.8856	1.6859	3.5140
I_{15}	1.7534	1.3537	2.6046	1.5678	1.4288	1.0632	1.7707
I_{16}	1.2999	2.5220	2.3768	2.1430	1.0738	3.7196	2.0292
I_{17}	1.4996	2.2533	1.8916	0.9594	1.8586	1.6593	1.7641
I_{18}	2.6757	1.7624	1.2152	0.8229	2.2208	1.4669	2.4419
I_{19}	0.9025	2.3152	5.1811	1.4835	1.7001	1.4049	1.8767

Table 7. The multi-weight combination

	w^1 (entropy approach)	w^2 (CRITIC method)	w^3 (standard deviation approach)	$w^{1\bullet 2\bullet 3}$
I_1	0.0534	0.0521	0.0545	0.0531
I_2	0.0529	0.0617	0.0555	0.0581
I_3	0.0528	0.0521	0.0610	0.0549
I_4	0.0528	0.0557	0.0452	0.0520
I_5	0.0517	0.0490	0.0492	0.0496
I_6	0.0522	0.0589	0.0511	0.0552
I_7	0.0537	0.0502	0.0555	0.0525
I_8	0.0535	0.0299	0.0652	0.0452
I_9	0.0526	0.0520	0.0474	0.0508
I_{10}	0.0526	0.0562	0.0626	0.0574
I_{11}	0.0532	0.0636	0.0537	0.0585
I_{12}	0.0533	0.0477	0.0503	0.0496
I_{13}	0.0529	0.0479	0.0481	0.0490
I_{14}	0.0519	0.0632	0.0443	0.0553
I_{15}	0.0530	0.0343	0.0481	0.0422
I_{16}	0.0521	0.0610	0.0526	0.0567
I_{17}	0.0533	0.0384	0.0523	0.0456
I_{18}	0.0522	0.0486	0.0550	0.0513
I_{19}	0.0497	0.0775	0.0486	0.0633

Then the weighted index value matrix is obtained as $T = [t_{s,i}]_{6\times19}$ (Table 8). Therefore, PIP and NIP are obtained (Table 8).

The REs to PIP and NIP and RE closeness are calculated in Table 9.

Based on RE closeness, the ranking result of seven PSS alternatives is also shown in Table 9, in which P3 is the best PSS alternative.

Table 8. The weighted index values, PIP and NIP

	P1	P2	P3	P4	P5	P6	P7	PIP	NIP
I_1	0.0976	0.1113	0.0726	0.1103	0.1157	0.1302	0.1519	0.1519	0.0726
I_2	0.1458	0.1109	0.1218	0.2007	0.0694	0.1632	0.1484	0.2007	0.0694
I_3	0.1785	0.1022	0.0967	0.1912	0.1226	0.0833	0.1466	0.1912	0.0833
I_4	0.0995	0.0599	0.1117	0.0781	0.0914	0.1321	0.1611	0.1611	0.0599
I_5	0.0508	0.0943	0.1680	0.0539	0.0777	0.0731	0.0702	0.1680	0.0508
I_6	0.1480	0.1771	0.2020	0.0556	0.1048	0.1209	0.1032	0.2020	0.0556
I_7	0.0969	0.0963	0.1306	0.1481	0.1367	0.1231	0.1343	0.1481	0.0963
I_8	0.1079	0.0863	0.0731	0.0700	0.0867	0.0689	0.0571	0.1079	0.0571
I_9	0.1187	0.0800	0.1763	0.0613	0.0915	0.0935	0.1019	0.1763	0.0613
I_{10}	0.1197	0.1278	0.0974	0.2010	0.0825	0.1793	0.0934	0.2010	0.0825
I_{11}	0.1846	0.1767	0.1206	0.0815	0.1471	0.1713	0.1734	0.1846	0.0815
I_{12}	0.0626	0.0763	0.0939	0.1139	0.0975	0.1006	0.1335	0.1335	0.0626
I_{13}	0.0706	0.0892	0.0750	0.0701	0.0996	0.0870	0.1544	0.1544	0.0701
I_{14}	0.0963	0.1347	0.1884	0.1360	0.0490	0.0932	0.1943	0.1943	0.0490
I_{15}	0.0740	0.0571	0.1099	0.0662	0.0603	0.0449	0.0747	0.1099	0.0449
I_{16}	0.0737	0.1430	0.1348	0.1215	0.0609	0.2109	0.1151	0.2109	0.0609
I_{17}	0.0684	0.1028	0.0863	0.0437	0.0848	0.0757	0.0804	0.1028	0.0437
I_{18}	0.1373	0.0904	0.0623	0.0422	0.1139	0.0753	0.1253	0.1373	0.0422
I_{19}	0.0571	0.1466	0.3280	0.0939	0.1076	0.0889	0.1188	0.3280	0.0571

Table 9. REs to PIP and NIP and RE closeness

	RE		RE closeness	Rank
	to PIP	to NIP		
P1	0.5610	0.3647	0.3940	5
P2	0.3854	0.4086	0.5147	3
P3	0.2439	0.9245	0.7913	1
P4	0.6068	0.3594	0.3719	6
P5	0.6198	0.1960	0.2403	7
P6	0.4343	0.4273	0.4959	4
P7	0.3358	0.5795	0.6332	2

7. Discussion

Due to the shortcomings of traditional TOPSIS, several modified TOPSIS methods have been presented by scholars through replacing Euclidean distance with other concepts [14,15]. We compared the results of the proposed model (modified TOPSIS by RE), traditional TOPSIS, modified TOPSISs [14,15] as shown in Table 10.

As shown in Table 10, the evaluation results of the proposed model and traditional TOPSIS are identical, which can prove the correctness and effectiveness of the proposed model. Because the existing literature have proved that traditional TOPSIS has obvious and clear shortcomings, traditional TOPSIS is not advisable. The overall evaluation trend of the four models is generally consistent, and P3, P7 and P2 are better than P1, P4 and P5, while P6 is about in the middle. However, by modified TOPSIS in Reference [14] the evaluation result of P2 and P3 is obviously different from other three models, and the opposite evaluation result appears. By modified TOPSIS in Reference [15] the closeness of P1 and P6 are completely equal and the evaluation of them cannot be executed. Therefore, modified TOPSIS models [14,15] cannot meet the evaluation requirements in some special scenarios. Based on the data in Table 10, the proposed model in which TOSIS is modified by changing Euclidean distance as RE can compensate for the shortcomings of existing modified TOPSIS methods.

Table 10. The comparing of the results of four models

	The proposed model		**Traditional TOPSIS**		**Modified model [14]**		**Modified model [15]**	
	Closeness	**Rank**	**Closeness**	**Rank**	**Closeness**	**Rank**	**Closeness**	**Rank**
P1	0.3940	5	0.5157	5	0.5761	5	0.6408	4
P2	0.5147	3	0.5877	3	0.7033	1	0.6854	3
P3	0.7913	1	0.6609	1	0.6154	3	0.7244	1
P4	0.3719	6	0.4879	6	0.5541	6	0.6091	6
P5	0.2403	7	0.4566	7	0.4896	7	0.5764	7
P6	0.4959	4	0.5312	4	0.5977	4	0.6408	4
P7	0.6332	2	0.6254	2	0.6842	2	0.7101	2

8. Conclusion

To achieve rapid evaluation of personalized PSS schemes, this paper proposes a new method. The feasibility, effectiveness and simplicity of the proposed method for complex evaluation problems in mixed uncertain environments were verified through implementation examples. The next step of the research will consider the impact of uncertainty in user satisfaction evaluation information on PSS scheme evaluation.

Conflict of Interest

The author declare that they have no competing interests.

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