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ECONOMIC EVALUATION OF SANITARY CERAMICS BASED ON ENTROPY-WEIGHT ATTRIBUTE RECOGNITION MODEL

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A B S T R A C T

This paper aims to establish a scientific, objective, and comprehensive economic assessment system for sanitary ceramic products. Addressing the limitations of traditional evaluation methods, this study introduces the Entropy Weight Method to determine the weights of various assessment indicators and integrates it with an attribute model for comprehensive evaluation. Firstly, an in-depth analysis of the economic characteristics of sanitary ceramic products and their key influencing factors is conducted. Secondly, an evaluation indicator system encompassing multiple dimensions such as cost, energy consumption, environment, and product performance is constructed. Subsequently, the theoretical basis and calculation steps for determining indicator weights using the Entropy Weight Method and performing comprehensive evaluation with the attribute model are elaborated. Finally, typical sanitary ceramic products are selected as research samples, and the constructed model is applied for empirical assessment. Based on the evaluation results, the economic performance of different products is ranked, graded, and thoroughly analyzed, providing decision-making suggestion for the sustainable development of sanitary ceramic enterprises.

1. INTRODUCTION

Before the 1990s, sanitary ceramics were used in public building decoration mainly. With the continuous development of the economy and the improvement of people's living standards, the demand for sanitary ceramics has shifted toward medium and high-end products gradually. In home decoration and public health facilities, sanitary ceramics not only meet basic functional needs but also receive increasing attention in terms of aesthetics, environmental protection, and human health (Li et al., 2025). Therefore, understanding and evaluating economics of sanitary ceramics industry has important theoretical and practical significance for promoting its sustainable development (Monteiro et al., 2022).

Traditional evaluation methods rely on quantitative analysis heavily, often ignoring dynamic market changes and diverse consumer demands (Zhang & Chang, 2021). Entropy-weight attribute recognition model can eliminate subjective weighting biases and has the advantage of clear attribute identification. Entropy weight method is an objective weighting method that determines index weights based on the amount of information contained in each index. The smaller the entropy of an index, the greater the degree of variation in its values, the more information it provides, the greater its role in comprehensive evaluation, and thus the greater its weight should be. Entropy weight method has simple calculation steps, effectively utilizes index data, and excludes the influence of subjective factors (Wu et al. 2022, Zhu et al., 2020).

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Attribute recognition model is a comprehensive evaluation method based on attribute space, with the principles of minimum cost, maximum measure, confidence, and scoring as its foundation. Combining it with entropy weight method, an objective weighting method, for economic evaluation of sanitary ceramics is expected to provide new ideas for economic evaluation of sanitary ceramics.

1.1 Overview of Ceramics

Ceramics is a general term for pottery and porcelain, with silicate minerals as its main raw materials. High-quality ceramics, renowned for their excellent heat resistance, wear resistance, and chemical stability, have become indispensable materials in modern manufacturing and daily life (Srivastava et al., 2022). Classified by application, ceramics can be divided into decorative art ceramics, daily-use ceramics, special ceramics, architectural ceramics, and sanitary ceramics roughly.

Daily-use ceramics refer to utensils serving daily life directly mainly, such as tableware, tea sets, and coffee sets (Duan, 2019). Their economic considerations include price, durability (resistance to breakage and glaze wear), and ease of cleaning (saving cleaning costs and time). Artistic decorative ceramics, such as vases and sculptures, focus more on aesthetic and collection value, and their "economic performance" may be reflected in potential appreciation space or the satisfaction degree of cultural consumption (De Mozota, 2003).

Architectural ceramics include ceramic tiles, glazed tiles, exterior wall panels, etc (Lasić & Šimunović, 2025). Their economic aspects involve initial procurement costs, installation costs, service life, maintenance and cleaning costs, as well as indirect impacts on overall energy consumption of buildings (e.g., exterior wall materials with good thermal insulation performance) (Dylewski & Adamczyk, 2011). Sanitary ceramics refer to glazed ceramic products used in sanitary facilities, such as daily washing sanitary wares (Desole et al., 2024). With continuous development of society, people's requirements for quality of life are increasing, and sanitary ceramics industry is moving towards functionalization, environmental protection, and personalization gradually (Yu et al., 2024). Currently, the focus in the field of sanitary ceramics not only lies in meeting basic living needs but also emphasizes ecological environmental protection and the improvement of living environments (Fukushima & Ohji, 2023). Common sanitary ceramic products include toilets, washbasins, and bathtubs, with the following characteristics (Yu et al. 2024): (1) Durability: Sanitary ceramics have strong resistance to wear and corrosion, making them suitable for long-term use. (2) Aesthetics: Products come in various design styles to meet the aesthetic needs of different consumers. (3) Environmental protection: Energy conservation and emission reduction under the dual-carbon policy help protect the environment.

Industrial ceramics, such as electronic ceramics, structural ceramics, and bioceramics, are applied in high-tech fields. Their economic evaluation is more complex, requiring consideration of R&D investment, production costs, efficiency improvements brought by performance, as well as reliability and service life in specific applications.

1.2 The collection and analysis of ceramics

China is a major producer of sanitary ceramics. Over the past decade, annual output of sanitary ceramic products has remained at a high rank globally (Wray, 2008). Sanitary ceramics include toilet bowls, washbasins, squatting pans, urinals, etc (Yin & Wang, 2021). Mainly. This study selects the fully enclosed siphonic one-piece toilet as evaluation object because it occupies a dominant position in sanitary ceramic products, with a large market share, rich product varieties, rapid technological iteration, and high consumer attention to its functionality such as water-saving and service life, which can reflect the comprehensive economic characteristics of sanitary ceramic products well.

The technical classification of sanitary ceramic toilets can be carried out from four dimensions: firstly,, they can be defined as three types of two-piece, one-piece, and wall-hung according to the overall structural differences; secondly, they can be divided into two systems of washdown and siphonic in terms of flushing principles, among which siphonic mechanism is further refined into two hydrodynamic modes of vortex siphon and jet siphon; thirdly, they are divided into conventional type and water-saving type based on the threshold of single water consumption; lastly, they can be divided into bottom-outlet and rear-outlet according to spatial orientation of the sewage outlet (Chen et al., 2003).

The production of sanitary ceramics in China is concentrated in Central and South China mainly. Report by China Building Sanitary Ceramics Association indicates that by the end of 2024, three major producing regions of Guangdong, Jiangxi, and Fujian had maintained their leading positions nationwide with strong production capacity (Zhang et al., 2025). To cover major ceramic-producing areas in North China, South China, Central China, and southeast coastal regions, this paper selects 5 sanitary ceramic brands, namely Huida Sanitary Ware, ARROW Home, Jomoo Group, R&T Ceramics, and Dongpeng Meilin Sanitary Ware. These five enterprises hold high market share and brand influence in China, and selecting their data for evaluation is highly representative in this paper.

2. EVALUATION METHODS

2.1 Entropy-Weight Attribute Recognition Model

In the context of multi-index decision-making, traditional qualitative evaluation methods often suffer from issues such as strong subjectivity and ambiguous conclusions. To achieve a scientific evaluation of economic performance of different sanitary ceramic enterprises, this paper introduces entropy-weight attribute recognition model for quantitative analysis. The core idea of the entropy-weight model lies in quantifying the importance of each attribute through calculation of information entropy (Zhu et al., 2020). This method considers the information contribution of different evaluation indicators in the entire evaluation process and avoids biases caused by subjective weighting fully (Al-Aomar, 2010). Based on the magnitude of entropy values, distribution of weights can reflect the impact of each attribute on overall performance evaluation, thereby making this model more scientific and impartial (Qi et al., 2015).

This model integrates entropy weight method with attribute recognition theory: it calculates objective weights of each evaluation indicator through information entropy, and then uses attribute measure functions to classify and rank multiple schemes. Entropy weight method can reveal the degree of variation of different indicators in sample data, thereby reflecting their relative importance; attribute recognition model measures the similarity between samples and preset standards to obtain final evaluation grade. With advantages such as objectivity, adaptability, and strong discriminative power, this method has been applied in comprehensive evaluations in various fields widely including water resource management, environmental risk assessment, and urban development.

2.2 Evaluation indicators selection

The selection of evaluation indicators forms cornerstone of an assessment system, and their quality affects the scientific validity and accuracy of evaluation results directly. For economic evaluation of sanitary ceramic products, the chosen indicators should adhere to the following principles (Table 1): (1) Scientificity: Indicators should reflect economic characteristics of sanitary ceramic products accurately, with clear definitions and quantitative standards. (2) Comprehensiveness: Indicators should cover, as much as possible, the main aspects influencing economics of sanitary ceramics, including initial investment and long-term usage costs. (3) Independence: Indicators should avoid high correlation to minimize information redundancy and duplicate calculations. (4) Accessibility: Indicator data should be easy to obtain and measure, ensuring operability. (5) Purposefulness: All indicators should serve core goal of "economic evaluation."

Typical energy sources consumed in sanitary ceramic production include water, coke oven gas, and electricity. The production costs of sanitary ceramics include costs related to the body, glaze, and labor. Service life reflects the durability cycle of products under normal usage conditions generally. The main pollutants from sanitary ceramic enterprises include waste gas and solid emissions: CO_2 is most emitted component in waste gas; water pollutants include COD, petroleum substances, SS, and ammonia nitrogen mainly. Solid waste is generated during production stage mainly, including waste porcelain, waste blanks, waste gypsum, waste glaze, and other wastes. Most of these are recycled, so solid waste in production process is not considered. Water flushing volume is a key indicator of water-saving performance, with a standard range of 3L to 6L generally regarded as qualified. Energy consumption, production costs, and pollutants all refer to those required for producing one ton of ceramic products. These indicators are both independent and interrelated, forming a systematic, hierarchical, and operable evaluation system collectively.

3. EVALUATION AND ANALYSIS

3.1 Construct sample space matrix

Let the evaluation object space be , from which samples are extracted, and each sample needs to measure indicators. Let measured value of the -th indicator of the -th sample be denoted as . Therefore, each sample can be expressed as a vector , where ranges from to (inclusive of and). These samples form an -order sample space matrix. Here, and .

The specific samples include fully enclosed siphonic one-piece toilets from sanitary ceramic products of Huida Sanitary Ware, ARROW Home, Jomoo Group, R&T Ceramics, and Dongpeng Meilin Sanitary Ware. Sample data are sourced from the following channels: corporate annual reports and officially disclosed production and financial data, statistical yearbooks of industry associations, prospectuses, news reports, shopping websites, etc. For some undisclosed items, estimates are made based on industry averages or data from adjacent enterprises. The resulting sample space matrix is shown in Table 2.

3.2 Set attribute classification standard matrix

To facilitate subsequent standardization and attribute recognition processing of each evaluation indicator, it is necessary to normalize and classify original sample data directionally (Table 3), and construct an attribute classification standard matrix. This matrix will clarify evaluation attribute direction (positive/negative) of each indicator. The criteria for dividing evaluation attribute directions are as follows: For positive indicators, the larger the value, the better the economic performance (such as service life); for negative indicators, the smaller the value, the better the economic performance (such as energy consumption, pollutant emissions, costs, etc.).

3.3 Calculate indicator's weights

Entropy, as a measure of disorder of system, has an inverse relationship with order: the higher the entropy value, the more chaotic the microstates; the lower the entropy value, the more regular the structure. Within the framework of information theory, entropy can also characterize information effectiveness of indicators. Based on this, entropy weight method is introduced to determine weight distribution of each indicator in the evaluation system. This method relies on the intrinsic information of data, quantifies the degree of indicator variation to eliminate subjective preferences, and thereby achieves the objectivity of weights. Its calculation process is as follows:

(1) Data standardization

Due to different dimensions of each indicator, it is necessary to perform dimensionless standardization on the original data matrix. According to direction of indicator attributes, the following methods are adopted:

Positive indicators (the larger the value, the better):

$$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \quad (1)$$

Negtive indicators (the little the value, the better):

$$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \quad (2)$$

Here, x_{ij} represents the original value of the i-th sample on the j-th indicator, and r_{ij} is standardized value.

Calculate the indicator entropy value

Perform normalization processing on the standardized matrix to obtain:

$$p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \quad (3)$$

Then calculate information entropy of j-th indicator:

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln(p_{ij}), k = \frac{1}{\ln m} \quad (4)$$

To avoid the mathematical error of $\ln(0)$, it is defined that $p_{ij}\ln(p_{ij}) = 0$ when $p_{ij} = 0$ (handled as a limit).

Calculate redundancy and weight

Redundancy (i.e., information utility):

$$d_j = 1 - e_j \quad (5)$$

Final indicator weight:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \quad (6)$$

(4)Results of Indicator Weight Calculation

Due to presence of zero values in the standardized values of sample data, to prevent subsequent natural logarithm values from being unsolvable, which would lead to distortion of standardized results and thereby affect weights of each indicator, this paper makes a translation adjustment of 0.0001 when calculating standardized values (Table 4 and Table 5).

As can be seen from above two table, there is an inconsistency in description: indicators such as labor cost, single flush volume, and electric energy have high redundancy, indicating that they vary among samples significantly and contain rich information, thus having large weights relatively. However, it is also mentioned that indicators like labor and single flush volume have low weights, which suggests that their variability among samples is small and their impact on the results is relatively limited.

3.4 Define Attribute Measure and Evaluation Grade

The attribute measure refers to degree to which sample indicator value x_{ij}(the j-th indicator value of the i-th sample) belongs to the p-th evaluation grade, denoted as μ_{ijp} The boundary value for dividing each grade is q_{jp} (the p-th grade boundary value of the j-th indicator). Then, the attribute measure $\mu_{ijp} = \mu$ which x_{ij}possesses a certain attribute.

If (1) $x_{ij} < q_{j1}$, then $\mu_{xj1} = 1$, $\mu_{xj2} = \mu_{xj3} = \cdots = \mu_{xjp} = 0$; (2) $x_{ij} > q_{jp}$, then $\mu_{xjp} = 1$, $\mu_{xj1} = \mu_{xj2} = \cdots = \mu_{xj(p-1)} = 0$; (3) if $q_{js} < x_{ij} < q_{j(s+1)}$, $(1 \le s \le P-1)$, then $\mu_{ijs} = \frac{|x_{ij} - q_{j(s+1)}|}{|q_{js} - q_{j(s+1)}|}$, $\mu_{ijs} = \frac{|x_{ij} - q_{js}|}{|q_{js} - q_{j(s+1)}|}$

Then the comprehensive attribute is:

$$\mu_{ip} = \sum_{j=1}^{n} \omega_j \mu_{ijp} (1 \le i \le m, 1 \le p \le P) \quad (7)$$

The grade of each sample is determined as follows based on the calculation results from above formula and using confidence criterion:

$$p_i^* = \left\{ p \middle| \sum_{k=1}^{p} \mu_{ik} \ge \lambda, 1 \le p \le P \right\} \quad (8)$$

In above criterion, λ is confidence level, which is required to satisfy $0.5 \le \lambda \le 1$. Generally, it is set in the range of $(0.6, 0.75)$, and here it is calculated as 0.6. We take values of p until previous formula is satisfied, and then the sample i is considered to belong to grad C_{pi}.

3.5 Summary of Evaluation Results

With support of the attribute measure model, a multi-dimensional evaluation of economic performance of five typical sanitary ceramics enterprises was conducted (Table 6). Based on entropy weight allocation principle and fuzzy recognition method, attribute measures of each sample under different grades were calculated. The grade determination results according to the confidence criterion show that Sample 2 is classified as Grade I, demonstrating significant economic advantages; Samples 1 and 3 are judged as Grade II, with overall good economic performance; while Samples 4 and 5 fall into Grade III, with low economic levels relatively. This distribution reflects substantial disparities in economic performance within the current sanitary ceramics industry, indicating that the industry as a whole is still in a process of improvement and optimization.

A further analysis of indicator performance of each enterprise reveals that the differences in economic grades stem from key factors such as unit energy consumption and service life mainly. According to entropy weight results, unit product energy consumption is the indicator with highest weight, exerting a significant impact on final grade determination. The confidence criterion was introduced into this measurement model to ensure the rationality and stability of grade judgments in a numerical sense. When the measure value of a certain grade does not exceed the threshold but is close to that of an adjacent grade, the sample exhibits a "fuzzy" attribute, meaning that its grade affiliation is not absolutely determined but has a certain degree of flexibility.

Sample 2 received the highest grade evaluation due to its advantages in unit energy consumption and service life, showing good life-cycle economic characteristics overall. In contrast, Samples 1 and 3 demonstrated moderate advantages in some indicators, thus failing to reach the highest grade in the comprehensive measurement. Samples 4 and 5 performed poorly in multiple high-weight indicators, with obvious shortcomings particularly in energy consumption levels and water flush volume, resulting in their attribute measures being mainly concentrated in lower grades.

4. CONCLUSIONS AND SUGGESTIONS

Enterprises need to plan resource allocation precisely based on the objective weights of various indicators in entropy-weighted attribute recognition model. Priority should be given to key areas that have a critical impact on overall economic performance, with enhancing energy efficiency and promoting green transformation as strategic priorities. Introduce high-efficiency energy-saving technologies vigorously, such as intelligent frequency conversion equipment, to reduce energy loss; deploy clean energy sources actively like photovoltaics and wind power to reduce reliance on traditional energy, while controlling carbon emissions to align with the general trend of low-carbon development strictly. At the same time, develop circular economy by establishing waste recycling systems and improving recycling efficiency fully. Starting from the production process, optimize technologies and increase material utilization rates to turn "waste" into "resources." This not only reduces production costs but also contributes to environmental improvement, achieving a dual upgrade in cost savings and environmental benefits, and driving enterprises toward sustainable and high-quality development.

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Table 1. Evaluation indicators

Indicator Category	Specific Indicator	Unit	Attribute
Energy Cost	Natural Gas	m^3	Negative
	Electric Energy	kJ	Negative
	Water	t	Negative
Production Cost	Blank	Yuan	Negative
	Glaze	Yuan	Negative
	Labor	Yuan	Negative
Environmental Impact	Air Pollution	kg	Negative
	Water Pollution	g	Negative
	Solid Waste	t	Negative
Usage Performance	Single Flush Volume	dm^3	Negative
	Service Life	a	Positive

Table 2. Sample space matrix

No	Natural Gas (m^3/t)	Electric Energy(kJ)	Water(t)	Blank(Yuan/unit)	Glaze(Yuan/unit)	Labor(Yuan/unit)	Air Pollution(kg/t)	Water Pollution(g/t)	Solid Waste(kg/t)	Single Flush Volume(dm^3)	Service Life(a)
1	25	115200	0.95	43.62	11.5	25	1176	285.23	330	3.5	13
2	22	100800	0.85	42.23	11	24	1553	280.57	485	4.5	12
3	23	100800	0.90	44.57	11	25.5	1192	291.48	388	4.5	12
4	26	11800	1.00	45.16	12.5	26	1209	305.55	395	4.8	10
5	27	122400	1.05	46.77	13	26	1665	320.18	401	4.6	11

Table 3. Attribute classification standard matrix

Indicator Category	Indicator Name	Unit	Attribute	Grade I Standard	Grade II Standard	Grade III Standard
Energy Cost	Natural Gas Consumption	m^3/t	Negative	<22	22-24	>24
	Electric Energy Consumption	KJ/kg	Negative	<100800	100800-108000	>108000
	Water Resource Consumption	m^3/t	Negative	<0.85	0.86-0.90	>0.9
Production Cost	Blank Cost	Yuan/unit	Negative	<43	43.01-44.5	>44.5
	Glaze Cost	Yuan/unit	Negative	<11	11.01-12	>12
	Labor Cost	Yuan/unit	Negative	<24	24.01-25	>25
Environmental Pollution	Air Pollution	Kg/t	Negative	<1200	1201-1250	>1250
	Water Pollution	g/t	Negative	<290	291-330	>330
	Solid Waste	kg/t	Negative	<350	351-400	>400
Product Performance	Single Flush Volume	dm^3	Negative	3-3.5	3.6-4.0	4.1-6
	Service Life	a	Positive	≥13	12	11

Table 4. Standardized value of data

No.	Natural Gas	Electric Energy	Water	Blank	Glaze	Labor	Air Pollution	Water Pollution	Solid Waste	Single Flush Volume	Service Life
1	0.4001	0.3334	0.5001	0.6939	0.7501	0.5001	1.0001	0.8825	1.0001	1.0001	1.0001
2	1.0001	1.0001	1.0001	1.0001	1.0001	1.0001	0.2291	1.0001	0.0001	0.2309	0.6668
3	0.8001	0.6668	0.7501	0.4847	1.0001	0.2501	0.9674	0.7247	0.6259	0.2309	0.6668
4	0.2001	0.1668	0.2501	0.3547	0.2501	0.0001	0.9326	0.3695	0.5807	0.0001	0.0001
5	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.5420	0.1539	0.3334

Table 5. Weights Distribution

No.	Indicator Name	Information Entropy (e_j)	Redundancy (d_j)	Entropy Weight (ω_j)
1	Natural Gas	0.768684	0.231316	0.091666
2	Electric Energy	0.748906	0.251094	0.099504
3	Water	0.795486	0.204514	0.081046
4	Blank	0.816238	0.183762	0.072822
5	Glaze	0.799299	0.200701	0.079534
6	Labor	0.594538	0.405462	0.160678
7	Air Pollution	0.795317	0.204683	0.081112
8	Water Pollution	0.826479	0.173521	0.068764
9	Solid Waste	0.841134	0.158866	0.062956
10	Single Flush Volume	0.669512	0.330488	0.130967
11	Service Life	0.820957	0.179043	0.070952

Table 6. Attribute Measure Results and Evaluation Grades

No.	Attribute Measure I	Attribute Measure II	Attribute Measure III	Evaluation Grade
1	0.572	0.314	0.114	II
2	0.677	0.193	0.130	I
3	0.211	0.516	0.273	II
4	0.104	0.209	0.687	III
5	0.000	0.174	0.826	III

References:

Al-Aomar, R. (2010). A combined ahp-entropy method for deriving subjective and objective criteria weights. *International Journal of Industrial Engineering: theory, applications and practice*, *17*(1), 12-24.

Chen, T., Yin, G., & Pan, Z. (2003, April). Interactive design and presentation of ceramic sanitary products. In *Third International Conference on Virtual Reality and its Application in Industry* (Vol. 4756, pp. 259-264). SPIE.

De Mozota, B. B. (2003). *Design management: using design to build brand value and corporate innovation*. Skyhorse Publishing Inc..

Desole, M. P., Fedele, L., Gisario, A., & Barletta, M. (2024). Life Cycle Assessment (LCA) of ceramic sanitaryware: focus on the production process and analysis of scenario. *International Journal of Environmental Science and Technology*, *21*(2), 1649-1670.

Duan, J. (2019). Daily ceramic design based on the concept of cultural creation. *Frontiers in Art Research*, *1*(2), 1-6.

Dylewski, R., & Adamczyk, J. (2011). Economic and environmental benefits of thermal insulation of building external walls. *Building and environment*, *46*(12), 2615-2623.

Fukushima, M., & Ohji, T. (2023). Macroporous ceramics for the sustainable development goals (SDGs). *International Journal of Applied Ceramic Technology*, *20*(2), 660-680.

Lasić, J., & Šimunović, K. (2025). Ceramics as an important element of design and architecture. *e-Zbornik: Electronic Collection of Papers of the Faculty of Civil Engineering*, (29/2025). DOI: 10.47960/2232-9080.2025.29.15.84

Li, X., Zhang, M., Yang, L., Yue, X., & Xiong, X. (2025). Current state and development trend of China's customized home furnishing industry. *Wood Material Science & Engineering*, *20*(3), 721-733.

Monteiro, H., Cruz, P. L., & Moura, B. (2022). Integrated environmental and economic life cycle assessment of improvement strategies for a ceramic industry. *Journal of Cleaner Production*, *345*, 131173.

Qi, X., Liang, C., & Zhang, J. (2015). Generalized cross-entropy based group decision making with unknown expert and attribute weights under interval-valued intuitionistic fuzzy environment. *Computers & Industrial Engineering*, *79*, 52-64.

Srivastava, S. K., Gupta, G. K., Joshi, T. C., Pandey, A., Muchhala, D., Shrivastava, V., ... & Ranjan, S. (2022). Existence of advanced ceramic materials in human life. In *Advanced ceramics for versatile interdisciplinary applications* (pp. 1-14). Elsevier.

Wray, P. (2008). CHINA: Ceramics world continues eastward shift. *American Ceramics Society Bulletin*, *87*(10), 26-30.

Wu, R. M., Zhang, Z., Yan, W., Fan, J., Gou, J., Liu, B., ... & Wang, Y. (2022). A comparative analysis of the principal component analysis and entropy weight methods to establish the indexing measurement. *PloS one*, *17*(1), e0262261.

Yin, W., & Wang, K. (2021). Sanitary wares (Wash-basin) product industry situation and quality analysis. In *E3S Web of Conferences* (Vol. 267, p. 02022). EDP Sciences.

Yu, C., Kong, R., & Sang, S. (2024, June). Innovative Design and Development of Chinese Sanitary Ceramics from the Perspective of Humanistic Care. In *2024 3rd International Conference on Social Sciences and Humanities and Arts (SSHA 2024)* (pp. 228-245). Atlantis Press.

Zhang, J. Z., & Chang, C. W. (2021). Consumer dynamics: Theories, methods, and emerging directions. *Journal of the Academy of Marketing Science*, *49*(1), 166-196.

Zhang, J., Zhang, H., Asutosh, A. T., Sun, N., & Li, X. (2025). The environmental sustainability assessment of building ceramic manufacturing based on the LCA-emergy approach. *Environment, Development and Sustainability*, *27*(3), 5999-6024.

Zhu, Y., Tian, D., & Yan, F. (2020). Effectiveness of entropy weight method in decision-making. *Mathematical problems in Engineering*, *2020*(1), 3564835.

Zhu, Y., Tian, D., & Yan, F. (2020). Effectiveness of entropy weight method in decision-making. *Mathematical problems in Engineering*, *2020*(1), 3564835.

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