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Cost-effective evaluation of air purifiers based on entropy weight method combined with TOSIS

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Abstract: With the rapid development of the economy, people pay more and more attention to the improvement of air quality, and we tend to choose air purifiers to clean the air in our living space as a way to take care of the health of our own lungs. This paper establishes a screening model, based on the screening principles and screening principles, and obtains the effective five indicators are: selling price, particulate CADR, formaldehyde CADR, noise range, and power rating. Then the TOPSIS model was established to get the processed decision matrix, and the scores of each evaluation object were obtained by using the decision matrix. After that, the entropy weighting method was combined to find out the occupied weight of each index. Finally, the TOPSIS method was combined to re-solve the scores to obtain the ranking of each air purifier.

1. Introduction

An "air purifier", also known as an "air cleaner", is a device that purifies dirty air as well as contaminated air that contains viruses, dust, and other contaminants. [1-4]. They are widely used in industry, homes, government and general construction. Over the years, air pollution has caused an increasing number of human diseases such as tuberculosis, lung cancer, nasal cancer and even leukemia. Therefore, the research, invention and manufacture of a qualified and effective air purifier is a top priority in the current scientific development and human health research.

The performance of air purifiers can often be evaluated by several attributes, such as purification efficiency, noise level, and energy consumption. Entropy weight TOPSIS is able to synthesize these attributes and take their weights into account. Through this method, the relative importance between each attribute can be synthesized to assess the cost-effectiveness of different air purifiers in a more comprehensive way. In this paper, entropy weight combined with TOPSIS [5-6] is used to comprehensively evaluate the cost-effectiveness of air purifiers to provide effective decision-making for the rational selection of air purifiers in the market.

2. TOSIS-based air purifier evaluation model

2.1 Data collection

For the mixed market of air purifier products, we selected ten air purifiers with large sales and good evaluation on e-commerce platforms such as Jingdong and Taobao as research samples. Their data come from Jingdong and Taobao shopping platforms. Finally, the information of the ten air purifiers selected in this paper is shown in Table 1 below:

Table 1: Information related to ten air purifiers

Design	**Selling price ($)**	**Particle CADR (m/h)**	**Formaldehyde CADR(m^3/h)**	**Noise range (db[AJ)**	**Rated power (W)**	**Filter life (months)**	**Antimicrobial rate (%)**
Xiaomi 4	899	400	150	32-62	30	10	99.9
Xiaomi AC-MD2-SC	1999	510	300	35-65	50	13	99.8
Xiaomi X	1799	400	300	32-65	41	12	99.9
352X86C	4099	693	428	35-64	150	13	99.9
PHILIPSAC2936	1699	360	220	30-66	43	12	99.8
Blueair570EF	6499	600	370	38-66	50	11	99.9
Smith JF1568	3698	468	343	33-63	73	12	99.8
Huawei C400	849	411	151	32-66	38	12	99.9
Midea JA32	1198	550	230	35-62	38	11	99.8
Off E33	1098	405	240	35-66	40	10	99.9

As can be seen from Table 1, this paper for the ten air purifiers found a total of six major evaluation indicators, in order to make these indicators contain the maximum amount of information to avoid the redundancy of the information, this paper needs to establish a model to screen the indicators.

2.2 Screening of evaluation indicators

Based on the daily use of air purifiers and the high screen indicators of the classic viewpoints of domestic and foreign authorities, this paper establishes a set of evaluation sea selection indicators based on the above data sources. Before screening the indicators, the unavailable data are eliminated according to the observability of the data [7].

2.3 Screening principles

(1) Coefficient of variation: Screening out the indicators that have a greater impact on the comprehensive evaluation of air purifiers and the information contained in different indicators reflects the discriminative ability of the differences in the indicator data on the evaluation of air purifiers - the greater the variability of the indicator data, the stronger the discriminative ability of the indicator on the rating of air purifiers, and vice versa, the weaker the discriminative ability. Therefore, this paper screens out the indicators with the strongest discriminatory ability among various types of data through the coefficient of variation to ensure that the screened indicators have the greatest impact on air purifier ratings.

(2) Correlation coefficient: eliminating indicators with redundant response information. If the indicator system contains more redundant indicators, the more confusing the information reflected in the evaluation results. Therefore, this paper analyzes the correlation coefficients to eliminate the indicators with large correlation coefficients in the same criterion layer, so as to avoid the duplicity

of the information reflected by the indicators.

2.4 Principle of indicator screening

The correlation coefficient between two indicators at the same criterion level is calculated through correlation analysis to reflect the set of indicators with redundant information, i.e., those with larger correlation coefficients, and then the coefficient of variation is calculated to calculate the information content of each indicator reflecting redundant information, so as to select the indicators with the largest information content in the same category, and then to finally eliminate those indicators with a large information content.

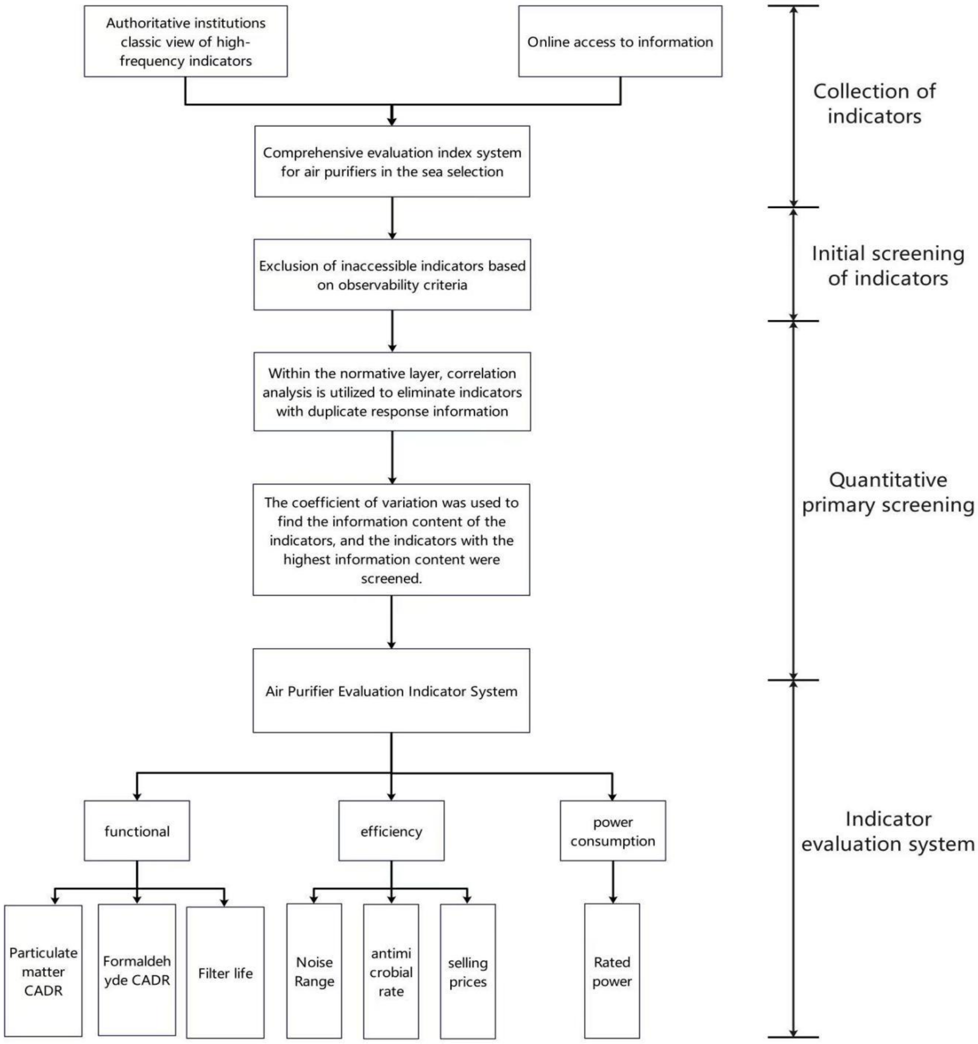

Figure 1: Indicator Screening Schematic

As can be seen from the analysis of Figure 1, this paper ensures that the screened indicators have the greatest impact on the evaluation of air purifiers in the market, and also avoids the duplication of information in the response of the indicator system. The three indicators finally established are: functional level, efficiency level and energy consumption level.

After the above principle this paper screens the following results:

Table 2: Screening results

Norm	Retention or non-retention
Selling prices	Reservations
Particulate matter CADR	Reservations
Formaldehyde CADR	Reservations
Noise Range	Reservations
Rated power	Reservations
Filter life	Deletion of coefficient of variation
Antimicrobial	Unpredictable deletion

The post-screening evaluation metrics obtained from Table 2 are: selling price, particulate CADR, formaldehyde CADR, noise range, and power rating.

2.5 Establishment of TOPSIS modeling

The TOPSIS method, also known as the ideal solution method, is an effective multi-indicator evaluation method [8]. It first constructs the positive ideal solution (optimal solution) and negative ideal solution (worst solution) of the evaluation problem, and then calculates the similarity closeness (i.e., the degree of proximity to the positive ideal solution and the degree of distance from the negative ideal solution) of each solution to the ideal solution, in order to score the solutions and select the optimal solution.

(1). The establishment of initialization decision matrix:

After obtaining the data of ten air purifiers, these ten air purifiers are used as the evaluation object, and five indexes are screened out as evaluation indexes. They are selling price, particulate CADR value, formaldehyde CADR value, noise range, and power rating. A total of m (m=10) evaluation objects and n (n=5) evaluation indexes are used to establish the initialized decision matrix of TOPSIS model.

(2). Normalization of the matrix

Very large indicators: particulate matter CADR value, formaldehyde CADR value;

Very small indicators: selling price, noise range (replaced by arithmetic mean), power rating;

Very small indicators are converted by max-x, and the conversion formula is as follows

$$\frac{x-\min}{\max-\min} \quad (1)$$

The transformed matrix is:

$$A=(a_{ij})_{m\times n} \quad (i=1,2\ldots m;\ j=1,2\ldots n) \quad (2)$$

(3). Normalization of the matrix

The normalized matrix is normalized to eliminate the effect of factors such as magnitude.

The normalized matrix is denoted as:

$$b_{ij}=\frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^{2}}} \quad (i=1,2\ldots m;j=1,2\ldots n) \quad (3)$$

Define the maximum value:

$$B^{+} = (B_1^{+}, B_2^{+} \dots B_n^{+}) \\ = \left[\max(\mathrm{B}_{11}, \mathrm{B}_{21} \dots \mathrm{B}_{m1}), \dots \max(B_{1n}, B_{2n}, \dots B_{mn})\right] \tag{4}$$

Define the minimum value:

$$B^{-} = (B_1^{-}, B_2^{-} \dots B_n^{-}) \\ = \left[\min(\mathrm{B}_{11}, \mathrm{B}_{21} \dots \mathrm{B}_{m1}), \dots \min(B_{1n}, B_{2n}, \dots B_{mn})\right] \tag{5}$$

Then define the distance of the $i(i = 1, 2 \dots m)$ evaluation object from the maximum and minimum values:

$$D_i^{+} = \sqrt{\sum_{j=1}^{n} (B_j^{+} - B_{ij})^2} \tag{6}$$

$$D_i^{-} = \sqrt{\sum_{j=1}^{n} (B_j^{-} - B_{ij})^2} \tag{7}$$

Define the $i(i = 1, 2 \dots m)$ evaluation object to normalize the score $S_i = \dfrac{D_i^{-}}{D_i^{+} + D_i^{-}}$ $(0 \le S_i \le 1)$

Finally, this paper calculated the scores of each evaluation object through the Excel table to get the following Table 3.

Table 3: Scores for each purification machine

Design	**D_i^+**	**D_i^-**	**S_i**	**Rankings**
Xiaomi 4	0.829536437	0.741053079	0.09224286	Seventh
Xiaomi AC-MD2-SC	0.553043815	0.655515593	0.10603791	Fourth
Xiaomi X	0.669176962	0.672986757	0.098027327	Sixth
352X86C	0.506364055	0.937664041	0.12694563	First
PHILIPSAC2936	0.809336458	0.63709361	0.086109674	Eighth
Blueair570EF	0.675676916	0.738687519	0.102104662	Fifth
Smith JF1568	0.553002707	0.681619466	0.107932951	Third
Huawei C400	0.836358415	0.618303068	0.083097049	Ninth
Midea JA32	0.52770411	0.747463402	0.114595834	Second
Midea E33	0.782358649	0.576074454	0.082906102	Tenth

According to Table 3, this paper concludes that based on the TOPSIS algorithm, the ranking results calculated in this paper should prove the ranking of the advantages and disadvantages of the products: 352X86C, JA32 of Midea, JF1568 of Smith, AC-MD2-SC of Xiaomi, Blueair570EF, Xiaomi X, Xiaomi 4, PHILIPSAC2936, Huawei C400, E33 of Midea.

(4). In this paper, the weights of these five indicators were calculated using MATLAB:

Figure 2: Percentage of weights for each indicator

According to Figure 2 analysis found that: particulate matter CADR value and formaldehyde CADR value accounted for a larger weight, and the impact on the evaluation object is also large. In addition, the three indicators of selling price, noise range and rated power account for a smaller weight, and the degree of influence on the evaluation object is also small.

3. Optimization of the air purifier evaluation model

For the above method, this paper finds the score of each evaluation object. Due to the different weights of each evaluation object, there will be an error between the actual score and the calculated score, so this paper introduces the entropy weight method to eliminate the error [9]. According to the definition and principle of entropy, when the system can be in several different states, the probability of each state is $p_i\ (i=1,2\ldots m)$. Then the entropy of the system can be defined as:

According to the above conditions, there are m evaluation objects and n evaluation indicators $(m=10, n=4)$

$$e=-\frac{1}{\ln m}\sum_{i=1}^{m} p_i \ln p_i \tag{8}$$

Using the standardized decision matrix: $B=(b_{ij})_{m\times n}$

i.e., the weight of the ith evaluation object on the value of the jth indicator

$$\text{Count: } p_{ij}=(i=1,2\ldots m;\ j=1,2\ldots n) \tag{9}$$

$$p_{ij}=\frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}} \quad (i=1,2\ldots m;\ j=1,2\ldots n) \tag{10}$$

Calculate the entropy of the i indicator:

$$e_j=-\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \quad (j=1,2\ldots n) \tag{11}$$

Calculation of the coefficient of variation for indicator $i: g_i=1-e_j$, $j=1,2\ldots n$

For the j indicator, the larger e_j is, the less variation there is in the value of the indicator

Calculation of the weight of indicator j:

$$w_j = \frac{g_i}{\sum_{j=1}^{n} g_j} \quad (j = 1, 2 \ldots n) \tag{12}$$

Then redefine the distance of the $(i = 1, 2 \ldots m)$ evaluation object from the maximum value:

$$D_i^+{}' = \sqrt{\sum_{j=1}^{n} (B_j^+ - B_{ij})^2} \tag{13}$$

$$D_i^-{}' = \sqrt{\sum_{j=1}^{n} (B_j^- - B_{ij})^2} \tag{14}$$

Define the $i(i = 1, 2 \cdots m)$ evaluation object to normalize the score: $S_i{}' = \frac{D_i^-{}'}{D_i^+{}' + D_i^-{}'}$ $(0 \le S_i{}' \le 1)$

Finally, this paper obtains a graph comparing the two evaluation scores of the original TOPSIS and the TOPSIS with the introduction of the entropy weighting method.

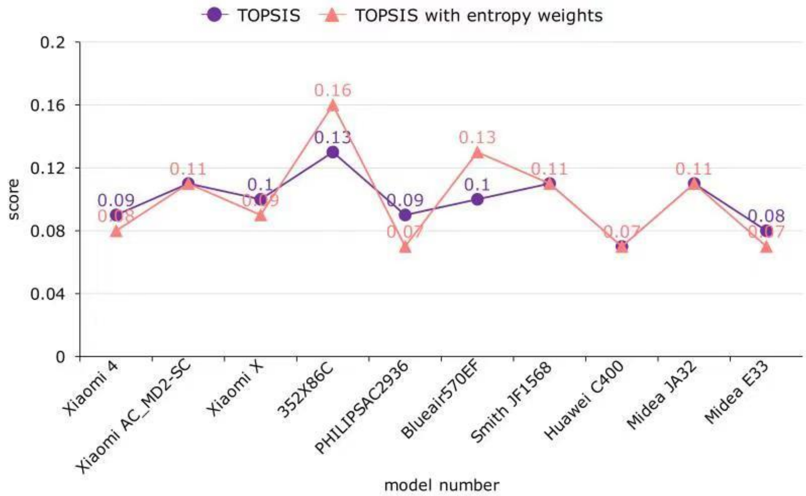

Figure 3: Comparison of TOPSIS in two states

Figure 3 can be analyzed to conclude that the TOPSIS with the introduction of entropy weighting method has a significant deviation from the original TOPSIS calculation score, indicating that the indicators have different weights and the final scores are quite different. 352X86C, PHILIPSAC29, Blueair570EF and Huawei C400 are four air purifiers whose scores have undergone a sudden change.

4. Conclusion

In order to provide a comprehensive and objective evaluation of air purifiers collected in the market, this paper chooses to use TOPSIS combined with the entropy weight method to evaluate the collected air purifiers, which combines the entropy weight method into the original TOPSIS method, so that the evaluation results are free from external interference, and improves the comprehensiveness of the evaluation results. Finally, the cost-effective evaluation results of air purifiers are obtained.

However, the model is sensitive to changes in initial data and different standardization methods, which affects the stability and reliability of the decision-making results. Considering the dynamic changes and technological advances in the air purifier market, it is studied how to deal with the uncertainty factors in the evaluation model. Methods such as fuzzy logic and gray system theory can be used to deal with uncertainty and incorporate it into the cost-performance evaluation model to improve the accuracy and reliability of the evaluation results.

References

[1] Wu Zhijian, Chen Jinzhen, Qiu Wenguang et al. Preliminary analysis of the health risk of secondary formaldehyde pollution from air purifiers [J]. Daily Electric Appliances, 2023(05):22-25+30

[2] Xiong Mingzhou, Wang Chengcheng, Shi Lei, et al. Research on predicting ambient voltage of an air purifier based on BP neural network [J]. Home Appliance Science and Technology, 2023(01): 114-117

[3] M. Zhao. Research on performance testing of indoor air purifier based on CFD simulation [J]. Measurement and Testing Technology, 2022, 49(11): 13-17

[4] Zheng Yifeng, Wang S. W. Research on the design of intelligent air purifier based on RAHP and QFD [J]. Packaging Engineering, 2022, 43(18): 72-79

[5] H. B. Luo. Improvement of formaldehyde clean air volume of air purifier based on QC method [J]. Clean and Air Conditioning Technology, 2021(04): 74-79.

[6] Wei Tian, Ding Heng. Analysis of the causes of persistent heavy polluted weather process in Linfen area [J]. Journal of Chengdu University of Information Engineering, 2023, 38(04): 484-491

[7] Peng, G. R. Screening model and empirical evidence of evaluation index of modern agriculture in prefecture and city based on correlation analysis-coefficient of variation [J]. Journal of Hubei College of Nationalities (Natural Science Edition), 2017, 35(03): 297-304

[8] Yueming H, Dan F, Hongyan Z, et al. Efficiency evaluation of intelligent swarm based on AHP entropy weight method [J]. Journal of Physics Conference Series, 2020, 1693:012072. DOI:10.1088/1742-6596/1693/1/012072.

[9] Zhang Sui, Zhang Mei, Chi Guotai. Scientific and technological evaluation model based on entropy power method and its empirical research [J]. Journal of Management, 2010, 7(01): 34-42