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Perceptual Discrepancies in Indoor Environmental Quality (IEQ) Within High-Density Offices: An Integrated AHP-Kano-IPA Comparative Study Based on Experts and Employees

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Abstract

Conventional evaluations of indoor environmental quality (IEQ) in office spaces are typically disproportionately influenced by expert experience, often overlooking the cognitive gap between decision makers (experts) and users (employees). To quantify and explain this discrepancy, this study develops a comprehensive evaluation framework including 20 IEQ indicators, grounded in Maslow's hierarchy of needs. Using the Shenzhen Science Park as a case study, evaluation data were collected from 13 experts and 432 employees. The Analytic Hierarchy Process (AHP) and the Kano model were applied to calculate expert weights and employees' nonlinear sensitivities, respectively, followed by the construction of an optimization matrix via Importance–Performance Analysis (IPA). The results reveal a notable cognitive gap: experts prioritize foundational physical elements regarding spatial technology, whereas employees place greater emphasis on factors such as privacy protection and flexible layouts. Both groups concur that "noise interference" and "lack of privacy" are the primary shortcomings of open-plan offices. Prospective assessments indicate that embodied AI-enabled robots currently remain in a "early adoption phase," with employees showing no functional dependency on them. This study confirms that merely improving building physical performance does not proportionally translate to increased employee satisfaction. Spatial optimization should adopt a human-centric approach, emphasizing acoustic control and the reconfiguration of privacy boundaries to enhance the scientific allocation of resources.

Keywords: office space; occupant satisfaction; high density; perceived bias; expert–user dual perspective; Shenzhen Science Park

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1. Introduction

Urban residents spend 85–90% of their time indoors, with even higher proportions reported in developed countries [1]. As an indoor place where knowledge production, organizational collaboration, and daily labor activities are highly concentrated, the IEQ of office spaces is no longer limited to environmental comfort such as acoustic environment, lighting environment, thermal comfort, and indoor air quality but also directly related to building energy efficiency, enterprise operation efficiency, employee well-being, and sustainable development [2]. Studies have shown that there is a mutual relationship between environmental factors such as sound, light, heat, and spatial scale in office space,

and the subjective evaluation of employees can often reflect the gap between building performance and comfort in the real use experience [3,4].

For high-density office space, building energy efficiency and environmental comfort are not two independent goals. In Shenzhen Science and Technology Park, a typical high-density office cluster, space intensification, and open layout have practical value in improving space utilization efficiency, promoting communication, and reducing operating costs, but they also simultaneously amplify the contradiction between environmental comfort and building energy efficiency: on the one hand, office buildings need more refined energy and spatial management to reduce operational loads. On the other hand, employees' requirements for noise control, privacy protection, air quality, light environment, and work mode autonomy are constantly increasing [2,5,6]. Especially in the post-epidemic era, remote work and hybrid work have gradually changed from temporary measures to part of the organizational system, and employees' psychological expectations of "where to work, when to work, and how to switch work scenarios" have changed [7,8]. Therefore, the update of office space should not be limited to the level of building physical performance or equipment efficiency. Building energy efficiency and environmental comfort should be discussed together. Further attention should be paid to how to evaluate these environmental factors among different groups and how the differences in this evaluation affect the allocation of resources in office space [3,9].

With the popularization of open-plan offices, these workplaces face many contradictions while bringing advantages. Noise interference and lack of privacy are among the most common environmental problems in open and high-density office spaces that cause employee dissatisfaction [10]. Open-plan layouts are often considered to facilitate communication and improve space utilization [10], but related research also shows that their benefits are often accompanied by costs such as noise, privacy loss [11], and interrupted attention [12]. Tao et al. indicated that technical pathways—including sound-absorbing materials, sound insulation structures, composite materials, micro-perforated panels, and multi-scale structural designs—provide material- and structure-level strategies for indoor noise control in buildings [13]. Taking indoor vertical partitions as a case study, Nicoletti et al. [14] conducted field measurements and predictive modeling of the airborne sound insulation performance of various partition walls. Their study further indicated that indoor acoustic environment issues can be effectively transformed into evaluable, predictable, and optimizable engineering problems through the strategic design of partition configurations, material properties, and separation methods.

Although existing studies have accumulated substantial findings regarding IEQ physical parameters, open-plan offices, post-occupancy evaluation (POE), and office satisfaction, a critical issue remains to be addressed. Current evaluation methodologies are predominantly developed from a single perspective of user satisfaction [3], building physical performance, or post-design evaluation, with limited systematic comparisons on whether consistency exists between the evaluations of experts and employees regarding the same environmental elements. Based on this, this study focuses on the high-density office spaces in Shenzhen Science and Technology Park to construct an integrated AHP-Kano-IPA model. Specifically, the Analytic Hierarchy Process (AHP) is used to quantify the normative weights of IEQ elements evaluated by experts; the Kano model is applied to identify the nonlinear psychological sensitivity of employees toward various environmental elements; and the Importance–Performance Analysis (IPA) is utilized to couple expert weights, user satisfaction, and spatial optimization priorities. This study aims to quantify and explain the expert–user priority gap between experts and employees, thereby identifying the priority of IEQ element updates and providing a decision-making basis for office spaces to optimize

building energy efficiency and environmental comfort while avoiding inefficient resource investment. Therefore, the core questions explored in this study are as follows:

1. In the office environment, what is the extent of the difference between experts and employees in the element priority of indoor environment quality?
2. How does this expert–user perceptual bias affect the allocation of office space resources?

2. Literature Review

The study of office space satisfaction has undergone a shift from physical performance evaluation to user experience evaluation. Early research mainly focusses on the impact of office space on work quality, productivity, and basic environmental comfort [3,15,16]. Among these, IEQ represents one of the core elements influencing occupant satisfaction [9,17,18]. In subsequent studies, IEQ is gradually subdivided into air quality, thermal comfort, light environment, sound environment, spatial layout, and other dimensions, and it has been confirmed that it is directly related to employees' work performance [19,20], employee health, and well-being [21–23]. In their review, Dávalos Quevedo et al. also pointed out that office space satisfaction is not determined by a single environmental parameter but rather by a complex result shaped by environmental conditions, spatial organization, work systems, and employees' psychological expectations [3].Therefore, the core research question of this study has expanded from asking "which physical factors influence satisfaction" to exploring "how different employees perceive these factors and how these perceptions are translated into spatial design decisions."

From the perspective of office space layout typologies, open-plan office, activity-based working (ABW), flexible office, remote work, and hybrid work are the more concentrated directions of post-epidemic discussions. By reducing physical partitions, open-plan offices help foster a flattened work environment [24] and enhance space-sharing efficiency to promote collaboration [25] while simultaneously reducing corporate operational costs [26]. However, open-plan offices also have clear side effects: noise interference, lack of privacy, difficulty in recovering attention, and reduced territoriality often become the main source of employee dissatisfaction [27,28] and seriously affect employees' health and concentration [11,29]. Conversely, the model combining ABW with remote working is considered capable of expanding employees' autonomous choices within limited square footage, thereby mitigating the privacy anxiety induced by completely open-plan layouts [30–32]. Post-pandemic remote and hybrid work has changed employees' and managers' assumptions about workplace and working hours. The office is no longer just a collection of fixed work stations but needs to take on the composite functions of collaboration, socializing, supporting health, and organizational identity [7,8].

Among the negative experiences of open-plan offices, noise interference and the loss of privacy reflect the deficiencies between subjective occupant perception and physical–technical strategies. Environmental psychology and POE studies have repeatedly pointed out that background sounds, conversational sounds, and inefficient partitions can significantly increase the sense of annoyance and weaken cognitive performance [11,28,29,33]. Recent acoustic engineering research provides more specific directions for mitigating spatial noise distractions: the selection of vertical partition materials and structures, as well as the testing of sound insulation performance, can be achieved through environmental prediction and field measurements using modeling techniques [14]. Meanwhile, porous sound-absorbing materials, micro-perforated panels, composite materials, and multi-scale structural designs offer technological pathways for noise control in open-plan offices [13]. Therefore, office satisfaction research must simultaneously connect the subjective perceptions of employees with objective modification strategies at the levels of architectural acoustics, materials, and structural configurations.

In recent years, cutting-edge literature has begun to discuss office space satisfaction alongside technological and cognitive contexts. On one hand, work processes, job roles, and human–computer collaboration methods are being reshaped by the emergence of artificial intelligence. Research on AI-supported workplaces indicates that while the introduction of AI improves employee productivity, it simultaneously exacerbates employee anxiety regarding potential job displacement, trust, and security [34–36]. In fields such as cognitive ergonomics and human–computer interaction, generative AI also foreshadows promising applications [37,38]. On the other hand, research in neuroarchitecture and cognitive–emotional design attempts to quantify the impacts of architectural space on the body, emotion, cognition, and social behavior by combining methods such as neuroscience, virtual reality, and physiological measurements [37,38]. Therefore, future research on office space satisfaction should not only remain confined to the evaluation of environmental elements but should also actively engage with emerging technologies and focus on deeper physiological, neural, and cognitive responses.

Existing studies have explained the influence mechanisms of office satisfaction from multiple dimensions, including IEQ, office typologies, health and well-being, acoustic privacy, AI intervention, and neuroarchitecture. However, these studies present three primary deficiencies. The first issue is that many studies analyze factors such as air quality, thermal comfort, lighting environment, office layout, or intelligent systems as isolated variables, lacking an integrated evaluation framework that synthesizes multiple requirements [39–41]. The second issue is that traditional satisfaction evaluations frequently adopt linear assumptions, defaulting to the premise that resource investment automatically enhances satisfaction, which fails to explain the asymmetric psychological responses revealed by the Kano model [9,42,43]. The third issue, which is also the central focus of this study, is that the limited literature directly compares the differences in IEQ prioritization between experts and employees, and few discussions address how this perceptual bias leads to the misallocation of design resources.

Therefore, this study integrates expert AHP weights, employee Kano sensitivity coefficients, and the IPA optimization matrix to compare “expert judgment” and “occupant experience” within a unified evaluation framework, thereby supplementing the theoretical explanation of expert–user perceptual bias in architectural and environmental behavior research.

3. Research Methods

This study focuses on high-density office buildings in Nanshan District Science and Technology Park in Shenzhen as an example. The research procedure consists of four stages as shown in Figure 1: indicator system construction, dual evaluation paths, weight correction and perceptual bias identification, and strategic decision output. The research adopts the parallel calculation logic of AHP and Kano instead of the traditional model of screening first and then weighting. The core is to consider the particularity of the evaluation of indoor environmental elements and avoid the omission of indicators caused by perception bias, such as low-perception index health security facilities, artificial intelligence, etc. By screening and eliminating the Reverse attributes and Indifferent attributes of Kano, the integrity of the index system can be realized. Combined with Importance–Performance Analysis, a composite judgement chart with both the importance and priority of indicator elements is formed.

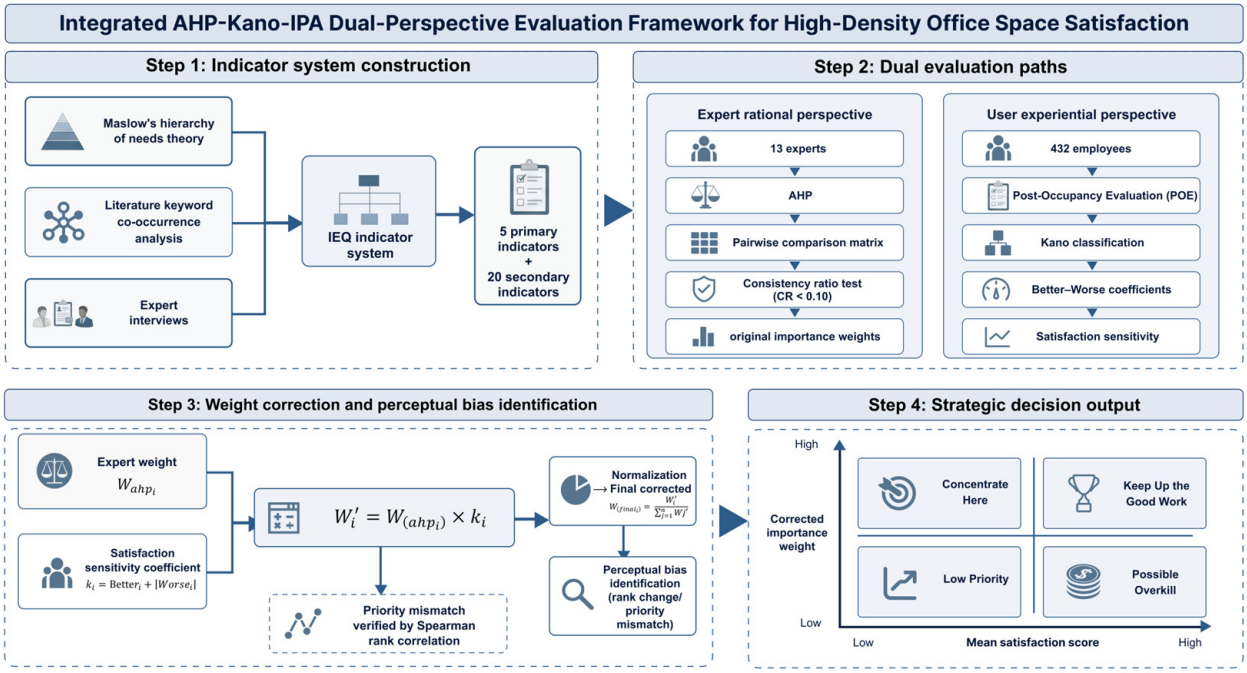


Figure 1. Research framework.

3.1. Evaluation System Expansion

Maslow proposed the hierarchy of needs in his 1943 article "A Theory of Human Motivation", published in *Psychological Review* [44]. It is specifically divided into Self-actualization Needs, Esteem Needs, Love and Belonging, Safety Needs, and Physiological Needs, presenting an increasing pyramid structure [45]. This study takes Maslow's hierarchy of needs as the basis for the division of the first layer of IEQ indicators. It needs to be noted that Maslow's hierarchy of needs itself has a hierarchical progressive relationship, but in this study, it is only used as an auxiliary measure to facilitate the classification of IEQ indicators. Therefore, the indicator framework in this study does not have a priority ranking.

Evaluation System Construction

In order to ensure the rigor and comprehensiveness of the indicators of the evaluation system, this study determines the evaluation system through literature retrieval and expert interviews. First of all, using the Web of Science database as the search source, the literature search takes "office space satisfaction" and "indoor environment quality" as the core keywords of the journal search and takes the journals included in the past ten years as the scope. A total of 157 relevant articles were obtained in the preliminary search. The relevance of the search results was filtered according to the following two criteria: 1. The title or abstract of the article should contain "satisfaction" or "comfort". 2. The article needs to take "office space" or "employee perceptions" as the research object. After manual screening, 49 articles with low relevance were eliminated, and the final valid articles were 108.

Then, the literature keywords are processed by combining quantitative and qualitative methods. The retrieved records were downloaded and imported into CiteSpace, version 6.4.2 version 6.4.2 (Drexel University, Philadelphia, PA, USA) literature analysis software for quantitative "keyword coexistence" processing to identify the core elements that have been concentrated in the past ten years in terms of office space satisfaction and sort out the top 20 keywords of "central" data (Appendix A Table A1) as the initial indicator pool. On this basis, the initial index pool is classified and screened by inviting scholars, enterprises, and designers of relevant majors from colleges and universities as expert groups. In addition, in view of the current and future technological development trends, this study integrates

the application of "intelligent robots" in office space into the index system, aiming to explore whether the intervention of new technologies has a significant impact on employee satisfaction and to provide certain data references for the future combination of office space and intelligence. Finally, the complete index system of this study was determined through the method of bibliometric keyword analysis and expert judgment, and the specific index structure was displayed in detail in Section 4.

3.2. Questionnaire and Data Acquisition

To comprehensively quantify IEQ, this study employed two parallel questionnaire surveys, conducting interviews and data collection with experts and employees of office spaces, respectively. Data collection utilized a parallel online and offline approach, utilizing the Wenjuanxing platform to create electronic questionnaires with QR codes for distribution while simultaneously distributing paper questionnaires offline.

3.2.1. Expert AHP Questionnaire

The purpose of the expert questionnaire was primarily to quantify the weights of the IEQ's fundamental elements. The expert panel consisted of 13 cross-disciplinary experts, including university professors, senior corporate employees, and architects (Table 1). Data collection spanned from November 2025 to January 2026. Indicators were evaluated using a 9-point Likert scale to reflect expert judgments. Finally, questionnaires with a total response time of less than 200 s were discarded, resulting in 13 valid questionnaires, a 100% effective response rate.

Table 1. Expert panel information form.

Order Number	Field	Professional Title/Position	Major	Educational Qualifications
1	Universities	Adjunct professor	Town and country planning	Doctor
2	Universities	Adjunct professor	Architectural design	Doctor
3	Universities	Lecturer	Architectonic	Doctor
4	Universities	Lecturer	Architectural design	Doctor
5	Enterprise	Business partner	Interior design	Master
6	Enterprise	Product engineer	Environmental engineer	Master
7	Enterprise	Research institute assistant	Architectural design	Master
8	Trade	Architectural designer	Architectural design	Master
9	Trade	Architectural designer	Environmental design	Master
10	Trade	Product designer	Product design	Master
11	Trade	Interior designer	Environmental design	Master
12	Trade	Interior designer	Environmental design	Master
13	Trade	Architectural designer	Architectural design	Master

3.2.2. Employee Post-Occupancy Evaluation Questionnaire (POE)

The purpose of the employee questionnaire is to capture the nonlinear relationships between office environment elements and their users, thereby facilitating insights into how building performance or the physical environment impacts employees [46]. Based on the hierarchical indicators established in the first phase and utilizing a 5-point Likert scale, the survey was designed with paired positive and negative questions in accordance with the Kano model. Conducted between December 2025 and January 2026, the study focused primarily on six office buildings located within the Science and Technology Park in Nanshan District, Shenzhen (Table 2). A total of 490 questionnaires were initially collected; however, responses exhibiting obvious logical inconsistencies or those completed in under

160 s were subsequently excluded. The final count of valid questionnaires stood at 432 (Table 3), yielding a valid response rate of 88.2%.

Table 2. Building information of the survey.

Order Number	Name	Year of Completion	Sample Size	Sample Proportion	Function Type	Office Format
1	Energy Storage Building	2016	90	0.21	Office, R&D, Business	Hybrid Work
2	Dashi Building	2015	108	0.25	Office, R&D, Business	Hybrid Work
3	Howe Technology Building	2014	56	0.13	Office, R&D, Business	Hybrid Work
4	Chuangzhi Tiandi Building A	2017	72	0.17	Office, R&D, Commercial, Apartment	Hybrid Work
5	Shenzhen Metro Financial Technology Building	2020	41	0.09	Office, Hotel, Business, Transportation Hub	Hybrid Work
6	SF Express Technology Co., Ltd.	2014	65	0.15	Office, R&D, Business	Hybrid Work

Note: The information was compiled by the authors based on field surveys and questionnaire records.

Table 3. Basic information of respondents.

Variable	Classification	Number of People	Ratio
Gender	Male	213	49.31%
	Female	219	50.69%
Age	22–30	254	58.80%
	31–40	122	28.24%
	41–50	55	12.73%
	More than 50	1	0.23%
Education level	Junior college education	142	32.87%
	Bachelor's degree	204	47.22%
	Postgraduate or above	86	19.91%
Major	Technology R&D and engineering	85	19.68%
	Creativity and visual design	55	12.73%
	Product category	69	15.97%
	Space design	70	16.20%
	Operations	76	17.59%
	AI-related roles	77	17.82%
Management position	Yes	66	15.28%
	No	366	84.72%

To enhance the design transparency and reproducibility of the Kano questionnaire, this study converted twenty secondary IEQ indicators individually into functional (positive) and dysfunctional (negative) questions. These two categories of responses were then classified into specific attributes according to the Kano evaluation matrix. The complete correspondence between the IEQ indicators and the functional/dysfunctional Kano questions is provided in Appendix A.

3.3. Construction of an Integrated AHP-Kano-IPA Model

The Analytic Hierarchy Process is a systematic analysis method for evaluation and decision making proposed by Professor Thomas L. Saaty, an American operations researcher [47]. AHP structures decision factors hierarchically and derives relative weights through pairwise comparisons. However, the results of AHP are often influenced by the normative knowledge of experts, so they cannot accurately reflect the user experience of real employees. Importance–Performance Analysis (IPA) was initially introduced by Martilla and James (1977) for analyzing product attributes within the automotive industry [48]. Lee et al. used the model to successfully quantify the "importance–performance" gap of green building IEQ [39]. However, IPA generally assumes a linear relationship between

attribute performance and overall satisfaction and therefore does not capture asymmetric psychological responses. Therefore, in order to make up for the shortcomings of the above single model, the Kano model identifies nonlinear user responses and provides sensitivity coefficients for weight adjustment, so as to achieve the purpose of correcting the weighting of experts. After being proposed by Professor Noriaki Kano in 1984 [49], this model has been widely used as a general evaluation method in the resource allocation guidance of IEQ factors in a broad sense [9,50,51].Therefore, this study realize the complementarity of the advantages of a single model through the integration method of AHP-Kano-IPA, so as to reflect the optimization and decision making of spatial resources more comprehensively and realistically.

3.4. The Model Fusion Mechanism of AHP-Kano-IPA

To accurately quantify the perceptual discrepancies between experts and employees, this study constructs a multi-level composite model that integrates the Analytic Hierarchy Process (AHP), the Kano model, and Importance-Performance Analysis (IPA). First, an expert panel evaluates the criteria within the hierarchical structure of the AHP to establish the initial weights, denoted as $W_{\mathrm{AHP},i}$ Second, the Kano model is employed to calculate the "Better" and "Worse" satisfaction coefficients for each criterion, thereby identifying the nonlinear characteristics of employees' psychological expectations; the sum of the absolute values of these coefficients $\mathrm{Better}_i + |Worse_i|$ determines the user-perceptual sensitivity adjustment coefficient k_i. Third, the expert-derived AHP weights are calibrated and refined using these sensitivity adjustment coefficients to generate adjusted weights via the following formula: $W_i' = W_{AHP,i} \times (\mathrm{Better}_i + |Worse_i|)$. After normalization to obtain the final weights, $W_{final,i}$, these calibrated weights are mapped alongside actual employee satisfaction ratings onto the y-axis and x-axis of the IPA matrix. Thus, the framework helps diagnose and reduce potential mismatches in decision making, and a comprehensive diagnostic framework is provided for the rational allocation of spatial resources.

4. Results

4.1. IEQ Indicator Framework

According to the steps of CiteSpace literature analysis and expert screening described above, this study finally established a comprehensive evaluation system including five first-level indicators of physiological needs, safety and security, social needs, esteem needs, and self-realization, as well as 20 s-level indicators such as air quality and noise control (Table 4). This framework covers the traditional physical environment elements and also integrates individual digital and intelligent indicators, thus providing a variable basis for subsequent data calculations.

Table 4. Evaluation hierarchy.

Target Layer	Primary Indicator Layer	Secondary Indicator Layer
Office space satisfaction deviation	Physiological Needs B1	Air Quality C1 Comfortable Light Environment C2 Noise Control C3 Adjustable Furniture C4
	Security B2	Personal Privacy C5 Health Care Facility C6 IT Facilities C7 Robotic Operation Safety C8 Eco-friendly Materials C9

Table 4. *Cont.*

Target Layer	Primary Indicator Layer	Secondary Indicator Layer
Office space satisfaction deviation	Social Needs B3	Formal Leisure Space C10 Informal Leisure Spaces C11 Pet-friendly Space C12 Childcare Space C13 Flexible Office Layout C14
	Esteem Needs B4	Employee Identity C15 Shared Private Space C16 Space Allocation Fairness C17
	Self-actualization B5	Work-mode Autonomy C18 Choose your Preferred Work Mode (Online/Offline) C19 Skill-learning Spaces C20

4.2. AHP-Based Expert Evaluation Results

The data calculation at this stage is based on the hierarchy of Table 4, and the scoring results of the experts are quantified. The specific weights of the first-level indicators and the second-level indicators are shown in Tables 5 and 6. The specific calculation steps are as follows: (1) establish a judgement matrix; (2) normalize all data; (3) perform weight calculation; (4) conduct a consistency test; and (5) calculate the comprehensive weight. After verification, the independent judgement matrix CR value of 13 experts is between 0.03 and 0.08. Therefore, the results meet the standard CR value of the consistency test < 0.1.

Table 5. Weights of primary indicators.

Evaluating Indicator	Weight
B1	0.3809
B2	0.2969
B3	0.1807
B4	0.0631
B5	0.0784

The data at this stage are mainly a collection of subjective evaluations made by expert groups based on their own experience and professional knowledge and do not directly measure actual occupant experience in office spaces. In order to more intuitively identify the differences between each element, a comprehensive weight radar map is drawn (Figure 2).

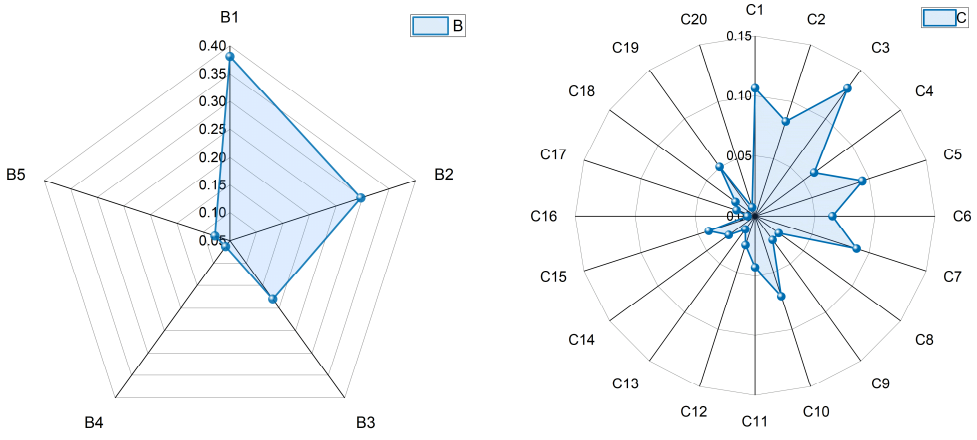


Figure 2. Weight distribution of primary and secondary indicators.

Table 6. Weight summary table.

Primary Indicators	Local Weight *W1*	Secondary Indicators	Local Weight *W2*	Global Weight = *W1* × *W2*	Ranking
B1	0.3809	C1	0.279	0.1063	2
		C2	0.217	0.0827	5
		C3	0.3422	0.1211	1
		C4	0.1598	0.0609	7
B2	0.2969	C5	0.3166	0.0940	3
		C6	0.2172	0.0645	6
		C7	0.2999	0.0890	4
		C8	0.0823	0.0244	15
		C9	0.084	0.0249	14
B3	0.1807	C10	0.3918	0.0708	8
		C11	0.2396	0.0433	10
		C12	0.1423	0.0257	13
		C13	0.0762	0.0138	18
		C14	0.1502	0.0271	12
B4	0.0631	C15	0.6431	0.0406	11
		C16	0.1005	0.0063	20
		C17	0.2564	0.0162	17
B5	0.0784	C18	0.2582	0.0202	16
		C19	0.6417	0.0503	9
		C20	0.1	0.0078	19

The data show that the total weights of physiological needs and safety and security account for nearly 68% of the weights, which is significantly higher than other weights, and include all the elements in the top 5 in the overall ranking: these are C3 Noise Control, C1 Air Quality, C5 Personal Privacy, C7 IT Facility Completeness, and C2 Comfortable Light Environment. In terms of weight distribution, expert evaluations are more focused on the two dimensions of physiological needs and safety and security indicators. Furthermore, within the dimension of safety and security, a forward-looking indicator regarding "Embodied AI-enabled robots" was introduced to investigate how current office employees perceive the presence of such smart robotic systems. The results indicate that this indicator ranked 15th. This only indicates that intelligent robots are not currently given a high priority in the expert weighting evaluation, and the specific reasons for this will be further analyzed in the Section 5.

4.3. Employee-Perspective Assessment Results Based on the Kano Model

Based on the questionnaire data, the indicators were categorized into specific attributes: Must be, One-dimensional, Attractive, Indifferent, and Reverse attributes (Table 7). The specific calculation steps are as follows: (1) data matching and cleaning; (2) verification of questionnaire reliability and validity; (3) attribute determination for individual samples; (4) frequency analysis and attribute finalization (Table 8); and (5) calculation of Better–Worse coefficients. Following separate reliability and validity tests for the positive and negative items within the questionnaire, the Cronbach's α coefficients for the positive and negative items were found to be 0.849 and 0.816, respectively, while the corresponding KMO values were 0.909 and 0.881. As the data successfully passed these reliability and validity tests, the questionnaire data were deemed valid. Data analyses were performed using SPSSAU (online version, QingSi Technology Ltd., Beijing, China; accessed on 18 June 2026) and IBM SPSS Statistics for Windows, version 27.0.1 (IBM Corp., Armonk, NY, USA).

Table 7. Summary of Kano model analysis results.

IEQ Features/Indicators	Classification Results	Better	Worse
Q1 Air Quality	Must-be attribute	37.62%	−58.41%
Q2 Comfortable Light Environment	One-dimensional attribute	59.91%	−62.00%
Q3 Noise Control	Must-be attribute	38.05%	−55.22%
Q4 Adjustable Furniture	One-dimensional attribute	60.23%	−61.63%
Q5 Personal Privacy	Must-be attribute	36.74%	−59.30%
Q6 Health Care Facility	Must-be attribute	28.21%	−55.48%
Q7 IT Facilities	Must-be attribute	31.09%	−60.32%
Q8 Robotic Operation Safety	Indifference attribute	34.50%	−32.40%
Q9 Eco-friendly Materials	Indifference attribute	33.41%	−32.95%
Q10 Formal Leisure Space	Attractive attribute	60.00%	−44.88%
Q11 Informal Leisure Spaces	Must-be attribute	27.15%	−58.70%
Q12 Pet-friendly Space	Attractive attribute	57.54%	−38.75%
Q13 Childcare Space	Attractive attribute	62.15%	−39.49%
Q14 Flexible Layout	One-dimensional attribute	55.14%	−57.71%
Q15 Employee Identity	One-dimensional attribute	51.86%	−59.07%
Q16 Shared Private Space	One-dimensional attribute	53.85%	−58.74%
Q17 Space Allocation Fairness	Attractive attribute	63.32%	−36.68%
Q18 Work-mode Autonomy	Must-be attribute	27.61%	−54.29%
Q19 Choose your Preferred Work Mode (Online/Offline)	One-dimensional attribute	50.81%	−60.79%
Q20 Skill-learning Spaces	Attractive attribute	59.91%	−27.74%

Table 8. Impact of demographic characteristics on overall satisfaction.

Demographic Variables	Statistical Method	F/t Value	Significance
Gender	Independent samples *t*-test	−6.899	<0.001 ***
Age	One-way ANOVA	29.294	<0.001 ***
Major	One-way ANOVA	2.582	0.026 *
Education	One-way ANOVA	13.803	<0.001 ***

Note: * $p < 0.05$; *** $p < 0.001$.

The empirical data primarily stems from employees' post-occupancy evaluations (POEs) of the indoor environment, aiming to objectively reflect employees' perceptions and evaluations of various design elements within actual office settings. The indicator classification results indicate that Must-be attributes represent the highest proportion, accounting for 35%. Among these, noise control (C3), personal privacy (C5), health and safety facilities (C6), IT infrastructure (C7), and informal breakout spaces are classified as Must-be attributes. One-dimensional attributes include six indicators, such as a comfortable light environment (C2) and adjustable furniture (C4). Attractive attributes encompass five indicators, including formal breakout spaces (C10) and pet-friendly spaces (C12). Meanwhile, intelligent robots (C8) and eco-friendly materials (C9) are classified as Indifferent attributes. Furthermore, the Better–Worse analysis shows that noise control (C3) and personal privacy (C5) have the highest absolute values among all indicators, with Worse coefficients of approximately −55% and −58%, respectively. Detailed data are shown in Table 7.

4.4. Test of Demographic Differences Among Respondents

To validate the integrity of the sample and to uncover potential perceptual differences regarding the indicators, this study first conducted demographic difference tests on the overall satisfaction levels of the 432 respondents. Since the data were primarily derived from a Likert scale (1–5 points), a certain degree of distributional skewness may be present; however, given the large sample size (n = 432), and in accordance with the relevant statis-

tical literature—which suggests that Analysis of Variance (ANOVA) exhibits a degree of robustness against deviations from normality under large-sample conditions—this study employed independent samples *t*-tests and one-way ANOVA to ensure the statistical power of the inter-group difference assessments [52].

The results of the data analysis are presented in Table 8. Within the highly standardized office environment of the Shenzhen Science and Technology Park, satisfaction scores vary depending on different demographic variables. Specifically, the variables of gender, age, and educational attainment were found to have a significant effect on office satisfaction.

To further elucidate the expert–user perceptual bias existing among the various indicators, the study selected the top five indicators—ranked by their AHP weights—for a more targeted cross-examination: noise, air quality, privacy, IT facilities, and lighting environment. The data analysis results in Table 9 revealed that significant inter-group differences were observed across age groups, including noise control and lighting environment. Meanwhile, gender showed significant differences in assessments of air quality, personal privacy, IT infrastructure, and comfortable light environment but no significant differences in noise control. The educational background variable demonstrated significant differences across four of the five elements; the professional background variable exhibited significant differences solely in relation to the IT facilities indicator.

Table 9. Significance tests of demographic differences for the top five AHP-ranked core indicators.

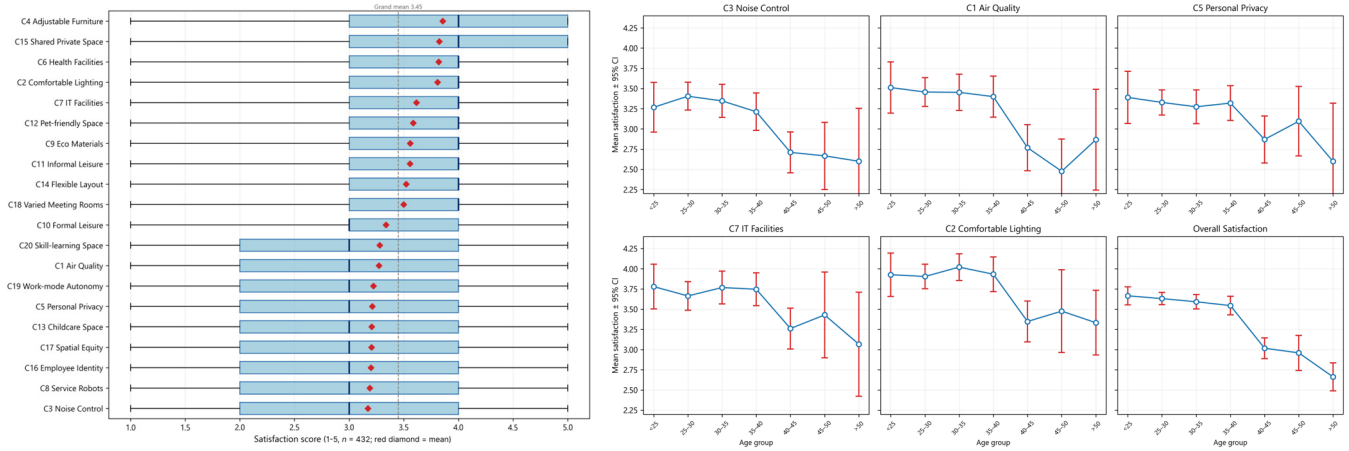
Core Indicators (Top 5 AHP)	Gender (t)	Age (ANOVA)	Education (ANOVA)	Major (ANOVA)
C3 Noise Control	0.057	<0.001 ***	0.011 *	0.344
C1 Air Quality	<0.001 ***	<0.001 ***	0.022 *	0.655
C5 Personal Privacy	<0.001 ***	0.007 **	0.039 *	0.067
C7 IT Facilities	<0.001 ***	0.004 **	0.032 *	0.041 *
C2 Light Environment	0.009 **	<0.001 ***	0.104	0.817

Note: * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Significance testing only determines whether differences exist between components. To enhance the transparency of the statistical results, this study further supplements information regarding effect sizes and data distributions. The results indicate that the gender variable reaches statistical significance in the evaluations of air quality, personal privacy, IT infrastructure completeness, and a comfortable light environment, with the effect size ranging from Cohen's $d = 0.255$ to 0.413, whereas noise control does not achieve statistical significance. The age variable reaches statistical significance across five core IEQ indicators, with the effect size ranging from $\eta^2 = 0.040$ to 0.084. The educational background variable achieves statistical significance in noise control, air quality, personal privacy, and IT infrastructure completeness, with the effect size ranging from $\eta^2 = 0.019$ to 0.026, while a comfortable light environment does not reach statistical significance. The disciplinary major variable only reaches statistical significance in IT infrastructure completeness, with $\eta^2 = 0.027$. The complete test statistics, effect sizes, confidence intervals, and grouped descriptive statistics are provided in Appendix B Tables A4–A6.

To further present the distributional characteristics of employee satisfaction evaluations, this study employs box plots and mean confidence interval plots to visualize the core results. The satisfaction distribution of the 20 IEQ indicators is illustrated in Figure 3a, where the red diamonds represent the mean values and the dashed line represents the grand mean. Figure 3b displays the means and 95% confidence intervals of representative indicators across different age groups. As shown in Figure 3, variations exist in the satisfaction means and degrees of dispersion among different IEQ indicators, and the

means and confidence intervals of each age group across certain indicators likewise exhibit specific differences.



(**a**) (**b**)

Figure 3. (**a**) Box plots of satisfaction distribution for the 20 IEQ indicators (boxes: interquartile ranges; dark lines: medians; red diamonds: means; dashed line: grand mean); (**b**) Group means (blue points and lines) and 95% confidence intervals (red error bars) across age groups.

4.5. Weight Adjustment Based on Satisfaction Sensitivity Coefficients

Given the discrepancy between the respondent groups for the AHP and Kano questionnaires, potential differences in sensitivity perception regarding their evaluations may arise, thereby influencing the determination of priority levels for office space environmental factors. Consequently, this section introduces a "satisfaction sensitivity coefficient" to adjust the AHP weight values. A similar methodology was first proposed by Tan et al. as early as 2001 [53].The specific calculation steps employed in this paper are as follows:

(1) The judgment matrix from the 13 experts above is used as the initial weights, with the normalized indicators defined as follows: W_{ahp_i}.

(2) Based on the mapping of the Better–Worse coefficient to employees' psychological perception, a perceptual sensitivity moderating coefficient is established: k_i.

$$k_i = \text{Better}_i + |Worse_i|$$

(3) The expert evaluation result weight $W_{AHP,i}$ is multiplied by the user perception coefficient k_i to obtain the comprehensive weight W_i'.

$$W_i' = W_{AHP,i} \times k_i$$

(4) The weights are then normalized to obtain the final adjusted weights $W_{final,i}$.

$$W_{final,i} = \frac{W_i'}{\sum_{j=1}^{n} Wj'}$$

The results following these adjustments are presented in Table 10. To more intuitively quantify the discrepancies in weighting between the expert perspective and user perception, a bidirectional deviation chart and a weight comparison radar chart have been generated (Figure 4).

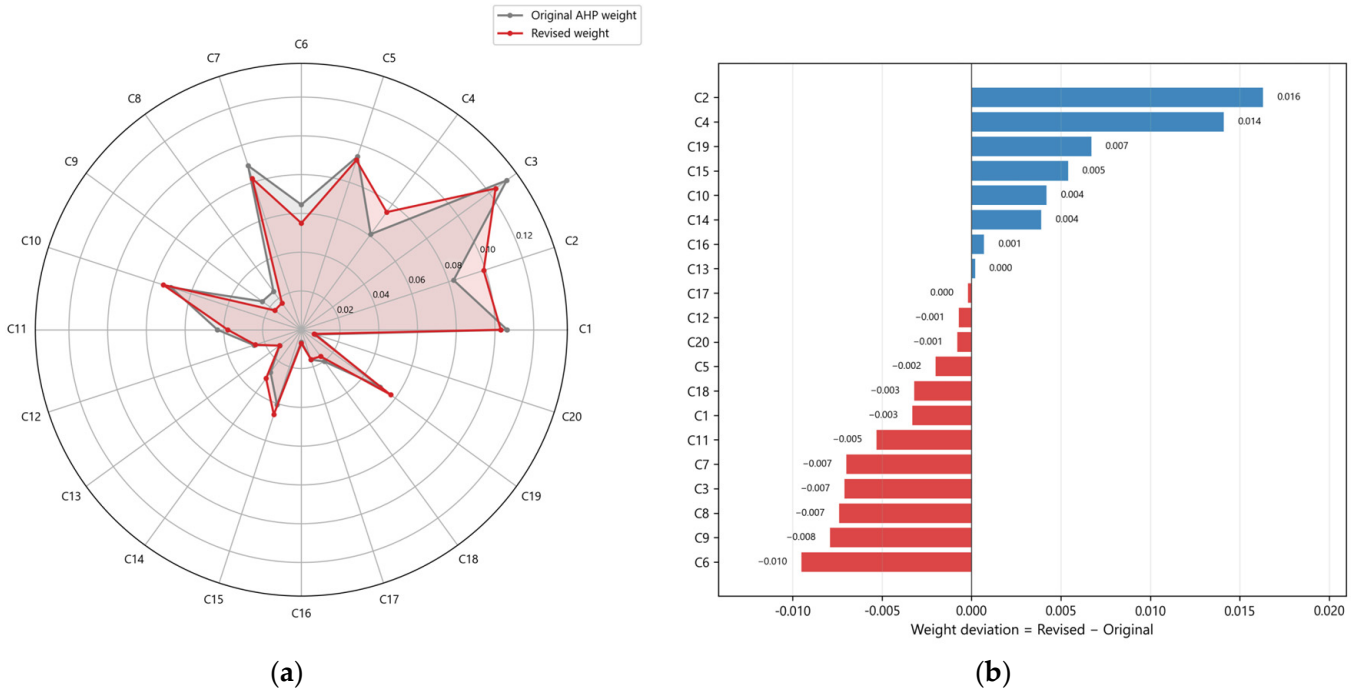
After introducing the Better–Worse coefficients, the weights assigned to various indicators underwent changes of varying magnitudes. The results indicate that noise control (C3) maintains a consistently high weight. The ranking of a comfortable light environment

(C2) exhibits an advancement of two positions. Furthermore, within the two categories of indicators—social needs and esteem needs—indicators including pet-friendly spaces (C12), flexible layouts (C14), and work-mode autonomy (C18) each demonstrate a ranking elevation of two positions.

Table 10. Comparison of modified weightings.

Indicators Number	W_i	Better	Worse	W_i'	$W_{(final_i)}$	Revise Rank	Original Rank	Rank Change
C1	0.1063	0.376	0.584	0.102	0.1035	2	2	→ 0
C2	0.0827	0.599	0.620	0.101	0.1022	3	5	↑ 2
C3	0.1311	0.381	0.552	0.122	0.1241	1	1	→ 0
C4	0.0609	0.602	0.616	0.074	0.0752	7	7	→ 0
C5	0.0940	0.367	0.593	0.090	0.0915	4	3	↓ 1
C6	0.0645	0.282	0.555	0.054	0.0547	9	6	↓ 3
C7	0.0890	0.311	0.600	0.081	0.0823	5	4	↓ 1
C8	0.0244	0.345	0.324	0.016	0.0166	16	13	↓ 3
C9	0.0249	0.334	0.330	0.017	0.0168	15	12	↓ 3
C10	0.0708	0.600	0.449	0.074	0.0753	6	7	↑ 1
C11	0.0433	0.272	0.587	0.037	0.0377	11	11	→ 0
C12	0.0257	0.575	0.388	0.025	0.0251	13	15	↑ 2
C13	0.0138	0.622	0.395	0.014	0.0142	18	18	→ 0
C14	0.0271	0.551	0.577	0.031	0.0310	12	14	↑ 2
C15	0.0406	0.519	0.590	0.045	0.0456	10	10	→ 0
C16	0.0063	0.539	0.584	0.007	0.0072	19	20	↑ 1
C17	0.0162	0.633	0.367	0.016	0.0164	17	17	→ 0
C18	0.0202	0.276	0.543	0.017	0.0168	14	16	↑ 2
C19	0.0503	0.508	0.608	0.056	0.0569	8	9	↑ 1
C20	0.0078	0.599	0.277	0.007	0.0070	20	19	↓ 1

Note: ↑, ↓, and → indicate an increase, decrease, and no change in rank, respectively;



(**a**) (**b**)

Figure 4. (**a**) Comparison of the original AHP weights and revised weights; (**b**) bidirectional weight deviations after Better–Worse correction (blue: upgraded; red: downgraded)

4.6. Expert–User Priority Comparison Based on Spearman Correlation

Since the surveyed demographic variables showed complex differences across the core indicators, we found it necessary to further quantify the systematic deviation between "expert weights" and "user satisfaction." To do this, we used Spearman correlation analysis for a deeper test. The results are shown in Table 11. The analysis indicates that the correlation coefficient between the original AHP weights and employee satisfaction is $\rho = 0.208$, $p = 0.379 > 0.05$, failing to reach statistical significance. After introducing the Better–Worse coefficients, the correlation coefficient between the revised weights and employee satisfaction is $\rho = 0.223$, $p = 0.346 > 0.05$, which likewise does not achieve statistical significance. Both pre- and post-introduction results demonstrate that within the sample of this study, no significant correlation exists between expert weights and employee satisfaction. Although the revised correlation coefficient exhibits an increase, it remains statistically non-significant; thus, this variation should not be used for causal or significance inference. Consequently, this study treats this weak, non-significant association as an indication of possible priority divergence and further combines it with the Kano classification and IPA matrix to precisely locate the differences among indicators, thereby further analyzing the optimization priorities of different indicators.

Table 11. Spearman rank correlation analysis between weights and satisfaction.

Correlation Items (N = 20)	Spearman Correlation Coefficient (ρ)	Significance	95% CI	Correlation Evaluation	Perceptual Status
Original Weight vs. Satisfaction	0.208	0.379	[−0.258, 0.596]	Extremely weak correlation	Significant misalignment
Revised Weight vs. Satisfaction	0.223	0.346	[−0.244, 0.606]	Extremely weak correlation	Optimized trend but non-significant

4.7. Visual Analysis of IPA Quadrant Charts Based on AHP and Kano Models

Based on the aforementioned AHP and Kano data, the final results are visualized and coupled through an IPA quadrant chart to construct a multidimensional quantitative decision model. This model offers a more intuitive representation of expert logic, nonlinear user psychology, and current performance status. The revised weights determined based on the modified AHP establish the Y-axis, while the mean values of the IPA satisfaction questionnaire establish the X-axis, with the overall mean values (importance = 0.05, satisfaction = 3.45) serving as the thresholds to construct the four-quadrant matrix (Figure 5).

By physically isolating the data sources, this methodology effectively mitigates the common-source bias inherent in relying on a single data source, thereby enhancing data objectivity.

Based on the results of the comprehensive decision-making analysis in Figure 5, the positioning of the 20 evaluation indicators exhibits notable strategic variations. Clustered within the "Concentrate Here" quadrant are air quality (C1), noise control (C3), and personal privacy (C5), which are categorized as Must-be attributes; formal leisure space (C10), categorized as an attractive attribute; and work mode selection (C19), categorized as a One-dimensional attribute. These indicators are characterized by high weights and low satisfaction. The "Keep Up the Good Work" quadrant encompasses One-dimensional and Must-be attributes such as comfortable light environment (C2) and health care facility C6, which exhibit the dual characteristics of high satisfaction and high weights. The "Overkill" quadrant contains multiple indicators including environmentally friendly materials (C9), informal leisure space (C11), and pet-friendly space (C12), manifesting as low revised

weights and high satisfaction. Additionally, indicators such as intelligent robots (C8), childcare space (C13), and shared private space (C16) fall into the "Low Priority" quadrant, presenting low weights and low satisfaction. The aforementioned results provide a data foundation for the subsequent analysis of the factors causing these variations.

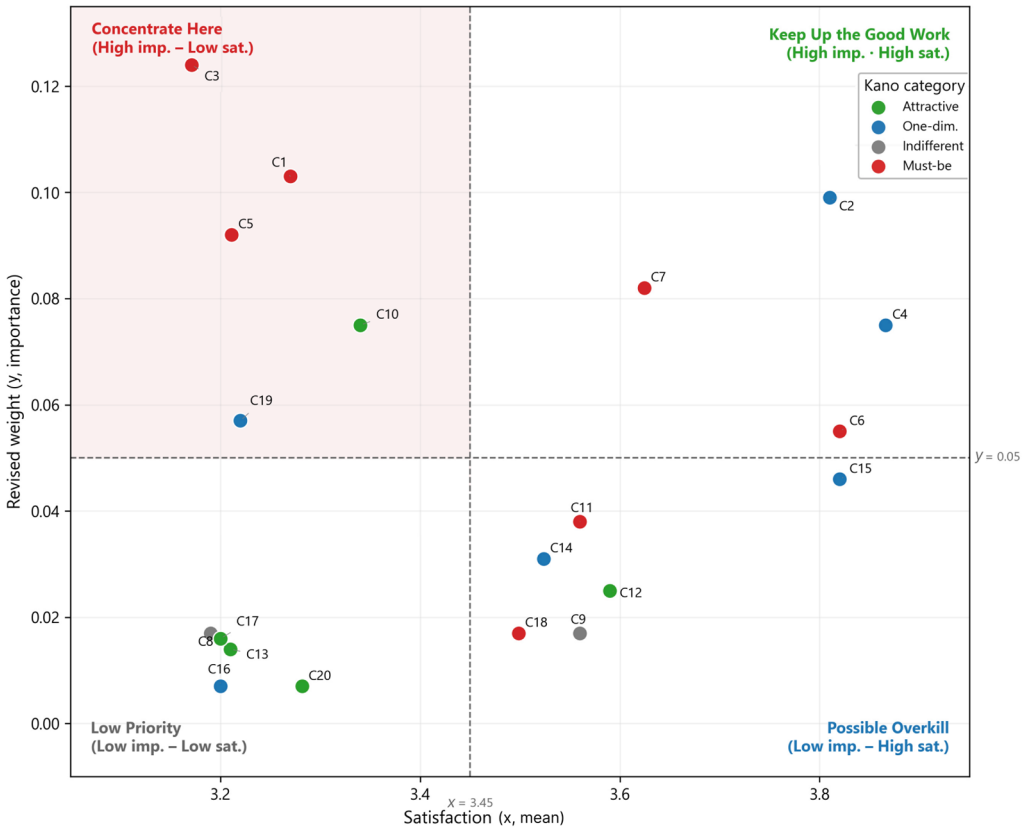


Figure 5. AHP-Kano-IPA integrated decision-making diagram.

5. Discussion

Based on the aforementioned survey, the integrated AHP-Kano-IPA model proceed through three sequential steps: data quantification, indicator adjustment, and result visualization. This section analyses these evaluation deviations in IEQ elements between experts and employees. The results indicate that the evaluations of the expert group lean more toward building physical performance, efficiency, and technical dimensions, while employees focused more on their personal experience, paying more attention to factors such as privacy, noise, and work facilities. In Spearman's correlation test, neither the original nor the adjusted weights reached a significant level with employee satisfaction. Within this study, this outcome is not interpreted as a significant linear correlation; instead, it demonstrates that the framework of this study reveals an objective difference in prioritization between the two parties, thereby providing a user-oriented basis for subsequent office space optimization.

5.1. The Cognitive Disconnect Between Expert Assessment and Employee Experience

The root cause of this outcome lies in the divergence of perspectives between the two groups. The expert community is heavily influenced by industry experience and accumulated knowledge; consequently, their approach to evaluation places a greater emphasis on the compliance and standardization of the physical built environment. Therefore, in the presentation of the AHP weight results, physiological needs and safety guarantees hold absolute importance, while noise control, air quality, personal privacy, and IT facilities are

listed as higher priorities. These indicators belong to Must-be attributes within the Kano classification, meaning that while the fulfillment of these elements for daily use does not significantly enhance employee satisfaction, their absence will lead to significant dissatisfaction. Consequently, the improvement of office space satisfaction and the enhancement of resources do not exhibit a distinct linear correlation but are closely related to employee perception, psychology, and behavior. The mechanism underlying this expert–user perceptual bias and its adjustment pathway is summarized in Figure 6.

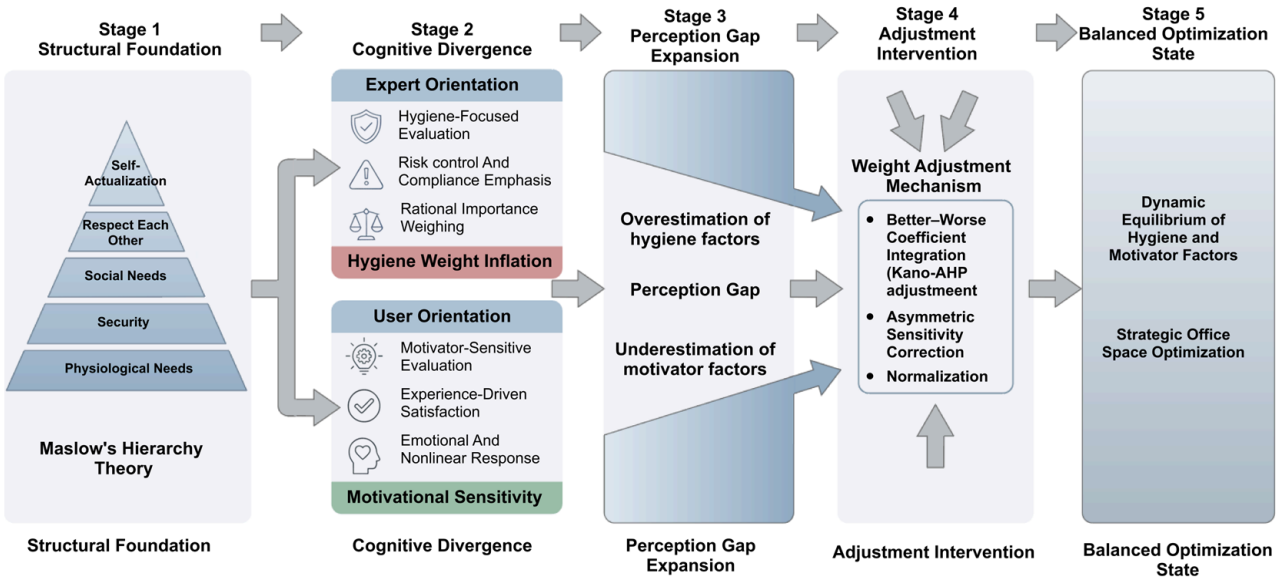


Figure 6. Expert–user perceptual bias mechanism model.

This finding also responds to the trade-off between building energy efficiency and environmental comfort. Although open-plan office spaces can significantly enhance communication efficiency and spatial utilization, the resulting advantages, such as energy efficiency, fail to translate into increased satisfaction if deficiencies in dimensions such as privacy and acoustics are neglected. Therefore, the coordination between efficiency and comfort must be emphasized during the optimization process of office spaces, and preliminary decision making must incorporate the actual perceptions of employees.

Additionally, it is noteworthy that the element of intelligent robots is not categorized as a priority element, partially because its frequency of use and penetration rate in daily office routines remain limited, failing to form a functional dependency for employees. This demonstrates that the introduction of intelligent elements in office spaces cannot be directly translated into an enhancement of employee satisfaction, and their implementation must be reasonably integrated with workflows and usage scenarios.

5.2. Design Strategies for Noise Control and Personal Privacy Issues

As indicated by the IPA results, noise and privacy issues are current concerns that require attention in office spaces, which also represent prevalent problems within open-plan office layouts. Environmental noise significantly disrupts employee focus, thereby reducing efficiency, whereas the lack of privacy diminishes employees' sense of environmental control and safety perception. Therefore, future optimization of office spaces must address acoustic control and privacy protection as an integrated strategy.

Regarding noise control, acoustic zoning can be established through physical partition walls to divide collaborative discussion areas, quiet work areas, and telephone communication areas. These areas can be separated along traffic circulation routes to form dynamic and static zones, further mitigating interference between regions. Because telephone and

interpersonal communications represent the primary sources of noise, highly mobile, small-scale shared spaces, such as accessible meeting pods and phone booths, can be deployed to physically separate communication activities from workstations, thereby reducing disturbance. In terms of materials and structures, sound-absorbing materials can be utilized to further attenuate noise; these can be applied to ceilings, wall surfaces, and soft furnishings, or mobile acoustic screens can be added to suppress noise propagation within the space.

Regarding privacy protection, the layout of office spaces should not be simplified as entirely open-plan but should establish multi-category work areas based on specific demands. Multiple functions, including open collaborative areas, semi-enclosed work areas, shared zones, and private work areas, should coexist to achieve functional separation. Additionally, for fixed workstations, methods such as appropriately increasing sound-absorbing low partitions, integrating green plants, and adjusting furniture orientations should be implemented to mitigate interference caused by noise and visual exposure.

5.3. Demographic Heterogeneity in Perceptions of the Office Environment

The results of Analysis of Variance (ANOVA) and *t*-tests show that significant differences were observed among employee groups. Specifically, the educational background variable exhibits significant differences across multiple core indicators, such as air quality and personal privacy. Significant differences were observed across age groups for all five top-ranked indicators. The gender variable demonstrates significance across four indicators, with the exception of noise control. The professional background is significant exclusively regarding IT facilities. The aforementioned results demonstrate that satisfaction evaluations among employees are not entirely identical; distinct cohorts, work types, personal experiences, and sensitivities all influence employee perceptions, thereby generating differentiated demands.

The explanation of differences in demographic attributes should not be construed as having a direct impact on environmental preferences but rather as revealing the objective existence of demand variations within the office space. In the optimization of office spaces, although it is impossible to tailor a private work environment for every individual employee, multi-category and selectable office environments should be provided to grant employees high autonomy, enabling them to select appropriate work environments based on their own needs, thereby enhancing environmental adaptability across different task scenarios.

5.4. Discussion on Research Applicability

The study context is the high-density office space in the Shenzhen Science and Technology Park, and the sample is subject to regional limitations. Climates, enterprise types, corporate cultures, and office modes vary across different regions to different degrees. Therefore, the specific indicators of this study are not suitable for direct generalization and application in other regions.

However, the integrated AHP-Kano-IPA framework possesses replicability at the methodological level. This framework can simultaneously identify the following issues: key elements from the expert perspective, key elements from the employee perspective, and which underperforming elements should be prioritized for improvement. The framework can be applied to shared offices, traditional offices, and government offices in different climatic regions to identify whether regional differences exist in the IEQ renovation priorities under varying conditions.

6. Conclusions

This study examined high-density office spaces in Shenzhen Science Park and constructed an integrated evaluation model of AHP-Kano-IPA. It introduces the Better–Worse

coefficient of the Kano model to construct a weight correction formula $W_i' = W_{(ahp_i)} \times (Better_i + |Worse_i|)$. It compares the differences in renovation priorities of office environmental elements from the dual perspectives of expert decision making and employee experience. This framework encompasses the normative judgments of experts, the nonlinear satisfaction of employees, and the actual satisfaction performance, thereby providing methodological support for the IEQ element renovation priorities in high-density office spaces.

The research results indicate that evaluations at the expert level focus more on foundational IEQ and technical infrastructure elements, such as noise control, IT facilities, and air quality, whereas employees assign greater importance to noise and privacy issues that align with their personal experiences. In the results of the Spearman correlation analysis, no statistically significant correlation exists between expert weights and employee satisfaction, further demonstrating that expert judgment cannot be directly equated with the actual perceptions of employees. Combining the Kano and IPA results reveals that noise control and personal privacy represent the core concerns that require priority improvement within the current high-density open-plan office environment. Therefore, while ensuring spatial efficiency and building operational performance, office space optimization must place greater emphasis on design strategies directly related to employee comfort perception, such as acoustic zoning, privacy boundaries, focus spaces, and flexible layouts. The primary contribution of this study lies in revealing the IEQ priority differences from the dual perspectives of experts and employees and providing a user-oriented decision-making basis for the synergistic optimization among building energy efficiency, spatial efficiency, and environmental comfort. Although the study effectively mitigated common method bias through the application of a composite model, the regional locations, urban climates, and demographic compositions of the primary subjects possess regional specificities, thereby limiting the generalizability of the results. Consequently, the configuration of specific indicators requires concrete adjustments in accordance with the corresponding city, office type, and office environment.

Furthermore, the research outcomes of this study at the current stage are primarily based on subjective questionnaire data. As this study represents an ongoing research endeavor, future research will integrate objective physical measurements, such as sound pressure level, temperature, and occupancy density to further identify and determine which IEQ elements impact employee comfort, health, and well-being, thereby providing more scientific data support for the optimization of office spaces.

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Institutional Review Board Statement: The ethical approval was waived because this study involves a non-invasive, anonymous questionnaire survey on office environment satisfaction. The research poses no risk to participants and does not collect sensitive personal identifiers.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets generated and analyzed during the current study are not publicly available due to participant privacy restrictions but are available from the corresponding author on reasonable request.

Conflicts of Interest: The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Appendix A

Table A1. Keyword collection table.

Order Number	Keywords	Frequency	Centrality	First Year	Indicator Correlation
1	Health	28	0.29	2015	B1 Safety and Security
2	Thermal comfort	13	0.12	2016	B2 Physiological Needs
3	Quality	10	0.1	2016	B1 Safety and Security
4	Performance	48	0.09	2015	B5 Self-actualization Needs
5	Noise	15	0.09	2015	B2 Physiological Needs
6	Productivity	18	0.07	2019	B5 Self-actualization Needs
7	Communication	15	0.07	2016	B3 Social Needs
8	Employee reaction	13	0.07	2015	B3 Social Needs
9	Open offices	11	0.07	2016	B3 Social Needs
10	Privacy	22	0.06	2015	B1 Safety and Security
11	Climate	21	0.06	2015	B2 Physiological Needs
12	Physical environment	3	0.05	2017	B1 Safety and Security
13	Space	9	0.05	2020	B3 Social Needs
14	Well-being	5	0.05	2017	B4 Esteem Needs
15	Comfort	7	0.04	2018	B2 Physiological Needs
16	Energy	4	0.04	2018	B1 Safety and Security
17	Discomfort glare	3	0.04	2018	B1 Physiological Needs
18	Temperature	6	0.03	2019	B1 Physiological Needs
19	Stress	5	0.03	2015	B4 Esteem Needs
20	View	4	0.03	2019	B3 Social Needs

Table A2. Comprehensive evaluation form.

Number	Indicator	Mean Satisfaction (S)	Revised Weight	Kano Attribute Category	IPA Quadrant Location
C1	Air Quality	3.27	0.103	Must be	2
C2	Comfortable Light Environment	3.81	0.099	One-dimensional	1
C3	Noise Control	3.17	0.124	Must be	2
C4	Adjustable Furniture	3.86	0.075	One-dimensional	1
C5	Personal Privacy	3.21	0.092	Must be	2
C6	Health Care Facility	3.82	0.055	Must be	1
C7	IT Facilities	3.62	0.082	Must be	1
C8	Robotic Operation Safety	3.19	0.017	Indifferent	3
C9	Eco-friendly Materials	3.56	0.017	Indifferent	4
C10	Formal Leisure Space	3.34	0.075	Attractive	2
C11	Informal Leisure Spaces	3.56	0.038	Must be	4
C12	Pet-friendly Space	3.59	0.025	Attractive	4
C13	Childcare Space	3.21	0.014	Attractive	3
C14	Flexible Office Layout	3.52	0.031	One-dimensional	4
C15	Employee Identity	3.82	0.046	One-dimensional	4
C16	Shared Private Space	3.20	0.007	One-dimensional	3
C17	Space Allocation Fairness	3.20	0.016	Attractive	3
C18	Work-mode Autonomy	3.50	0.017	Must be	4
C19	Choose your Preferred Work Mode (Online/Offline)	3.22	0.057	One-dimensional	2
C20	Skill-learning Spaces	3.28	0.007	Attractive	3

Table A3. IEQ indicators and Kano functional/dysfunctional question correspondence.

Indicator No.	IEQ Indicator	Functional Question (Attribute Present)	Dysfunctional Question (Attribute Absent)
C1	Air Quality	How would you feel if the office space had fresh air and good ventilation?	How would you feel if the office space had poor air quality and insufficient ventilation?
C2	Comfortable Light Environment	How would you feel if the office space had sufficient daylight or comfortable lighting?	How would you feel if the office space had insufficient light, glare, or uncomfortable lighting?
C3	Noise Control	How would you feel if the office space could effectively control noise?	How would you feel if the office space was frequently disturbed by conversations, equipment noise, or other noise sources?
C4	Adjustable Furniture	How would you feel if the office space were equipped with adjustable and ergonomic office furniture?	How would you feel if the office furniture were difficult to adjust or did not meet your needs?
C5	Personal Privacy	How would you feel if the office space could protect your visual, acoustic, and behavioral privacy?	How would you feel if the office space lacked privacy protection and you were easily disturbed or observed by others?
C6	Health Care Facilities	How would you feel if the office space were equipped with necessary health-support facilities?	How would you feel if the office space lacked health-support facilities?
C7	IT Facilities	How would you feel if the office space provided stable and well-developed network and information technology facilities?	How would you feel if the network were unstable or the information technology facilities were insufficient?
C8	Robotic Operation Safety	How would you feel if intelligent robots in the office space operated safely and reliably?	How would you feel if intelligent robots in the office space posed operational risks or safety hazards?
C9	Material Environmental Friendliness	How would you feel if the office space used environmentally friendly and low-pollution finishing materials?	How would you feel if the materials used in the office space were insufficiently environmentally friendly or might cause pollution?
C10	Formal Leisure Space	How would you feel if the office space provided formal and fixed leisure spaces?	How would you feel if the office space lacked formal and fixed leisure spaces?
C11	Informal Leisure Space	How would you feel if the office space provided flexible and informal leisure and communication spaces?	How would you feel if the office space lacked flexible and informal leisure and communication spaces?
C12	Pet-friendly Space	How would you feel if the office space provided pet-friendly supporting spaces or management conditions?	How would you feel if the office space did not support pet-friendly needs at all?
C13	Childcare Space	How would you feel if the office space provided spatial conditions for temporary child companionship or care?	How would you feel if the office space completely lacked child-companionship-related spaces?
C14	Flexible Office Layout	How would you feel if the office layout were flexible and could adapt to different work tasks?	How would you feel if the office layout were fixed and difficult to adapt to different work tasks?
C15	Employee Identity	How would you feel if the office space enhanced your sense of organizational belonging and identity?	How would you feel if the office space failed to reflect organizational culture or employee identity?
C16	Shared Private Space	How would you feel if the office space provided shared private spaces?	How would you feel if the office space lacked shared private spaces?

Table A3. *Cont.*

Indicator No.	IEQ Indicator	Functional Question (Attribute Present)	Dysfunctional Question (Attribute Absent)
C17	Space Allocation Fairness	How would you feel if office space allocation were fair and different employees had relatively equal opportunities to use the space?	How would you feel if office space allocation were unfair and some employees had difficulty obtaining suitable space?
C18	Work-mode Autonomy	How would you feel if the office space provided meeting rooms of different sizes to accommodate various meeting needs?	How would you feel if the meeting rooms were limited to a single size and could not meet different meeting needs?
C19	Autonomous Choice of Work Mode	How would you feel if you could independently choose online or offline work modes according to task needs?	How would you feel if you could not independently choose online or offline work modes according to task needs?
C20	Skill-learning Space	How would you feel if the office space provided areas for training, learning, or skill development?	How would you feel if the office space lacked areas for training, learning, or skill development?

Appendix B

Table A4. Complete statistics, effect sizes, and confidence intervals for demographic difference tests of core IEQ satisfaction indicators.

Indicator	Grouping Variable	Test Method	Test Statistic	*p*-Value	Effect Size	95% CI	Result
TOTAL_S Overall Satisfaction	Gender	Welch *t*-test	t = −6.899, df = 387.913	<0.001	d = 0.668	[−0.433, −0.241]	Significant
C3 Noise Control	Gender	Welch *t*-test	t = −1.911, df = 427.090	0.057	d = 0.184	[−0.382, 0.005]	Not significant
C1 Air Quality	Gender	Welch *t*-test	t = −3.340, df = 418.158	<0.001	d = 0.322	[−0.558, −0.144]	Significant
C5 Personal Privacy	Gender	Welch *t*-test	t = −4.097, df = 426.859	<0.001	d = 0.395	[−0.585, −0.206]	Significant
C7 IT Facility Completeness	Gender	Welch *t*-test	t = −4.281, df = 423.540	<0.001	d = 0.413	[−0.588, −0.218]	Significant
C2 Comfortable Light Environment	Gender	Welch *t*-test	t = −2.640, df = 418.650	0.009	d = 0.255	[−0.408, −0.060]	Significant
TOTAL_S Overall Satisfaction	Age	One-way ANOVA	F(6, 425) = 29.294	<0.001	η^2 = 0.293; ω^2 = 0.282	Group mean 95% CI shown in Appendix B Table A6	Significant
C3 Noise Control	Age	One-way ANOVA	F(6, 425) = 5.876	<0.001	η^2 = 0.077; ω^2 = 0.063		Significant
C1 Air Quality	Age	One-way ANOVA	F(6, 425) = 6.487	<0.001	η^2 = 0.084; ω^2 = 0.071		Significant
C5 Personal Privacy	Age	One-way ANOVA	F(6, 425) = 2.981	0.007	η^2 = 0.040; ω^2 = 0.027		Significant
C7 IT Facility Completeness	Age	One-way ANOVA	F(6, 425) = 3.258	0.004	η^2 = 0.044; ω^2 = 0.030		Significant
C2 Comfortable Light Environment	Age	One-way ANOVA	F(6, 425) = 5.696	<0.001	η^2 = 0.074; ω^2 = 0.061		Significant

Table A4. *Cont.*

Indicator	Grouping Variable	Test Method	Test Statistic	*p*-Value	Effect Size	95% CI	Result
TOTAL_S Overall Satisfaction	Education	One-way ANOVA	F(3, 428) = 13.803	<0.001	$\eta^2 = 0.088$; $\omega^2 = 0.082$	Group mean 95% CI shown in Appendix B Table A6	Significant
C3 Noise Control	Education	One-way ANOVA	F(3, 428) = 3.770	0.011	$\eta^2 = 0.026$; $\omega^2 = 0.019$		Significant
C1 Air Quality	Education	One-way ANOVA	F(3, 428) = 3.250	0.022	$\eta^2 = 0.022$; $\omega^2 = 0.015$		Significant
C5 Personal Privacy	Education	One-way ANOVA	F(3, 428) = 2.804	0.039	$\eta^2 = 0.019$; $\omega^2 = 0.012$		Significant
C7 IT Facility Completeness	Education	One-way ANOVA	F(3, 428) = 2.956	0.032	$\eta^2 = 0.020$; $\omega^2 = 0.013$		Significant
C2 Comfortable Light Environment	Education	One-way ANOVA	F(3, 428) = 2.067	0.104	$\eta^2 = 0.014$; $\omega^2 = 0.007$		Not significant
TOTAL_S Overall Satisfaction	Major	One-way ANOVA	F(5, 426) = 2.582	0.026	$\eta^2 = 0.029$; $\omega^2 = 0.018$	Group mean 95% CI shown in Appendix B Table A6	Significant
C3 Noise Control	Major	One-way ANOVA	F(5, 426) = 1.130	0.344	$\eta^2 = 0.013$; $\omega^2 = 0.002$		Not significant
C1 Air Quality	Major	One-way ANOVA	F(5, 426) = 0.658	0.655	$\eta^2 = 0.008$; $\omega^2 = 0.000$		Not significant
C5 Personal Privacy	Major	One-way ANOVA	F(5, 426) = 2.081	0.067	$\eta^2 = 0.024$; $\omega^2 = 0.012$		Not significant
C7 IT Facility Completeness	Major	One-way ANOVA	F(5, 426) = 2.338	0.041	$\eta^2 = 0.027$; $\omega^2 = 0.015$		Significant
C2 Comfortable Light Environment	Major	One-way ANOVA	F(5, 426) = 0.444	0.817	$\eta^2 = 0.005$; $\omega^2 = 0.000$		Not significant

Table A5. Descriptive statistics and distribution of the 20 IEQ satisfaction indicators.

Indicator	N	Mean	SD	Min	Q1	Median	Q3	Max
C1 Air Quality	432	3.273	1.102	1	2	3	4	5
C2 Comfortable Light Environment	432	3.808	0.925	1	3	4	4	5
C3 Noise Control	432	3.171	1.026	1	2	3	4	5
C4 Adjustable Furniture	432	3.856	0.910	1	3	4	5	5
C5 Personal Privacy	432	3.211	1.019	1	2	3	4	5
C6 Health Care Facilities	432	3.819	0.916	1	3	4	4	5
C7 IT Facility Completeness	432	3.616	0.997	1	3	4	4	5
C8 Intelligent Robots	432	3.188	1.053	1	2	3	4	5
C9 Material Environmental Friendliness	432	3.558	1.036	1	3	4	4	5
C10 Formal Leisure Space	432	3.336	1.053	1	3	3	4	5
C11 Informal Leisure Space	432	3.556	0.993	1	3	4	4	5
C12 Pet-friendly Space	432	3.586	1.041	1	3	4	4	5
C13 Childcare Space	432	3.206	1.095	1	2	3	4	5
C14 Flexible Layout	432	3.521	1.064	1	3	4	4	5
C15 Shared Solitary Space	432	3.824	0.922	1	3	4	5	5
C16 Personal Identification	432	3.199	1.082	1	2	3	4	5
C17 Space Allocation Fairness	432	3.204	1.066	1	2	3	4	5
C18 Multi-specification Meeting Space	432	3.498	1.073	1	3	4	4	5
C19 Autonomous Choice of Work Mode	432	3.222	1.047	1	2	3	4	5
C20 Skill-learning Space	432	3.280	1.041	1	2	3	4	5

Table A6. Group descriptive statistics and 95% confidence intervals for core IEQ indicators by demographic variables.

Grouping Variable	Group	Indicator	*n*	Mean	SD	SE	95% CI	Min	Max
Age	Over 50 years old	TOTAL_S Overall Satisfaction	15	2.663	0.313	0.081	[2.490, 2.836]	2	3
	25–30 years old (including 30)		116	3.631	0.412	0.038	[3.556, 3.707]	2	4
	25 years old or below (including 25)		41	3.666	0.353	0.055	[3.554, 3.777]	3	4
	30–35 years old (including 35)		95	3.592	0.435	0.045	[3.503, 3.681]	2	4
	40–45 years old (including 45)		69	3.017	0.530	0.064	[2.889, 3.144]	2	4
	35–40 years old (including 40)		75	3.545	0.503	0.058	[3.429, 3.661]	2	4
	45–50 years old (including 50)		21	2.960	0.478	0.104	[2.742, 3.177]	2	4
	Over 50 years old	C3 Noise Control	15	2.600	1.183	0.306	[1.945, 3.255]	1	5
	25–30 years old (including 30)		116	3.405	0.932	0.087	[3.234, 3.577]	1	5
	25 years old or below (including 25)		41	3.268	0.975	0.152	[2.960, 3.576]	1	5
	30–35 years old (including 35)		95	3.347	0.998	0.102	[3.144, 3.551]	1	5
	40–45 years old (including 45)		69	2.710	1.059	0.127	[2.456, 2.964]	1	5
	35–40 years old (including 40)		75	3.213	1.004	0.116	[2.982, 3.444]	1	5
	45–50 years old (including 50)		21	2.667	0.913	0.199	[2.251, 3.082]	1	4
	Over 50 years old	C1 Air Quality	15	2.867	1.125	0.291	[2.243, 3.490]	1	5
	25–30 years old (including 30)		116	3.457	0.964	0.089	[3.280, 3.634]	1	5
	25 years old or below (including 25)		41	3.512	1.003	0.157	[3.196, 3.829]	1	5
	30–35 years old (including 35)		95	3.453	1.099	0.113	[3.229, 3.677]	1	5
	40–45 years old (including 45)		69	2.768	1.190	0.143	[2.482, 3.054]	1	5
	35–40 years old (including 40)		75	3.400	1.103	0.127	[3.146, 3.654]	1	5
	45–50 years old (including 50)		21	2.476	0.873	0.190	[2.079, 2.874]	1	4
	Over 50 years old	C5 Personal Privacy	15	2.600	1.298	0.335	[1.881, 3.319]	1	5
	25–30 years old (including 30)		116	3.328	0.852	0.079	[3.171, 3.484]	2	5
	25 years old or below (including 25)		41	3.390	1.022	0.160	[3.068, 3.713]	1	5
	30–35 years old (including 35)		95	3.274	1.026	0.105	[3.065, 3.483]	1	5
	40–45 years old (including 45)		69	2.870	1.212	0.146	[2.579, 3.161]	1	5
	35–40 years old (including 40)		75	3.320	0.932	0.108	[3.105, 3.535]	1	5
	45–50 years old (including 50)		21	3.095	0.944	0.206	[2.666, 3.525]	2	5
	Over 50 years old	C7 IT Facility Completeness	15	3.067	1.163	0.300	[2.423, 3.711]	1	5
	25–30 years old (including 30)		116	3.664	0.960	0.089	[3.487, 3.840]	1	5
	25 years old or below (including 25)		41	3.780	0.881	0.138	[3.503, 4.058]	2	5
	30–35 years old (including 35)		95	3.768	0.994	0.102	[3.566, 3.971]	1	5
	40–45 years old (including 45)		69	3.261	1.052	0.127	[3.008, 3.514]	1	5
	35–40 years old (including 40)		75	3.747	0.887	0.102	[3.543, 3.951]	2	5
	45–50 years old (including 50)		21	3.429	1.165	0.254	[2.898, 3.959]	1	5
	Over 50 years old	C2 Comfortable Light Environment	15	3.333	0.724	0.187	[2.933, 3.734]	2	5
	25–30 years old (including 30)		116	3.905	0.823	0.076	[3.754, 4.057]	1	5
	25 years old or below (including 25)		41	3.927	0.848	0.132	[3.659, 4.195]	1	5
	30–35 years old (including 35)		95	4.021	0.812	0.083	[3.856, 4.186]	2	5
	40–45 years old (including 45)		69	3.348	1.055	0.127	[3.094, 3.601]	1	5
	35–40 years old (including 40)		75	3.933	0.935	0.108	[3.718, 4.148]	1	5
	45–50 years old (including 50)		21	3.476	1.123	0.245	[2.965, 3.988]	1	5

Table A6. *Cont.*

Grouping Variable	Group	Indicator	*n*	Mean	SD	SE	95% CI	Min	Max
Education	High school or below (including vocational high school, technical secondary school, etc.)	TOTAL_ Overall Satisfaction	48	3.021	0.561	0.081	[2.858, 3.184]	2	4
	Postgraduate or above		86	3.570	0.496	0.054	[3.463, 3.676]	2	4
	Bachelor's degree		154	3.515	0.488	0.039	[3.438, 3.593]	2	4
	Junior college		144	3.441	0.520	0.043	[3.356, 3.527]	2	4
	High school or below (including vocational high school, technical secondary school, etc.)	C3 Noise Control	48	2.729	1.125	0.162	[2.403, 3.056]	1	5
	Postgraduate or above		86	3.326	1.057	0.114	[3.099, 3.552]	1	5
	Bachelor's degree		154	3.188	0.975	0.079	[3.033, 3.344]	1	5
	Junior college		144	3.208	0.996	0.083	[3.044, 3.372]	1	5
	High school or below (including vocational high school, technical secondary school, etc.)	C1 Air Quality	48	2.812	1.142	0.165	[2.481, 3.144]	1	5
	Postgraduate or above		86	3.372	1.018	0.110	[3.154, 3.590]	1	5
	Bachelor's degree		154	3.312	1.100	0.089	[3.137, 3.487]	1	5
	Junior college		144	3.326	1.115	0.093	[3.143, 3.510]	1	5
	High school or below (including vocational high school, technical secondary school, etc.)	C5 Personal Privacy	48	2.812	1.142	0.165	[2.481, 3.144]	1	5
	Postgraduate or above		86	3.267	0.975	0.105	[3.058, 3.477]	1	5
	Bachelor's degree		154	3.273	0.992	0.080	[3.115, 3.431]	1	5
	Junior college		144	3.243	1.012	0.084	[3.076, 3.410]	1	5
	High school or below (including vocational high school, technical secondary school, etc.)	C7 IT Facility Completeness	48	3.229	1.096	0.158	[2.911, 3.547]	1	5
	Postgraduate or above		86	3.733	0.926	0.100	[3.534, 3.931]	2	5
	Bachelor's degree		154	3.662	0.958	0.077	[3.510, 3.815]	1	5
	Junior college		144	3.625	1.023	0.085	[3.456, 3.794]	1	5
	High school or below (including vocational high school, technical secondary school, etc.)	C2 Comfortable Light Environment	48	3.500	0.968	0.140	[3.219, 3.781]	2	5
	Postgraduate or above		86	3.837	0.866	0.093	[3.652, 4.023]	1	5
	Bachelor's degree		154	3.870	0.883	0.071	[3.729, 4.011]	1	5
	Junior college		144	3.826	0.978	0.081	[3.665, 3.987]	1	5
Major	Intelligent-position roles	TOTAL_S Overall Satisfaction	33	3.417	0.507	0.088	[3.237, 3.596]	2	4
	Space design		69	3.490	0.505	0.061	[3.369, 3.611]	2	4
	Technology R&D and engineering		137	3.543	0.501	0.043	[3.458, 3.628]	2	4
	Operations		52	3.446	0.561	0.078	[3.290, 3.602]	2	4
	Product related		66	3.275	0.573	0.071	[3.134, 3.416]	2	4
	Creative and visual design		75	3.395	0.534	0.062	[3.272, 3.517]	2	4
	Intelligent-position roles	C3 Noise Control	33	3.182	1.074	0.187	[2.801, 3.563]	1	5
	Space design		69	3.348	0.983	0.118	[3.112, 3.584]	1	5
	Technology R&D and engineering		137	3.226	1.007	0.086	[3.056, 3.396]	1	5

Table A6. *Cont.*

Grouping Variable	Group	Indicator	*n*	Mean	SD	SE	95% CI	Min	Max
Major	Operations	C3 Noise Control	52	3.173	0.944	0.131	[2.910, 3.436]	1	5
	Product related		66	3.091	1.092	0.134	[2.823, 3.359]	1	5
	Creative and visual design		75	2.973	1.065	0.123	[2.728, 3.218]	1	5
	Intelligent-position roles	C1 Air Quality	33	3.394	1.144	0.199	[2.988, 3.800]	1	5
	Space design		69	3.406	1.167	0.141	[3.125, 3.686]	1	5
	Technology R&D and engineering		137	3.285	1.036	0.088	[3.110, 3.460]	1	5
	Operations		52	3.115	1.078	0.150	[2.815, 3.416]	1	5
	Product related		66	3.152	1.126	0.139	[2.875, 3.428]	1	5
	Creative and visual design		75	3.293	1.148	0.133	[3.029, 3.557]	1	5
	Intelligent-position roles	C5 Personal Privacy	33	3.091	0.980	0.171	[2.743, 3.438]	2	5
	Space design		69	3.449	0.883	0.106	[3.237, 3.662]	2	5
	Technology R&D and engineering		137	3.248	0.991	0.085	[3.081, 3.416]	1	5
	Operations		52	3.250	1.082	0.150	[2.949, 3.551]	1	5
	Product related		66	2.909	1.034	0.127	[2.655, 3.163]	1	5
	Creative and visual design		75	3.213	1.106	0.128	[2.959, 3.468]	1	5
	Intelligent-position roles	C7 IT Facility Completeness	33	3.515	0.906	0.158	[3.194, 3.836]	2	5
	Space design		69	3.594	0.975	0.117	[3.360, 3.828]	1	5
	Technology R&D and engineering		137	3.796	0.964	0.082	[3.633, 3.958]	1	5
	Operations		52	3.731	0.992	0.138	[3.454, 4.007]	1	5
	Product related		66	3.333	1.043	0.128	[3.077, 3.590]	1	5
	Creative and visual design		75	3.520	1.031	0.119	[3.283, 3.757]	1	5
	Intelligent-position roles	C2 Comfortable Light Environment	33	3.848	1.004	0.175	[3.493, 4.204]	1	5
	Space design		69	3.942	0.889	0.107	[3.728, 4.156]	1	5
	Technology R&D and engineering		137	3.796	0.900	0.077	[3.643, 3.948]	1	5
	Operations		52	3.712	0.915	0.127	[3.457, 3.966]	1	5
	Product related		66	3.773	0.941	0.116	[3.541, 4.004]	1	5
	Creative and visual design		75	3.787	0.977	0.113	[3.562, 4.011]	1	5

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