Research on Aroma-Releasing Flooring based on Kano-AHP-TRIZ Model

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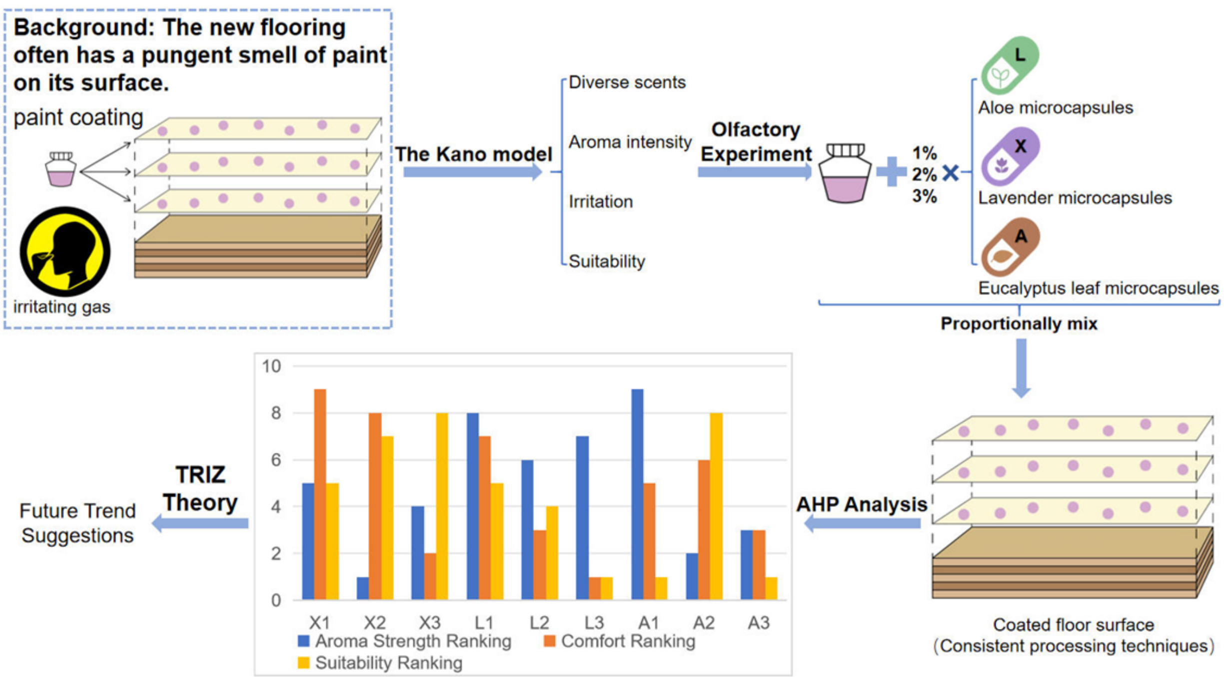
GRAPHICAL ABSTRACT



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The concept of the "olfactory economy" has recently emerged as a novel consumer trend. Flooring has been observed to emit an undesirable olfactory sensation during its initial use. The implementation of scented flooring has been demonstrated to mitigate this concern. This study examines the problem of undesirable odors emitted by engineered wood flooring during its initial application. A Kano-AHP model in conjunction with TRIZ theory was used to investigate market demand for fragranced flooring and to offer novel insights into its advancement. A questionnaire survey was administered to ascertain market demand for aromatic flooring. The Kano model was employed to assess user requirements, with a focus on individuals seeking aromatic flooring. This finding emerged after the investigation of fragrance intensity, comfort, and suitability. The aromatic flooring surface was then subjected to artificial olfactory testing, and the findings were statistically analyzed using the Hierarchical Analysis Method to rank user olfactory preferences by weight and priority. TRIZ theory was ultimately employed to transform these requirements into enhancement strategies for aromatic flooring. The findings demonstrate the efficacy of this research approach in translating user requirements into research and development trajectories, thereby enhancing the relationship between users and goods and offering novel insights for the research and development of indoor furniture panels.

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Keywords: KANO model; AHP; TRIZ theory; Fragrance-releasing flooring; Microcapsule technology

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INTRODUCTION

Conventional solid wood composite flooring frequently emits a potent, disagreeable odor during and soon after its manufacturing due to the presence of volatile compounds in the surface finish. This chemical residue persists during the initial use of the flooring, thereby diminishing interior comfort and contradicting the emerging "olfactory economy" consumer trend. Presently, there is an absence of systematic analysis regarding user demand and conversion models to inform the development of aromatic flooring. The advent of innovative microcapsule technology for scent release has emerged as a solution to this challenge. This approach involves encapsulating natural plant essential oil molecules into a polymer matrix to provide regulated, progressive emission of functional aromas. The combination of the flooring's surface coating produces a flooring that emits a fragrance and perpetually neutralizes hazardous elements like formaldehyde while emitting a calming, woody aroma. This imparts the flooring product with dual benefits for air cleansing and emotional restoration. The integration of fragrances into flooring materials can yield long-lasting deodorizing effects, exhibiting superior durability compared to temporary air fresheners. However, the irreversible installation method may limit its applicability for individuals who are susceptible to allergies. Nevertheless, this presents new opportunities for the "olfactory added value" of sustainable building materials (Kang *et al*. 2024).

The establishment of the Kano-AHP model will enable more scientific evaluation of the feasibility of qualitative and quantitative analyses between the levels. For example, Huo, J. Y., and others, in order to ensure the objectivity of the evaluation indexes, used AHP to assess and quantify the human health state, conduct matrix establishment, and analyse the evaluation of the tester's physical condition (Huo *et al*. 2024); Wang and others used the Kano model and the AHP method to determine the attributes of the user needs and the ranking of the demand weights after researching on the ageing shoe-changing seat, to obtain a more accurate user demand and transformed into the characteristic demand and important demand ranking of the ageing shoe-changing seat, in order to design the furniture products suitable for the elderly to add to the ageing design (Wang and Fan 2024). Zhang *et al*. (2023) used the AHP method to classify the complex problems in the ageing kitchen cupboards into multiple tiers, created a judgement matrix, and carried out quantitative and qualitative analyses of the different tiers to check the consistency and the validity of the study.

Previous studies have demonstrated that combining the Carnot model with the analytic hierarchy process model is effective. This work made use of the Kano model, AHP (The Analytic Hierarchy Process), and TRIZ theory to quantify user demand data and serve as a reference for systematically analyzing users' fundamental needs and performance preferences regarding fragrance-releasing flooring. It aims to quantify the significance of key indicators, identify and transform demand contradictions into precise technical optimization directions, address initial odor issues, enhance user experience, and propose innovative strategies for product development.

Market Demand

Due to the increased awareness of consumer health and the emergence of the "olfactory economy," the demands for ornamental wood products has transitioned from traditional durability and aesthetics to environmentally friendly and health-promoting functionality. For the early use of artificial boards, they are sometimes accompanied by volatile chemicals, resulting in annoying scent problems. The release of incense-type came into existence and is highly appreciated by the market. Research indicates that atomizing wood with herbal extracts including raw Chuanwu and licorice, or incorporating powdered aromatic herbs, can yield healthcare panels possessing both antibacterial and mood-regulating properties. Lavender variants can soothe nerves and promote sleep, mint variants can invigorate the mind, and rose variants can mitigate melancholy (Song 2022). The utilization of plant essences, particularly the emission of volatile organic compounds with bactericidal, antiviral, and immunomodulatory properties, exemplifies an innovative integration of traditional plant extracts with contemporary materials technology, thereby advancing the evolution of wood-based materials towards health, environmental sustainability, and multifunctionality.

Technical Support

Microencapsulation technology provides a way to deliver flavor, pesticides, and other trace substances wrapped in polymer film technology, which can store liquids, solids, and gases to form tiny particles of technology made of microcapsules with a capsule wall so as to achieve the effect of protection, controlled release, *etc*. When the goal is to release a flavor, the microencapsulated substance is an essential oil as the core material. Microencapsulation technology can effectively protect the flavor or essential oil from the external environment (such as light, heat, oxygen, *etc*.), thus improving its stability and persistence. The microencapsulation technology protects the flavor of essential oil from the environment (such as light, heat, oxygen, *etc.*) to improve its stability and durability and to achieve the slow release control of the flavor essential oil for long-lasting fragrance.

Flavour Characteristics and Applications

Lavender essential oil is a volatile compound derived from the lavender plant. Lavender possesses numerous advantageous impacts, such as easing colds, enhancing gastrointestinal function, fortifying cognitive abilities, reducing moisture, and mitigating pain. It enhances sleep difficulties, mitigates anxiety and sadness, reduces mania, and affects endocrine function. It is applicable for the treatment of migraines and the alleviation of neuropathic pain. Microcapsules containing lavender aroma are extensively utilized in furniture. Microcapsules were synthesized by a polymerization process to investigate the influence of hot-pressing temperature, duration, and fragrance application quantity on the surface bonding strength of eco-friendly fragranced plywood (Huai *et al*. 2013). Eucalyptus essential oil is a volatile compound derived from the branches and leaves of the eucalyptus tree. It possesses antibacterial, antiviral, antioxidant, and insecticidal qualities and is extensively utilized in the food, cosmetics, fragrance, and pharmaceutical sectors. Ren (2018) found that the inclusion of eucalyptus leaf essential oil in toothpaste and mouthwash exhibits significant antibacterial activities. Historically, eucalyptus leaf water has been utilized for bathing, purportedly possessing therapeutic benefits for upper respiratory tract ailments. Aloe vera essential oil is an extract derived from the aloe vera plant. Aloe vera exhibits potent antibacterial and anti-inflammatory activities, along with cardiac, immunological, regenerative, antitumor, detoxifying, and anti-aging actions. Xu *et al*. (2020) examined the integration of aloe vera microcapsules into silk fabrics to enhance antibacterial efficacy, provide a persistent aroma, and improve comfort and aesthetics. The aforementioned three smell categories are highly prevalent and readily available in everyday life, often encountered by individuals; consequently, flooring with coatings that incorporate these.

Theoretical Foundations

The Kano model can excavate user needs and reasonable demand attribute division so as to get the design focus and design decision bias as an important basis. In the study of user needs, the Kano model classification of user needs, the key issues of concern to the user research to obtain, and the key issues generated by the key needs of the precise division of analysis, this paper focuses on the user's needs for the release of the aroma flooring questionnaire design.

The Analytic Hierarchy Process (AHP) is employed to discern and rank the most essential user requirements. The Kano model inadequately represents the issue of demand weighting across several attribute levels. The AHP method effectively integrates qualitative and quantitative analysis, providing objectivity and a methodical framework.

The AHP method can be utilized to enhance demand weighting analysis within the Kano model, addressing the constraints of conventional weighting calculations. This entails developing a hierarchical framework by amalgamating expert insights and user demand survey data to ascertain the weights.

TRIZ theory synthesizes essential principles and universal laws from several interdisciplinary knowledge systems by examining the invention patterns of more than two million high-level patents, thus establishing a systematic innovation approach characterized by a stringent logical framework (Wang *et al*. 2005). The Kano model, Analytic Hierarchy Process (AHP), and Theory of Inventive Problem Solving (TRIZ) are often employed methodologies in design research.

In this paper, a KANO-AHP-TRIZ model was constructed to analyze the demand for fragrance-releasing flooring and make subsequent optimization suggestions. The first step was to quantify the user demand through the KANO model, and then AHP was employed to analyze the choice of aroma-expelling flooring. Then, TRIZ contradiction transformation mechanism was applied to transform the demand pain point into a technical parameter contradiction. Ultimately, the invention principle library was used to generate optimization solutions that meet both the user experience expectations and technical feasibility, which realizes the dynamic balance between market orientation and technological innovation and provides a quantifiable path of innovation for product design. Figure 1 shows the technology roadmap for product design. A questionnaire was designed for aroma-releasing flooring to explore the user's demand attributes for this type of flooring (Wen and Zhang 2022; Li 2024; Mou *et al*. 2025; Xiao 2025).

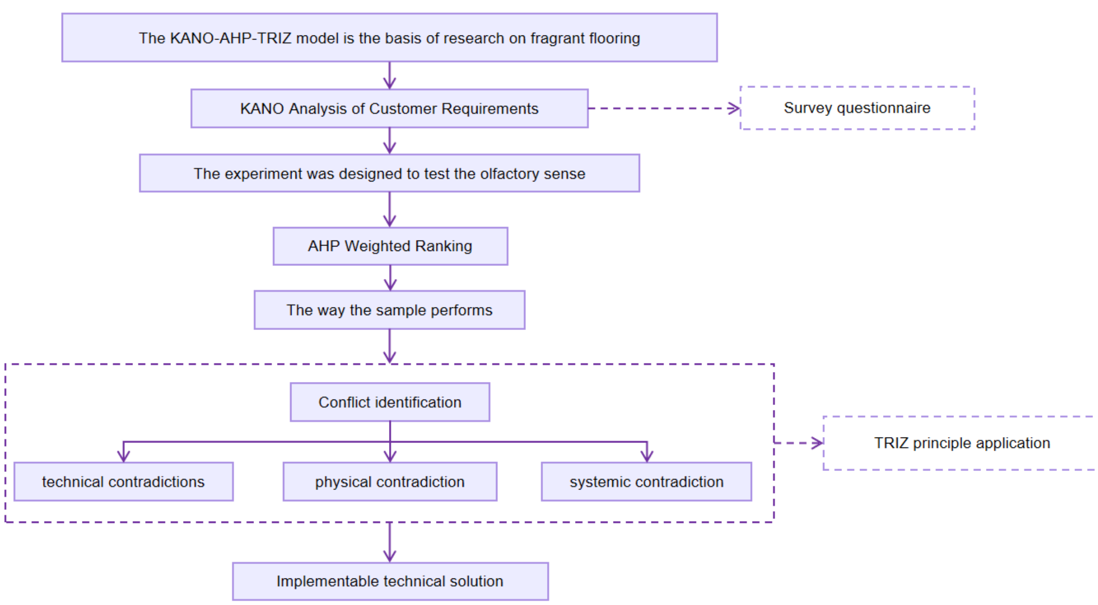

Fig. 1. Technology roadmap

A systematic analysis of user demand conversion models for aromatic flooring is lacking in extant studies. This discrepancy hinders the alignment of research and development with prevailing trends in the olfactory economy, a challenge that the present Kano-AHP-TRIZ model aimed to address.

Construction of KANO-AHP-TRIZ Model

The KANO Model is a theoretical framework that aims to explain the relationship between the characteristics of a product or service and its market success. The classification of user needs into five attributes (Attractive, One-dimensional, Must-be, Indifferent, Reverse) is achieved through the utilization of paired questionnaires. The quantification of sensitivity is achieved through the employment of better-worse coefficients. The formulas are as follows:

$$Better = (A + O) \div (A + O + M + I) \quad (1)$$

$$Worse = (-1) \times (O + M) \div (A + O + M + I) \quad (2)$$

The analytic hierarchy process (AHP) uses the comparison method and the eigenvector method to derive weights. Then, the consistency index (CI < 0.1) is checked to ensure the results are valid.

TRIZ is a methodology that utilizes 40 inventive principles to address technical contradictions.

EXPERIMENTAL

Kano Questionnaire Design

The main approach was to conduct an analysis based on the collected results from the network data. Firstly, the "Octopus" software (Octopus is a data collection tool used for extracting information from web pages) was utilized to gather information related to the aromatic flooring. A total of five keywords were obtained: "suitable", "environmentally friendly", "irritating odor", "aroma intensity", and "diverse scents". Since microcapsule technology helps with air purification, the keyword "environmentally friendly" was disregarded during the keyword determination process. Finally, the demand types were classified into four categories, as shown in Table 1. A total of 120 comments about the fragrant flooring were collected for the spider software. It was found that: "suitable" accounted for 57%, "irritating odor" accounted for 92%, "Aroma intensity" accounted for 65%, and "diverse scents" accounted for 78%.

Table 1. Categorisation of Symbols

Categorisation	Demand (economics)
Technical performance	A_1 Diverse scents
Sensory experience	A_2 Aroma intensity
Safety	A_3 Irritation
Economics	A_4 Suitability (Refers to the general applicability to common household environments)

The procedure was to administer a survey to assess user requirements through a questionnaire. A series of affirmative and negative inquiries were formulated, centered on four fundamental requirements to differentiate users' perspectives on 'need fulfillment' and 'need unfulfillment'. Participants were able to select from the following five options: 'I prefer it this way', 'It is necessary this way', 'I am indifferent', 'I can endure it', and 'I detest it this way' Quality was classified into five dimensions: basic (M), expected (O), attractive (A), indifferent (I), and reverse (R) qualities. The specific positive and negative questionnaire questions are shown in Table 2.

Table 2. Positive and Negative Question Setting

Positive question	Reverse question
1. If there were only one single option for the fragrance of the aromatic floor, what do you think?	2. If there were various options for the fragrance of the aromatic flooring, do you think that would be good?
3. What do you think if the fragrant floor could be controlled by intelligent language?	4. What do you think if the fragrance of the aromatic floor cannot be controlled artificially (can only be preset by the manufacturer)?
5. If the fragrance of the aromatic floor is quite strong, would you?	6. If the fragrance of the aromatic floor is relatively fresh, would you?
7. If the fragrant flooring is suitable for general use, would you?	8. If the fragrant flooring is only suitable for use in a single setting, would you?

Experimental Design of Olfaction

In this work, lavender, aloe vera, and eucalyptus aroma microcapsules were incorporated at concentrations of 1%, 2%, and 3% into the floor surface varnish film to create a scent-releasing flooring, based on the user demand analysis from the KANO model (Wang *et al.* 2024). Olfactory experiments were designed to assess users' evaluations of odor comfort, aroma intensity, and suitability within a typical home environment, aiming to synthesize the evaluation scores of these factors and quantify user preferences.

Materials

Lavender microcapsules were acquired from Anhui Meikedi Intelligent Microcapsule Technology Co., Ltd. The pH is 5.4, the viscosity is 370 mPa·s, and the solid content is around 40%.

Eucalyptus leaf microcapsules were acquired from Anhui Meikedi Intelligent Microcapsule Technology Co., Ltd., exhibiting a pH of roughly 5.5, a viscosity of 260 mPa·s, and a solid content of around 45%.

Aloe vera microcapsules were acquired from Anhui Meikedi Intelligent Microcapsule Technology Co., Ltd. The pH is roughly 6.0, the viscosity is 120 mPa·s, and the solid content is about 35%.

The oil paint was a UV elastic topcoat with a viscosity of around 590 mPa·s, a pH of about 6.9, and a solid content of roughly 58%. It was provided by Zhejiang Shenghua Yunfeng New Materials Co., Ltd.

The floor base material was a three-layer solid wood composite floor manufactured by Zhejiang Shenghua Yunfeng New Materials Co., Ltd., utilizing eucalyptus veneer with dimensions of 910 mm × 115 mm × 17 mm, exhibiting a regulated moisture content of 5% to 12%, and adhered with urea-formaldehyde resin adhesive. The plywood preparation method entails establishing the single-sided adhesive application rate at 220 g/m², conducting hot pressing at 125 °C for 5 min under a pressure of 1.1 MPa, and attaining an odor grade that complies with Environmental Protection Grade 1 criteria.

Microcapsules of lavender, eucalyptus, and aloe vera were incorporated into the floor's UV elastic topcoat, resulting in concentrations of 1%, 2%, and 3% for the respective lavender, eucalyptus, and aloe vera topcoats. Table 3 presents the fundamental details of the prepared microcapsule topcoats. The microcapsules and UV coating mixture were applied to the solid wood composite flooring surface and allowed to dry.

Table 3. Information on Microcapsule Topcoats

		1%	2%	3%
Lavender microcapsule varnish	solid content	≈56%	≈57%	≈56%
	Viscosity (mPa·s)	630	680	840
	pH	5.6	5.4	5.0
Eucalyptus leaf microcapsule varnish	solid content	≈57%	≈61%	≈62%
	Viscosity (mPa·s)	740	850	940
	pH	5.4	5.4	5.3
Aloe vera microcapsule varnish	solid content	≈57%	≈58%	≈57%
	Viscosity (mPa·s)	610	660	780
	pH	5.8	5.7	5.5

Experimental procedure

Nine varieties of scented floor samples (lavender, aloe vera, and eucalyptus leaf at 1%, 2%, and 3% concentrations) were prepared to maintain uniformity in carrier material and microcapsule dimensions. The samples were created by applying three layers of microcapsule topcoat to the floor substrate and thereafter subjected to UV curing. This produces solid wood composite flooring, including a natural, plant-derived, fragrant paint coating. The samples were designated as follows: Lavender (X1, X2, X3), Aloe Vera (L1, L2, L3), and Eucalyptus (A1, A2, A3). The sample numbers are presented in Table 4 below.

Table 4. Aroma Release Floor Sample Numbers

Fragrance | Concentration	1%	2%	3%
Lavender	X1	X2	X3
Aloe Vera	L1	L2	L3
Eucalyptus	A1	A2	A3

The floor was maintained in a naturally ventilated condition, with the test environment set at 27 °C and 67% humidity, imitating the circumstances at the time of purchase. A sensory evaluation method (olfactory assessment) was employed, and a blind testing procedure was designed. Fifty-two testers were invited to participate in a sniffing test, during which each tester first inhaled the scent of the lacquer film surface from the control group (which contained no microcapsules and only the basic UV topcoat). The study's participants were selected through a stratified sampling method, with 52 testers (28 male, 24 female; aged 20 to 50) taking part in the study. Subsequently, they sniffed the surfaces of various fragrance types at the same concentration on the identical flooring to mitigate olfactory adaptation.

The correspondence of the samples was known solely to the designer and remained undisclosed to the participants. Identical concentrations of various scented floor surfaces were evaluated at one-minute intervals, utilizing coffee beans for olfactory resetting to mitigate olfactory adaptation. Only the designer was privy to the sample correspondence. At the same time, the testers remained unaware, and the sequence of presentation for the different scented samples within the same concentration group was randomized. The participants' assessment of aroma intensity (1 to 5 points), comfort (1 to 5 points), and suitability (1 to 5 points) was documented, with the explanatory notes for the evaluation criteria presented in Table 5.

Table 5. Explanation of Scoring Indicators

Strength of Aroma	Comfort	Suitability
Refers to the strength of the aroma for sniffing	Whether the overall feeling of the aroma is pleasant, relaxing and free from harshness, dizziness or other discomforts.	Indicates the suitability of the type and intensity of the aroma in a typical home environment (*e.g.* bedroom, living room, study, *etc.*)

RESULTS AND DISCUSSION

Analysis of the Kano section

The questionnaire survey investigated the demand for aromatic flooring to conduct preliminary research, reflecting user preferences for aroma-releasing flooring and supplying raw data for demand model construction. A total of 80 questionnaires were distributed and recovered, with 74 deemed valid. A total of 80 valid questionnaires were collected from homeowners aged 25 to 45 residing in Jiangsu and Zhejiang provinces. Respondents selected their preferences by ticking boxes, facilitating the integration of the results.

Table 6. KMO and Bartlett's Test

KMO value	0.798	
Bartlett Sphericity Check	approximate chi-square (math.)	2788.230
	df	120
	p-value	0.000

Table 7. Comparison Table for the Classification of Kano Model Evaluation Results

Functions/Services		Negative question				
		Dislikes (1 point)	Tolerable (2 points)	Doesn't matter. (3 points)	as it should be (4 points)	Likes (5 points)
forward question	Dislikes (1 point)	Q	R	R	R	R
	Tolerable (2 points)	M	I	I	I	R
	Doesn't matter. (3 points)	M	I	I	I	R
	as it should be (4 points)	M	I	I	I	R
	Likes (5 points)	O	A	A	A	Q
*Remarks: A: Attractive Attributes, O: Desired Attributes, M: Mandatory Attributes, I: Indifference Attributes, R: Reverse Attributes, Q: Suspicious Attributes						

The reliability and validity of the questionnaire developed using the KANO model were assessed using SPSSAU. The analysis of the 74 collected questionnaires revealed a Cronbach's α coefficient of 0.740, indicating high reliability, as it falls between 0.7 and 0.8 (The SPSSAU project 2025). Additionally, the KMO value was 0.798 (KMO > 0.7), and the significance P-value was less than 0.001, confirming the appropriateness of the research data for information extraction. As shown in Table 6.

Numerical calculation of the Better-Worse coefficient

The classification summary of user demands was organized according to the Kano model evaluation results, as illustrated in Table 7.

The statistical outcomes of the KANO model questionnaire survey are summarized in Table 8. Based on the subjective evaluations of the respondents' selections, the requirement type with the highest frequency of selection corresponds to each design requirement.

Table 8. Summary of KANO Model Analysis Results - Numerical Results

Demand (economics)	A	O	M	I	R	Q	Classification results	Better	Worse
A_1	0	0	11	29	17	17	I	0.00%	-27.50%
A_2	2	0	10	36	42	10	R	4.17%	-20.83%
A_3	0	0	13	42	31	14	I	0.00%	-23.64%
A_4	1	0	14	39	29	17	I	1.85%	-25.93%

The goal was to identify the superior and inferior values, where superior (Satisfactory Influence) is computed as (A+O)/(A+O+M+I). The indicator spanned from 0 to 1, with elevated values denoting heightened sensitivity and priority. Worse (Unsatisfactory Influence) was computed as -1 * (O+M)/(A+O+M+I); the metric ranged from -1 to 0, where lower values indicate heightened sensitivity and greater significance. Figure 2 depicts the Better-Worse coefficient plot, showcasing the coordinates of each condition.

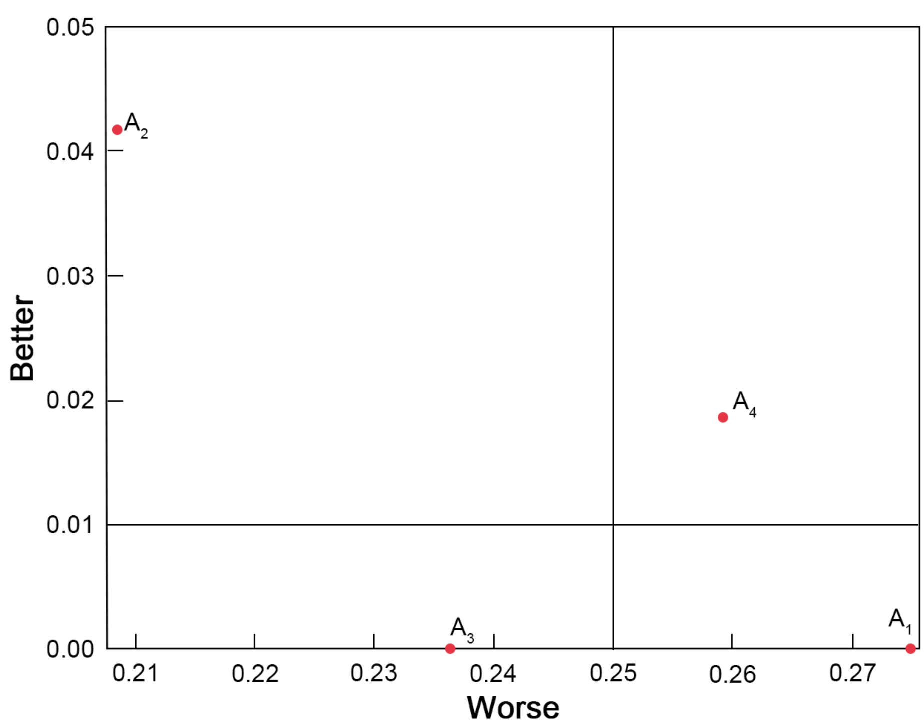

Fig. 2. Plot of Better-Worse coefficients

Summary of Kano analysis

From the analysis results, it can be seen that A_2 is a reverse attribute. When the degree of improvement is high, user satisfaction decreases. That is, users are disgusted by floors with vigorous fragrance intensity. Therefore, in subsequent research, the concentration ratio of microcapsules can be set as a fixed value. The A_1 scent diversity, A_3 presence of irritating compounds, and A_4 suitability are indistinct traits, suggesting that users deem them nonessential and that they do not influence satisfaction.

Based on the Better-Worse coefficient graph of the Kano model, the warning effect of the reverse attribute (A_2): its Worse value is relatively high, indicating that improper intensity control will significantly reduce satisfaction, which affects the experts' views on the weight of aroma intensity parameters (attention should be paid to control). The deeper meaning of the non-differentiated attributes (A_1, A_3, A_4) were as follows: "No difference" merely means that "existence or non-existence" is unimportant, but when the function is provided, its specific manifestations (comfort, suitability) are crucial to the quality of the experience.

This article mainly focused on the problem of the irritating odor that accompanies the initial use of the floor. An in-depth assessment was conducted of the sensory experience of the specific product (fragrance-releasing floor). Under the condition of the research objective (improving the initial irritating odor and enhancing the aromatic experience), although Kano showed that A_1, A_3, and A_4 were non-differentiating attributes, and A_2 is a reverse attribute (requiring control of intensity), this only indicated that users are not sensitive or opposed to having these functions themselves. When the product possesses these functions, the specific implementation methods (such as fragrance type selection, intensity control, comfort level, and suitability) will affect the quality of the user's experience. Therefore, the subsequent experiments will focus on examining within the selected fragrance type (lavender/ aloe vera/ eucalyptus)*concentration (1%/2%/3%), where comfort is the core feeling of users for the aroma experience, which combines pleasure, irritation, etc. Thus, it will be correlated with sensory scores and aroma intensity (controlled within an acceptable range), comfort (core feeling), and suitability (enhanced value) to guide the optimization of specific product parameters.

The Analysis of the AHP Section

AHP hierarchical construction

This study employed a weighted composite scoring method and utilized the raw scoring data from sensory experiments for analysis.

Hierarchical modelling

The performance of samples was evaluated in terms of comfort under three specific fragrances (lavender, aloe vera, and eucalyptus) and their varying concentrations, given that the Kano model indicates that users' demand for "fragrance diversity" (A_1) is non-differentiated, meaning that the presence of a variety of choices does not influence satisfaction. The aroma intensity and suitability of the three specific performance dimensions regarding the advantages and disadvantages of the target layer are essential for selecting the optimal overall performance of fragrance-concentration combinations. Subsequently, the criterion layer, which encompasses comfort, aroma intensity, and suitability, necessitates the construction of a judgment matrix that requires expert scoring to ascertain the weights. The sub-criteria layer comprises a combination of nine fragrance-concentration pairs, as illustrated in the hierarchical structure model diagram in Fig. 3.

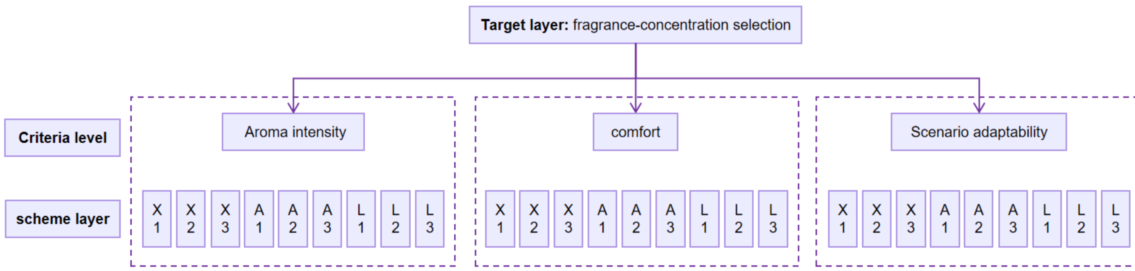

Fig. 3. AHP hierarchical model diagram

Determination of normative layer weights: *Judgement matrix construction*

Ten seasoned specialists from many disciplines, including materials science, furniture design, sensory evaluation, and marketing, were assembled to complete a questionnaire evaluating the relative significance of aroma intensity, comfort, and suitability, and to score them accordingly (Huang *et al.* 2022). It was concluded that comfort is the paramount aspect, followed by suitability. The weights of each characteristic in the criteria layer were subsequently computed and are presented in the judgment matrix in Table 9 below. The evaluation was conducted by a total of 10 evaluators, including materials science experts (4), sensory evaluation experts (3), and design experts (3). Firstly, each expert compared the three criteria pairwise and provided a judgment matrix. Then, for the comparison values at each position (*i.e.*, each cell), the geometric mean of the judgments from 10 experts was calculated to obtain the comprehensive judgment matrix.

Table 9. Judgement Matrix

	Comfort	Suitability	Strength of Aroma
Comfort	1	3	5
Suitability	1/3	1	2
Strength of Aroma	1/5	1/2	1

Weighting calculation

The results of the judgment matrix were imported into SPSSPRO (an online tool for conducting Analytic Hierarchy Process analysis), and the judgment matrix in Table 6 was input into SPSSPRO for AHP weight analysis. The results are shown in Table 10. Among them, the weight of comfort level was 64.8%, the weight of suitability was 23.0%, and the weight of aroma intensity was 12.2%.

Table 10. Results of AHP Hierarchical Analysis

Term (In A Mathematical Formula)	Eigenvector (Math.)	Weighted value (%)	Maximum characteristic root	CI value
Comfort level W_C	1.944	64.8	3.004	0.002
Suitability W_S	0.690	23.0		
Aroma intensity W_I	0.367	12.2		

The results of the consistency test indicate that the maximum characteristic root from the hierarchical analysis method was 3.004. According to the CI value obtained from the checklist, the corresponding RI value is 0.525. Consequently, the result indicates that CR = CI/RI, a value of 0.004, which is less than 0.1. This finding confirms the consistency of the test.

Weighted composite calculation based on sensory scores

The scores from the program strata are amalgamated, a composite score is computed for each sample, and the results are ordered. The weighting method should be,

$$S = (W_C \times C) + (W_S \times S_a) + (W_I \times I) \quad (3)$$

where S represents the composite score, while W_C (64.8%≈0.65), W_S (23.0%≈0.23), and W_I (12.2%≈0.12) denote the weights assigned to comfort, suitability, and fragrance intensity, respectively. The quantities C, S_a, and I refer to the average scores for comfort, suitability, and aroma intensity, respectively.

According to the calculation formula previously outlined, a total of 52 data sets were collected. The weighting values in Table 10 indicate that comfort was approximately 0.65, suitability was approximately 0.23, and scent intensity was approximately 0.12. The mean values are presented in Table 11.

Table 11. Mean Value Calculation Results

Sample number	Comfort Grand mean (C)	Suitability Grand mean (S_a)	Aroma intensity Grand mean (I)
X1	2.50	3.04	2.69
X2	2.85	3.00	3.31
X3	3.23	2.85	2.85
L1	3.00	3.04	2.50
L2	3.15	3.12	2.65
L3	3.65	3.27	2.54
A1	3.12	3.27	2.00
A2	3.08	2.85	3.19
A3	3.15	3.27	3.00

As demonstrated in Tables 10 and 11 above, and as delineated in the calculation formula for S above, the example weight values are illustrated in Table 12.

Table 12. Example of AHP Weight Calculation

Sample number	Comfort	Suitability	Aroma intensity	Overall
X1	=2.50×0.65	=3.04×0.23	=2.69×0.12	=2.5×0.65+3.04×0.23+2.69×0.12
X2	=2.85×0.65	=3.00×0.23	=3.31×0.12	=2.85×0.65+3.00×0.23+3.31×0.12
…	…	…	…	…

The weighted composite calculations for each sample (aroma intensity, comfort, suitability) were ranked, as presented in Table 13, which displays the composite scores and corresponding rankings. L3 ranked highest in the weighted composite scores, indicating that users are more likely to prefer the aloe vera-scented flooring with a concentration of 3% based on comprehensive evaluation.

Table 13. Composite Scores and Corresponding Rankings

Sample number	S (two decimal places)	Overall Ranking	Comfort Ranking	Suitability Ranking	Aroma Strength Ranking	Core strengths
X1	2.65	9	9	5 (side by side)	5	/
X2	2.94	8	8	7	1	Highest average aroma intensity
X3	3.10	3	2	8 (parallel)	4	Higher mean comfort level
L1	2.95	7	7	5 (side by side)	8	/
L2	3.09	4	3 (parallel)	4	6	/
L3	3.41	1	1	1 (parallel)	7	Comfort had the highest mean value and tied for 1st place in suitability mean value
A1	3.02	6	5	1 (parallel)	9	Tied for 1st place in suitability mean ranking
A2	3.04	5	6	8 (parallel)	2	Higher average aroma intensity
A3	3.16	2	3 (parallel)	1 (parallel)	3	Higher overall ranking mean and tied for 1st place in suitability mean ranking

The separate ranks for scent intensity, comfort, and suitability were represented in a clustered bar chart, as illustrated in Fig. 4. Under the same lavender fragrance type, the 3% concentration of lavender-scented flooring exhibited the highest comfort, the 2% concentration demonstrates the greatest aroma intensity, and the 1% concentration ranked highest in suitability.

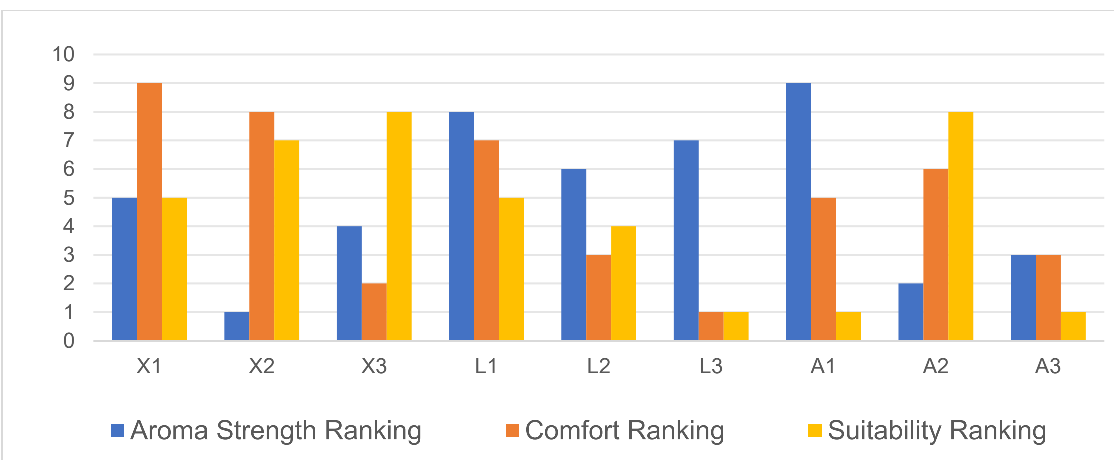

Fig. 4. Bar chart of aroma intensity, comfort, and suitability ranking

In the case of the aloe aroma type, the 3% concentration of aloe-scented flooring ranked highest in comfort, while the 2% concentration achieved the highest aroma intensity. The aloe vera-scented flooring exhibited the highest ranking for suitability; conversely, the eucalyptus-scented flooring achieved the highest comfort rating at a 3% concentration, the highest fragrance intensity at a 2% concentration, and the highest suitability at both 1% and 2% concentrations. Eucalyptus-scented flooring achieved the highest comfort rating at a 1% concentration, while aloe-scented flooring attained the highest comfort ratings at both 2% and 3% concentrations. Additionally, the bar chart feedback indicated a negative correlation between fragrance intensity rankings and both comfort and scenario suitability rankings.

TRIZ Theory: Needs Transformation and Contradiction Resolution

Utilizing the primary user concerns delineated by the Kano model (emphasizing aroma intensity, comfort, and suitability) alongside the user preference weights derived from the AHP analysis (comfort (0.65) > suitability (0.23) > aroma intensity (0.12)) and the specific sample performances (Table 10), this section will employ TRIZ theory to convert user demand preferences and product performance discrepancies into practical optimization strategies (Wang and Sun 2025).

Definition of paradox deepening (based on data-driven)

Utilizing the strengths and weaknesses identified in the AHP analysis results (refer to Table 13) alongside the fundamental strengths and weaknesses of the AHP samples and the Kano attribute classification (noting that A_2 is a reverse attribute while A_1, A_3, and A_4 are non-differentiating attributes), pinpoint and articulate the essential contradictions that require resolution. The detailed analysis is shown in Tables 14, 15, and 16.

Table 14. Analysis of Technical Contradictions

Serial number	Sample number	Improved parameters (↑) *vs.* deteriorated parameters (↓)	Data support (tables 13)	TRIZ engineering parameter pairs
B1	X2	Suitability (↑) *vs.* aroma intensity (↓)	X2 is ranked 7th for suitability and 1st for aroma strength.	Adaptability or versatility (35) vs. material loss (23)
B2	A3	Comfort (↑) *vs.* Aroma intensity (↓)	A3 tied for 3rd in comfort and 3rd in aroma intensity	Harmful factors arising from objects (31) vs. intensity (14)
B3	L3	Suitability/comfort (↑) *vs.* Aroma intensity (↓)	L3 ranked 1st for suitability, 1st for comfort, and 7th for aroma intensity	Harmful factors arising from objects (31) vs. intensity (14)

Table 15. Analysis of Physical Contradictions

Serial number	Parameters	Rival demand	KANO-AHP chain of evidence	TRIZ Definition
B4	Strength of Aroma	Need to be strong (preferred user) *vs.* need to be weak (disliked user)	A_2 for reverse attributes (Better=4.17%, Worse=-20.83%)	Periodicity (19)
B5	Fragrance diversity	Needs to be enriched (attractiveness) *vs.* needs to be simplified (cost control)	A_1 is a non-differentiating attribute (low user-perceived value)	Principles of Dynamic Characterisation (15)

Table 16. System Optimisation Requirements

serial number	Type of problem	intrinsic contradiction	Basis of data
S1	Insufficient functional added value	Basic Fragrance Release *vs.* Users' Expectation of Emotional Healing Value	Lavender is noted in the literature as having "anxiolytic" effects (section 1.3) (Huang *et al.* 2025).
S2	Technology Pathway Solidification	Static Microcapsules *vs.* Dynamic Environmental Response Requirements	A_4 Suitability weighted at 0.23 (second only to comfort)

Upgrading the application of TRIZ principles

To address the discovered contradictions and requirements, the TRIZ Contradiction Matrix and Inventive Principles Library were utilized to suggest targeted optimization solutions, as shown in Tables 17, 18, and 19.

Table 17. Solutions to Technical Contradictions

serial number	TRIZ Principles	Specific technical programmes	Description of innovations
B1	Segmentation principle (1) + dynamic behaviour (15)	Development of double-layer smart coatings: 1. Substrate: Fixed-concentration microcapsules (aroma-preserving) 2. Response layer: temperature-sensitive hydrogel wrapped with essential oils (humidity >60% degrades the fragrance)	Automatic enhancement of adaptability in high humidity environments (*e.g.* bathrooms)
B2	Principles of Localised Mass (3) + Principles of Composite Materials (40)	Microcapsules with core-shell structure: 1. Nucleus: Eucalyptus essential oil (highly antibacterial) 2. Shell: Aloe Vera Essential Oil Slow Release Layer (provides a gentle initial release to reduce possible irritation)	Soft Aloe Vera fragrance at the beginning and Eucalyptus functional fragrance at the end.
B3	Principle of cyclic action (19) + mechanical vibration (18)	Pressure-triggered aroma release: microcapsule wall material doped with piezoelectric ceramic particles, walking pressure generates micro-current to accelerate the release of aroma	Temporary boost in intensity when the user is active, restoration of comfort when static

Table 18. Physical Paradox Solutions

serial number	TRIZ Principles	schematic design	user value
B4	Time separation (16)	Daytime mode: 1% concentration (office-ready) Night mode: 3% concentration (sleep aid scenario)	Automatic switching by means of a light sensor
B5	Nesting Principle (7)	Interchangeable scent snaps: floor reserved slots, user-selected scent modules (lavender / aloe / eucalyptus)	Diversity at low cost, avoiding line complexity

Table 19. System Conflict Resolution

serial number	TRIZ Principles	schematic design	technical support point
S1	Versatility (6)	Complex Essential Oil Formulation Aloe Vera (antibacterial) + Lavender (calming) + Eucalyptus (refreshing)	Literature reference(For example, Ren, Xu, and Wang's respective articles) demonstrates the feasibility of essential oil compounding
S2	Evolutionary trends towards supersystems	Access to smart home platform: linkage of air conditioning/lighting through APP, dynamic adjustment of aroma intensity	Reduce development costs by leveraging existing IoT technologies

Results

KANO-AHP Correlation Explanation

The reverse attributes in the Kano model (*e.g*., fragrance intensity) serve as the foundation for AHP weight constraints. The quantification of indifference attributes, such as fragrance diversity, is achieved through comparative analysis, whereby three types of fragrance boards with an addition ratio of 1% are grouped for evaluation.

Programme integration and value

The application of TRIZ theory effectively converts user demand preferences and product performance contradictions derived from Kano-AHP analysis into a set of precise and directive guidelines for R&D technological solutions. The essence of these programs resides in:

1. A dynamic response system designed to address the conflict between suitability and intensity, exemplified in Table 16: temperature-sensitive hydrogel coating (for bathroom settings) and piezoelectric-triggered microcapsules (for living room environments), facilitating spatial self-adaptation (humidity response coupled with pressure activation) and behavioral interconnection, thereby augmenting user value and directly addressing the primary.

2. The material innovation system, which balances comfort and functionality, is illustrated in Table 17: core-shell structure microcapsules and composite essential oil formulations. The core-shell process is anticipated to elevate costs by approximately 8% based on preliminary material cost estimates; however, it can be optimized to decrease the quantity of expensive essential oils, such as lavender, thereby managing expenses (Gui *et al.* 2023).

3. User-customizable module (addressing physical contradictions), as illustrated in Table 18: Interchangeable fragrance snaps and light-controlled day and night modes introduce scent diversity (A_1 was initially a non-differentiated attribute) to augment the value of this feature for consumers, aligning it more closely with the intended attribute, enhancing user retention, and achieving Kano conversion.

4. Intelligent ecological integration (overcoming system evolution constraints), as illustrated in Table 18: IoT protocol compatibility (with Huawei/Xiaomi smart home systems) and an AI scene learning engine (modulating aroma based on user preferences) may serve as a prospective avenue to augment commercial value, mitigate competition arising from the homogenization of microcapsule technology, and create a closed-loop ecosystem of data-feedback-service.

These optimization strategies directly address user needs and product deficiencies identified in this study, while also offering innovative concepts for the research and development of scented flooring to effectively align with the three primary trends of health management, emotional healing, and customization within the "olfactory economy," thereby establishing a technological foundation for industrial advancement.

As those under 35 years of age filled out the majority of the surveys, this younger group may lack sensitivity to odors. Alternatively, users may induce ambiguity in semantic processing through fuzzy mathematics (*e.g.*, 'indifferent' may suggest a marginal preference). This may result in the underestimation of indifference traits in the Kano questionnaire, together with the requirements of odor-sensitive groups. Subsequent research ought to employ clustering algorithms such as K-means to categorize user demographics, namely middle-aged and elderly individuals, and delineate the unique requirements of each cohort.

Discussion

Analysis of the advantages and disadvantages of AHP

Advantages: The objective weighting is based on expert opinion. A review of the potential disadvantages is warranted. Subjective bias is a potential issue in group comparisons, necessitating the verification of consistency.

The following limitations should be noted: The sample is predominantly composed of young users. Long-term odor stability remains to be verified. Allergy risks have not yet been assessed.

CONCLUSIONS

1. This work employed the Kano-analytic hierarchy process (AHP)-TRIZ model to examine user requirements and performance preferences for deodorizing flooring, tackling the problem of unpleasant odors upon initial use of the flooring. Integrating user needs analysis (Kano-AHP) with technological problem-solving (TRIZ) allows AHP weight analysis to transform subjective user descriptions into measurable weights, hence enhancing the quantitative assessment of user preference priorities. This establishes a definitive framework for prioritizing product development and creates a closed-loop decision-making process utilizing the KANO model, AHP, and TRIZ theory.
2. The KANO model user requirements analysis initially identified scent intensity as a reverse characteristic using a questionnaire survey; however, fragrance diversity, the presence or absence of irritating compounds, and suitability were recognized as non-differentiating attributes. Microcapsules are non-toxic, and AHP evaluates the influence of specific performance parameters on user experience and satisfaction when a function is present. Fragrance diversity was standardized at nine types, with floor samples at concentrations of 1%, 2%, and 3% (Lavender, Aloe Vera, and Eucalyptus Leaf). Olfactory evaluations were performed, and an experiment was devised based on comfort, aroma intensity, and adaptation to various scenarios.
3. A total of 52 test subjects were recruited jointly to conduct an olfactory experiment in order to evaluate nine samples. Quantitative analysis was also conducted on the data regarding the comfort level, fragrance intensity, and suitability of the three types of

floor samples that release fragrance. The AHP analysis indicated that: (*i)* The expert panel concluded that comfort superseded situational flexibility, which was prioritized over fragrance intensity. The corresponding weights were roughly 0.65, 0.23, and 0.12. (*ii)* The calculation of the aggregate scores for the three weight groups in the olfactory testing indicated that people generally favored the 3% aloe vera fragrance in the overall ranking. The floor scenario featuring a 3% aloe vera scent (L3) achieved the greatest comfort score, while the scenario with a 2% lavender fragrance (X2) attained the highest fragrance intensity score.

4. Ultimately, through a theoretical analysis grounded in TRIZ, we identified and delineated the fundamental contradictions, categorizing and examining technical, physical, and systemic problems. We synthesized the seven categories of contradiction and aligned them with the relevant TRIZ principles. Subsequently, we suggested optimization strategies and formulated precise technological answers. This established the theoretical foundation and new avenues for creating the next generation of fragrance-dispensing flooring goods that satisfy the requirements of the 'olfactory economy' while improving user health and emotional experiences.

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