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Research Article

Relationship between Indoor Living Environment and Housing Prices: A Case Study of the Taojinjiayuan Residential Quarter in Guangzhou, China

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The indoor living environment of residential buildings is an important part of the habitat environment, affecting the living experience and well-being of the residents, which in turn influences the price of housing. However, few existing studies systematically concentrate on the integrated influence of the various elements of the indoor living environment on prices, and even fewer analyze the relationship between the indoor living environment and housing prices of different houses within the same residential quarter from a microperspective. Therefore, we use the Taojinjiayuan Residential Quarter, located in central Guangzhou City, China, as a case study area and analyze the extent and direction of the effect of the indoor living environment on housing prices. The study found that the quantitative evaluation results of the indoor living environment were reasonable. The integrated indoor living environment factors are closely related to housing prices. Orientation, view, and acoustic environment are significantly and positively related to housing prices, which have a different intensity of influence. These findings are beneficial to real estate developers, building designers, and residential users in quantitatively understanding the value of the indoor living environment.

1. Introduction

Urban property values are at the heart of China's residential problem and have become a constant focus for the government and residents. Since the housing policy reform in 1998, China's real estate industry has increased significantly, and housing prices around the country have continued to rise rapidly. The average real housing prices in 35 large and medium-sized cities in China have increased at a rate of around 17% per year during the past decade, being thus much higher than the average income growth rate of 11% and the national average GDP growth rate of 10% [1]. Guangzhou is a representative central city, where residential sale prices increased from an average of RMB 3,000 per square meter in 1998 to RMB 35,293 per square meter in 2021, for a nominal increase of 10.76 times. The increase in housing prices has also led to a rise in the cost of living [2], increased the pressure to buy a house, and affected the normal lives of residents. This highlights the practical significance of conducting research on housing issues. An in-depth analysis of the factors influencing housing prices and the internal mechanisms of action among these factors will provide an empirical basis for alleviating the rapidly rising urban housing prices and the imbalance in supply structure. Moreover, it will provide a basis for decision-making on the formulation of macroeconomic policies to control housing prices.

The indoor living environment (ILE) of residential buildings is an important reflection of the comfort and happiness of the occupants of that space [3]. People spend 80% to 90% of their time in indoor spaces, where they conduct main activities such as living, working, and transportation [4]. As such, the conditions of ILE have a large influence on the well-being of the population. As far back as the first century B.C., people have understood the value of ILE [5]. With the continuous development of society, people's living standards and aesthetic abilities have increased, as has the importance of safety and comfort in the residential environment [6]. The quality of ILE has a direct impact on people's daily lives [7], affecting the well-being and satisfaction of residents as well as housing prices [8–10]. Thus, exploring the relationship between ILE factors and housing prices is essential.

A wide range of factors influences housing prices; the hedonic price theory is an important theoretical perspective for explaining housing price differences [11]. From this perspective, the factors influencing housing prices include architectural, neighbourhood, and locational characteristics, as well as external environmental factors. The specific factors can be summarized as follows: first, architectural characteristic factors, including building age, design quality, room size, number of rooms, number of toilets and bathrooms, quality of building materials, and layout design [12–14]. For instance, Zhang et al. analyzed the relationship between the internal structure of dwellings, such as the number of bedrooms, living rooms, or bathrooms, and residents' life satisfaction [15]. Tarque et al. focused on housing quality issues such as seismic resistance and building safety [16]. Second, neighbourhood characteristic factors include convenience related to transportation [17], accessibility to employment [18], health care and education security [19, 20], and convenience of public service facilities [21, 22]. For instance, Ruan et al. examined the advantages and disadvantages of five public facilities at residential prices: subway stations, schools, hospitals, green spaces, and commercial centers [22]. Third, in terms of location condition factors, spatial location is the main determinant of people's assessments of the value of housing [23]. Additionally, proximity to workplaces, shopping centers, and markets affects residential property value [13]. In general, housing prices increase as the distance from the major business center decreases [24]. Finally, external environmental factors (mainly the physical environment or landscape) include inner-city green landscapes [25, 26], parks [27], watersheds [28], and not-in-my-back-yard (NIMBY) facilities [29, 30]. For example, Trojanek et al. analyzed the effect of proximity to urban green spaces on apartment prices in Warsaw and found that green spaces within 100 m of an apartment increased residential prices by 2.8% to 3.1% [31]. La Roche et al. studied the external effects of residential rehab centers on nearby real estate and found an association between a decrease in nearby housing prices and substance abuse treatment centers [32].

Based on the cited studies, it is clear that housing prices are influenced by complex factors, the extent of which affects prices differently. Regarding the impact of ILE on housing prices, most of the existing studies focus on single components (thermal comfort, noise, light, and air quality) rather than on the combined impact of these components [33]. Few studies focus specifically on the impact of ILE quality on housing prices within the same residential quarter at the microlevel. People spend between 80% and 90% of their day in an indoor microenvironment [34], which is why residents tend to prefer housing that meets their work, study, and living needs. ILE, as an important guarantee of occupants' health, maintenance, and work efficiency, naturally becomes an important consideration in the public's choice of housing and requires further focus. Therefore, it is essential to examine the connection between ILE and housing prices.

This study examines not only the relationship but also which components of ILE have the greatest impact on housing price differences. That is, which of the five factors—orientation, natural light, ventilation, view, and acoustic environment—has the greatest effect on housing prices? Current research has shown a tendency to primarily examine the influence of macrolevel environmental factors or a specific type of ILE factor on housing prices. Researchers have paid less attention to the relationship between the integrated ILE and housing price differences, which is the aspect on which we should focus. Moreover, it is difficult to quantitatively evaluate the advantages and disadvantages of ILE because there are no indicators that can be easily evaluated quantitatively. As such, we attempt to apply rules to quantitatively evaluate ILE to provide a reference for subsequent studies.

The Taojinjiayuan Residential Quarter is situated in the center of Guangzhou City, and the characteristics of ILE, namely, floor level, house type, orientation, natural light, ventilation, view, and acoustic environment, vary greatly among different housing units within the residential quarter, which results in significantly different prices among houses. Prices range from 53,849 RMB/m^2 to 129,718 RMB/m^2, making the quarter a representative study area.

This study constructed a conceptual framework for ILE that may affect housing prices and explored the relationship between the environment and prices. Specifically, we used 57 housing units in the Taojinjiayuan Residential Quarter to construct a cross-sectional dataset of nine indicators, covering orientation, natural light, ventilation, view, and acoustic environment, among others, to explore the extent and direction of the influence of ILE on housing prices. This is helpful for quantitatively understanding the value of ILE and screening which elements of the subsystem of the environment have the highest influence on housing prices. The results thus provide a reference for relevant management departments and housing developers to make decisions regarding architectural design, urban renewal, real estate development, and indoor environment renovation.

2. Concept and Methods

2.1. Conceptual Framework of ILE's Effect on Housing Price Differences. ILE is a rich term, and scholars with different research needs have varied concerns and understandings of the connotation and extension of ILE. The ILE of housing is generally determined by a combination of orientation, natural light, ventilation, view, acoustic environment, and air quality of the housing, and these six aspects also theoretically affect residential values. Thus, we propose a framework to study

the influence of ILE on housing prices from a microperspective. This framework is applicable to studying the differences in ILE for different houses within residential quarters (Figure 1).

2.1.1. Orientation. The orientation of a housing unit determines how sunlight will reach it. In general, multiorientation housing is superior to single-orientation housing. In the northern hemisphere, when housing orientation is consistent, the optimal orientation is toward south [35], and the worst is toward the north. Further east orientation is generally superior to west orientation. If further subdivided, possible orientations, ranked from most superior to inferior, are as follows: north-south permeable, south or southeast, southwest, east-west permeable, east, west, northeast, northwest, and north. In general, the better the orientation, the higher the housing price [36]. Case studies in Nanjing [37], Shenyang [38], and Harbin [39] in China have shown that orientation has a significant effect on housing prices.

2.1.2. Natural Light. Natural light determines the brightness and hygiene of a housing interior, which in turn affects occupants' comfort and psychological state. Daytime lighting is an essential fundamental factor affecting the natural light conditions of a house. Edwards et al. [40] found that natural light can provide occupants with satisfactory residential utility. Orientation, number of floors, building shading, and window area together determine daylight exposure. For natural light, the view, window area, and housing depth condition are important determinants. Zhen et al. [41] showed that natural light in dwelling architecture can lower lighting energy usage and enhance the quality of the ILE. Rahadi et al. [42] showed that consumers in the Jakarta Metropolitan Region were willing to spend more money on better-lit housing.

2.1.3. Ventilation. Ventilation is a crucial component that influences the sanitary condition of housing, indoor temperature, and occupancy comfort and can eliminate indoor pollutants without consuming energy [43]. The level of ventilation in a housing unit is determined by floor height, orientation, the presence or absence of windows, location and unit sizes, and the presence or absence of obvious obstructions from other buildings. In the case of housing with windows and no obvious shading, housing orientation has a substantial impact on ventilation. Generally, ventilation is better in housing that is permeable (e.g., north-south and east-west) and whose orientation faces the main wind direction of the city, and high-rise housing tends to have better ventilation than low-rise housing. Poor ventilation can cause air pollution problems and a heat island effect. Therefore, ventilation is correlated with housing prices [44].

2.1.4. View. The view of a housing unit determines the housing landscape and has a certain influence on the psychology of the occupants, which in turn affects their comfort. Housing with a better view tends to have better ventilation and lighting conditions. Generally, people prefer housing with an open view and the ability to look far away, and housing with a view of a river, lake, ocean, park, or rich city skyline is more popular. If the view is poor, significantly blocked

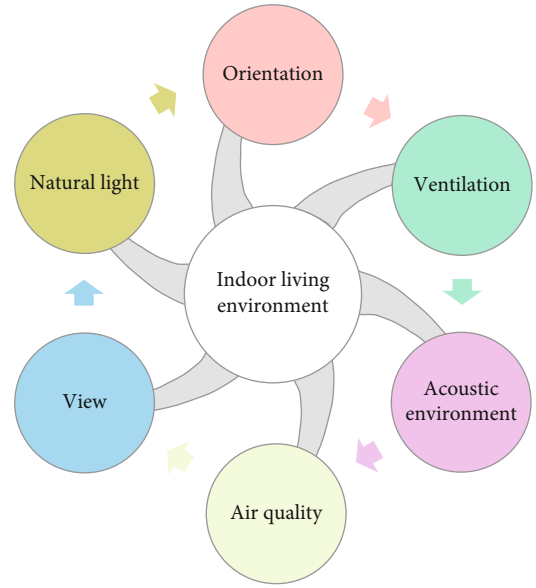

Figure 1: Conceptual framework for ILE.

by objects, or negative (e.g., elevated roads, cemeteries, high-voltage lines, garbage dumps, communication towers, and dilapidated buildings), the housing's rental experience and comfort will be reduced. Zhang and Dong [45] showed that homebuyers in Beijing prefer to live in homes with good visual perception, especially those with a high green visual index. In terms of housing demand, the view is positively correlated with housing prices [46].

2.1.5. Acoustic Environment. Noise is an essential element influencing the environment of a housing habitat. In terms of the external acoustic environment, housing is more likely to be affected by noise when it is oriented toward adjacent railroads, highways, expressways, factories, airports, transportation hubs, wholesale markets, logistic centers, squares, commercial areas, and so on. Housing is also affected by the internal acoustic environment, such as noise from businesses and neighbors in the immediate vicinity. Housing noise often has a negative effect on real estate value. Zheng et al. [47] analyzed the effects of the demolition of Kai Tak Airport in Hong Kong on house prices and showed that the disappearance of aircraft noise increased prices around the airport by an average of 24.43%. Zambrano-Monserrate and Ruano [48] concluded that living in a noisy environment for long periods of time can lead to health problems. The results of their study showed that for each unit rise in noise level (db) around a residence, the housing price decreased by an average of 1.97%. Thus, excessively intense ambient noise is negatively associated with house prices.

2.1.6. Air Quality. Indoor air quality (IAQ) is closely related to human health and is an environmental comfort factor that affects housing prices. The level of indoor air pollution in residential buildings is an important consideration for residents' marginal willingness to pay for clean air, and pollutants include [1] airborne fine particulate matter ($PM_{2.5}$), carbon dioxide, sulfur dioxide, and nitrogen oxides from

household gas cooking and heating [27, 49]; [2] volatile organic compounds (formaldehyde, toluene, and xylene) from renovation materials; [3] semivolatile organic compounds from plasticizers in indoor electronics and household products [50]; and [4] biological pollutants (bacteria, fungi, and dust mites) from daily life [4, 51]. For the same residential quarter, the outdoor air quality is basically the same, whereas indoor air pollution is exposed to occupant-specific behavioral factors, such as using poor-quality building materials for renovation, purchasing formaldehyde-excessive furniture, smoking, and cooking with gas. Generally, IAQ is difficult to detect by sight and smell alone and requires long-term monitoring. The subjective willful behaviors of residents such as changing their lifestyles, adjusting the materials used for renovation, and replacing furniture will change the air quality, which also makes it difficult to measure and evaluate accurately. Therefore, considering the long monitoring period and uncertainty of IAQ, this indicator has not been highlighted in the subsequent case study.

2.2. Study Area. The Taojinjiayuan Residential Quarter, located in Guangzhou, China, is the focus area of this study. The residential quarter includes three sections; groups A and B/C are separated by Taojin Road East (Figure 2). The residential quarter covers a total area of 86,400 m^2, with a total construction area of 299,000 m^2 and a total of 638 housing units. The residential quarter also includes 12 residential buildings (23 units), one business building, and one kindergarten. The north side of the residential quarter is affected by noise from Hengfu Elevated Road and Guangzhou-Shenzhen Railway; the traffic flow along Taojin East Road on the north side of group A is relatively high, which also has a certain noise impact on the buildings on the street. The traffic flow on other roads is reduced, and the impact on the living environment of the residential quarter is relatively low.

2.3. Research Design, Indicator System, Quantitative Evaluation, and Model

2.3.1. Research Design. To examine the impact of ILE on housing prices, this study builds a research framework used to analyze the differences in the direction and intensity of the effects of various ILE conditions on housing prices. The specific analysis process is as follows. First, we used the Taojinjiayuan Residential Quarter as the work object to examine the features of the differences in the spatial distribution of housing prices among 57 housing units. Second, we constructed the model of the affecting factors of housing prices from ILE (including five variables), namely, the floor where the housing is located, the number of bedrooms, apartment layout, and decoration, to quantitatively evaluate the quality of ILE. Third, the study revealed the influence of ILE factors on housing prices in the Taojinjiayuan Residential Quarter. Finally, we conducted a reasonable analysis and interpretation of the research results. The research design is shown in Appendix A: Figure S1.

In previous studies, the floor level [52, 53], the number of bedrooms [54, 55], the apartment layout [56, 57], and the furnishing [58, 59] have been shown to affect housing prices. The number of floors in a house determines the house's natural light, ventilation, view, noise, and vertical travel convenience. The number of bedrooms reflects the compactness of the housing design and the number of people it can accommodate. The merits and demerits of an apartment layout reflect a housing's design level. For housing units of similar size, the overall pattern of the apartment, the functional partitioning and use of space, and the conformity to daily living habits are important considerations of the advantages and disadvantages of the apartment layout. The degree of interior furnishing determines the aesthetics and living experience of a housing unit, and it can generally be divided into luxury decoration, high-grade decoration (fine decoration), mid-range decoration, simple decoration, and unfurnished. Thus, we select these factors as the control variables.

2.3.2. Indicator System and Quantitative Evaluation of Indicators. This study constructs a system of indicators to explore how ILE affects housing prices, as per Table 1.

The details of the quantitative evaluation scores for the nine factors mentioned above are shown in Appendix B.

2.4. Data Sources. The study was conducted on 57 second-hand housing units (with elevators) listed for sale on the Centaline Property website (https://gz.centanet.com/) from March 29, 2021, to April 9, 2021, and from July 25, 2021, to July 29, 2021. For housing with price changes between the two periods, the period from July 25 to July 29, 2021, prevails. Centaline Property is a well-known real estate agency with a high market share and a large influence in Guangzhou. The data related to housing prices, characteristics, locations, etc. used in this study were obtained from Centaline Property and verified through field research. The base map of the Taojinjiayuan Residential Quarter was obtained from Baidu Maps. The characteristics of these houses vary greatly, and the price range is high. The highest unit price is 129,718 RMB/m^2, while the lowest is only 53,849 RMB/m^2, a difference of 2.41 times.

2.5. Model Specification. The hedonic price theory is an effective approach to studying the quantitative relationship between housing characteristics and prices. This theory is mainly based on the consumer theory of Lancaster [60] and the model of Rosen [11], which emphasize the calculation of implicit prices for heterogeneous product characteristics. Given the continuous refinement of the theory, the hedonic price model has been widely used in many fields related to product pricing, especially in the study of urban real estate prices [61]. When studying the effect of different characteristics of housing on prices, the same characteristic of housing architecture is usually included as an attribute. Therefore, we set the model of the effect of a single ILE factor on HP in Appendix C: (1). To avoid the existence of covariance among the variables affecting the final results, we calculated the variance inflation factor (VIF) of the nine variables before conducting the model, and there was no multicollinearity between the factors.

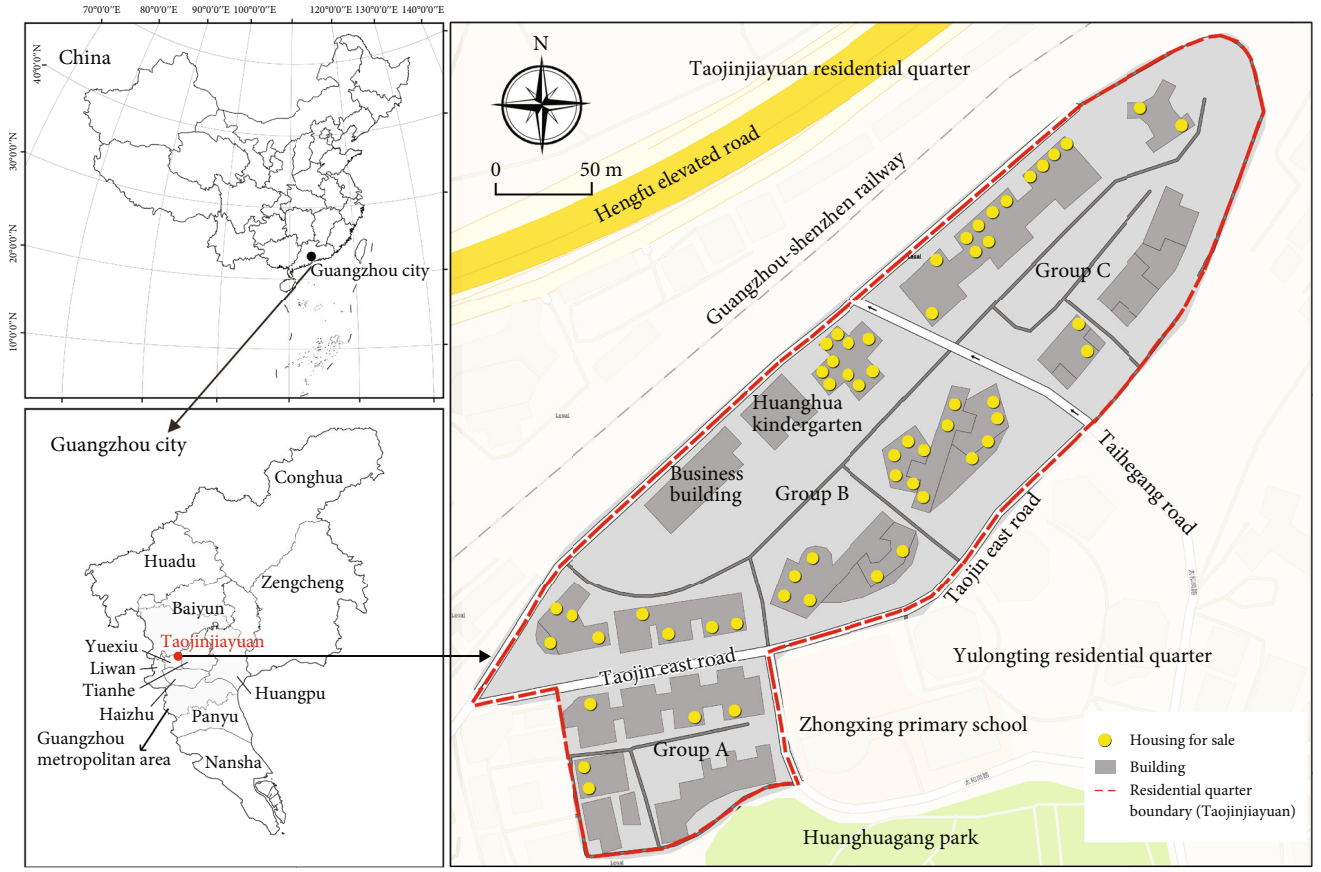

Figure 2: Study area.

Table 1: Definition of indicator systems.

Variables (symbol)	Influencing factors	Unit	Brief explanation of the indicator	Expected direction
Dependent variable	Housing prices (HP)	RMB/m^2	Housing unit sales price	
Explanatory variables	Orientation (OR)	Score	Points are assigned according to the orientation of the housing	+
	Natural light (NL)	Score	Comprehensive evaluation based on the lighting in the living room and bedrooms	+
	Ventilation (VE)	Score	Comprehensive assessment of ventilation based on the floor level, number of window openings, and extent of window openings	+
	View (VI)	Score	Comprehensive assessment based on screening by other buildings or trees, etc., and observed urban landscape effects	+
	Acoustic environment (AE)	Score	Comprehensive assessment of the noise impact of the main orientation of the housing on traffic facilities (e.g., railways, elevated roads, and streets)	+
Control variables	Floor (FL)	Score	Points are assigned according to the floor on which the house is located	+
	Number of bedrooms (NB)	PCS	Total number of bedrooms in the house	+
	Apartment layout (AL)	Score	Comprehensive assessment of the overall shape of the house, functional partitioning of space, and degree of conformity with daily living habits	+
	Furnishing (FU)	Score	Points are assigned according to a combination of newness, soft furnishings, and style of decoration	+

In fact, the impact of a single indoor environment characteristic on HP is limited. Residents tend to consider a combination of housing characteristics when purchasing a home, which inevitably calls into question the hedonic price model of a single ILE (i.e., a single model is not sufficient to clearly explain the issue of HP). To obtain the integrated effect of ILE on HP, we set the integrated ILE effect on the HP model in Appendix C (2).

3. Results

3.1. Evaluation Results of ILE in the Taojinjiayuan Residential Quarter in Guangzhou. According to the rules of quantitative evaluation, the scores of OR, NL, VE, VI, and AE of the 57 houses for sale in the Taojinjiayuan Residential Quarter are shown in Appendix A: Figure S2. OR and AE kernel density estimation curves are relatively uniform and stable. Among them, the OR scores are hourglass-shaped, and the houses for sale are mostly distributed in the range of 2 ± 1 and 8 ± 1; the number of houses for sale in each score segment of AE is balanced. The NL, VE, and VI scores are unbalanced, and the houses for sale are more concentrated in the range of 5 ± 1 and above. The starting point for the NL and VE factors is 3, and the starting point for VI is 2. In addition, there are no outliers or few outliers in the scores of the five ILE factors, which also indicates that our quantitative evaluation results are reasonable.

3.2. Spatial Variation Pattern of the Housing Prices in the Taojinjiayuan Residential Quarter in Guangzhou. We categorized the 57 housing units for sale into five classes according to their price characteristics (Figure 3). The results show that there is a significant unevenness in the spatial distribution of the prices of these 57 units. Among the three groups, A, B, and C, the extreme difference in housing prices in group C is large and far exceeds those in groups A and B. The prices of housing for sale near business buildings and kindergartens are generally high, while the housing price on the north side of the Guangzhou-Shenzhen railroad is obviously lower. Overall, the spatial distribution of housing prices in the Taojinjiayuan Residential Quarter is clearly different.

3.3. Relationship between ILE and Housing Prices in the Taojinjiayuan Residential Quarter in Guangzhou

3.3.1. Linear Relationship between ILE and Housing Prices. Without considering the effects of control variables, we first analyzed the relationships between individual ILE factors and housing prices. Specifically, we tested the linear relationship between five factors: OR, NL, VE, VI, and AE, and housing prices, respectively (Appendix A: Figure S3). The results showed a linear relationship between OR and AE and housing price at P less than 0.05, but the correlation coefficient between both factors and housing price was less than 0.50, and the correlation was small. Meanwhile, NL, VE, and VI had no correlation to housing prices. These results also indicate a complicated relationship between individual ILE elements and housing prices.

3.3.2. Impact of ILE on Housing Prices. Before analyzing the impact of ILE on housing prices, we first performed a covariance test on the nine influencing factor indicators. The test results showed that the nine indicators' VIF values were all well below 10, and they could all be incorporated into the model.

The single and integrated ILE factors on housing prices are as follows (Table 2). Models 1–5 show the effects of five factors (OR, NL, VE, VI, and AE, respectively) on housing prices, while models 6 and 7 show the effects of five ILE factors, the indoor living environment composite index (ILECI), on housing prices, respectively. When considering the relationship between OR, NL, VE, VI, and AE and housing prices individually, we found that the R^2 and adjusted R^2 of models 1–5 were generally low, and the explanatory power is weak. In models 1 and 5, orientation and acoustic environment, respectively, have significant positive effects on housing prices, which verifies our assumption that orientation and acoustic environment affect housing price changes. In models 2–4, lighting, ventilation, and view are all insignificantly related to housing prices. When considering the relationship between ILE and housing price, the R^2 of model 6 is 0.52, and the adjusted R^2 is 0.43, which has much higher explanatory power than the other models. The strength of the effect of the ILECI on housing prices is much higher in model 7 than in the other models, which also illustrates that the combined influence of integrated ILE on housing values far exceeds individual factors.

We further analyzed the relationship between integrated ILE and housing price differences based on the significance of the regression coefficient in models 6 and 7. The results showed that three ILE indicators (orientation, view, and acoustic environment) and ILECI have significant positive effects on housing prices in the Taojinjiayuan Residential Quarter ($P < 0.05$), and ILECI has the greatest intensity of the effect. In the selection of a house purchase, residents should not only comprehensively consider the impact of core indoor environmental factors, such as orientation, view, and acoustic environment, on the price of housing but should also focus on the comprehensive condition of the ILE of residential buildings. The elasticity of the impact of the ILE on housing prices was as follows:

Building orientation had a positive driving effect on housing prices. For each one-point improvement in orientation score, the prices subsequently increased by 1,692 RMB/m^2. In other words, the better the orientation of a house (e.g., north-south permeability), the higher the price [62]. In Chinese traditional architectural design culture, buildings are usually designed with feng shui principles in mind, and the superiority of a south-facing landscape largely stems from feng shui [63]. Of course, in addition to the belief in feng shui factors, one important benefit is the availability of sufficient sunlight [35]. Guangzhou is located in the northern hemisphere, and sunlight comes mainly from the south. Housing units facing south have easier access to sunlight, which ensures that the interior is warm in winter and cool in summer. It also makes the balcony convenient for drying clothes, improving household efficiency, and bringing health and convenience to the residents. Therefore, orientation has a substantial influence on property prices,

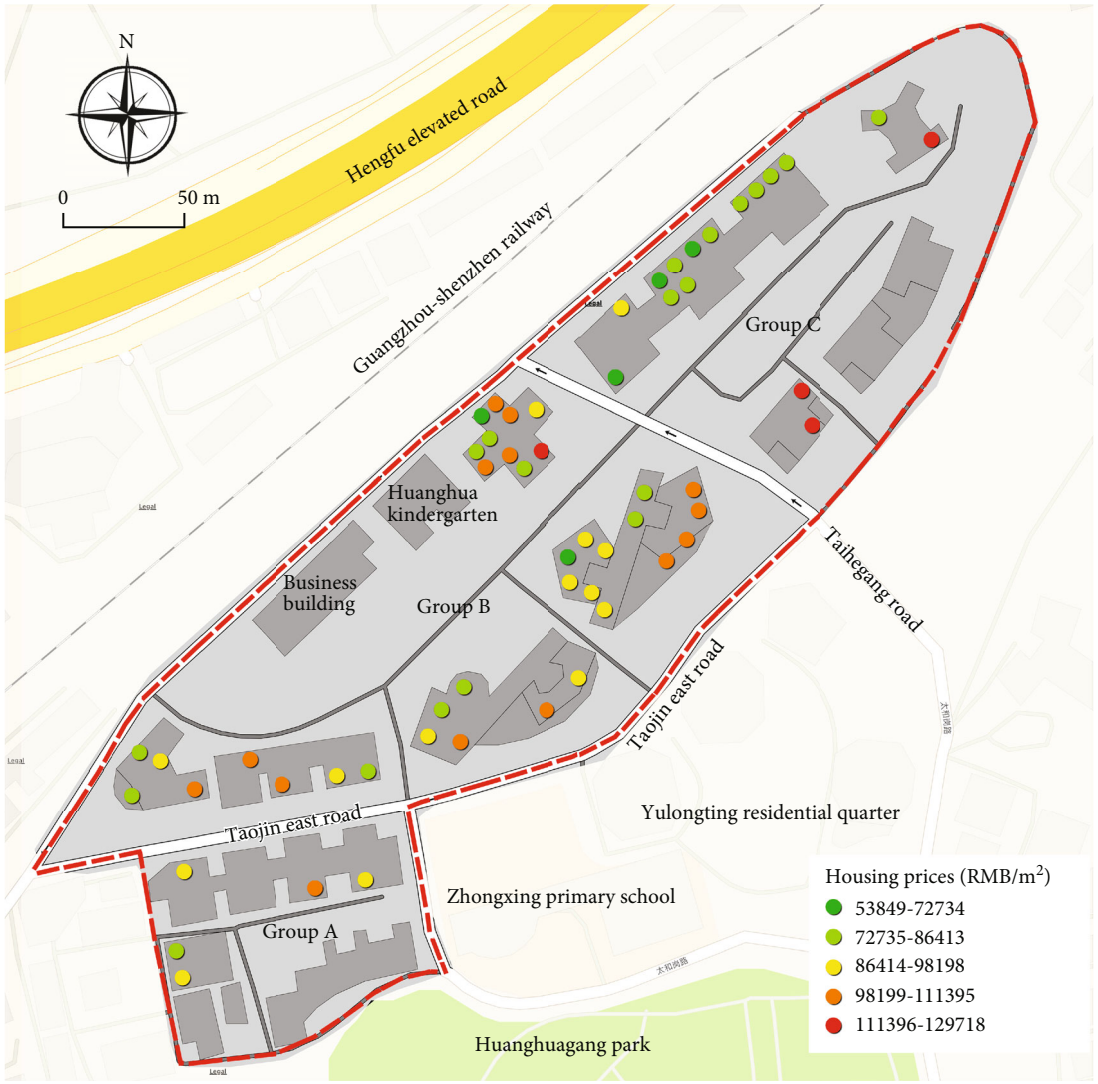

Figure 3: Housing prices spatial divergence pattern of 57 housing units for sale in the Taojinjiayuan Residential Quarter.

and south-facing homes have become the first choice of prospective buyers.

For each one-point improvement in view score, the prices increase by 3,935 RMB/m^2. View is a crucial feature affecting a home's market value and has a positive correlation with property prices [64]. Based on people's love for aesthetic landscapes, human visual factors are usually considered in housing design. Generally, housing with an open view also has better ventilation and lighting conditions, is located on a relatively high floor, and has visual access to a richer landscape. Houses that satisfy people's visual appreciation for aesthetic views are more expensive than similar homes without such vistas [46]. The market value of housing units increases as the view improves. This confirms the importance of view in housing choice as a correlative function of housing value.

For each one-point improvement in the acoustic environment score, the prices increase by 1,741 RMB/m^2. This value reflects how significantly the acoustic environment affects housing prices. Among environmental factors, the acoustic environment is a determinant of human health and urban quality [8]. If it is not possible to ensure that the acoustic environment is suitable for living, housing prices will be lower. The houses for sale in the Taojinjiayuan Residential Quarter are near the Guangzhou-Shenzhen railroad, where traffic noise is relatively high. The traffic facilities bring convenience to the residents but inevitably generate noise, which reduces housing values because people are more inclined to choose a peaceful living environment. Therefore, the significant correspondence between the acoustic environment and housing prices is obvious.

The ILECI is a centralized reflection of the indoor environmental quality of housing. For each one-point increase in the indoor living environment index score, the price increased by 5,793 RMB/m^2. The interaction of ILE factors, such as orientation, natural light, ventilation, view, and acoustic environment, comprehensively affects the multisensory comfort of the human body, such as acoustic perception, heat perception, light perception, and air quality perception, thereby causing the human body to produce a comprehensive response physiologically and psychologically. Compared with a single

Table 2: Hedonic price mode results.

Variables	Model 1 OR—HP	Model 2 NL—HP	Model 3 VE—HP	Model 4 VI—HP	Model 5 AE—HP	Model 6 ILE—HP	Model 7 ILECI—HP
OR	2778.10^{C**} $(5.36)^{T}$					1692.12* (2.13)	
NL		-694.46 (-0.47)				-2542.56 (-1.93)	
VE			2134.71 (1.44)			-756.44 (-0.54)	
VI				2534.96 (1.53)		3934.55** (2.91)	
AE					2839.47** (5.32)	1741.09* (2.10)	
ILECI							5793.31** (5.01)
FL	748.37 (1.20)	-58.99 (-0.08)	-225.15 (-0.31)	-1599.06 (-1.35)	419.40 (0.69)	-1011.34 (-1.12)	-419.78 (-0.68)
NB	1448.13 (0.81)	2201.45 (0.96)	-712.14 (-0.25)	2057.73 (0.94)	446.61 (0.25)	2779.91 (1.24)	-692.37 (-0.36)
AL	996.00 (0.87)	1256.88 (0.86)	327.85 (0.22)	1562.02 (1.09)	647.79 (0.56)	2295.82 (1.94)	407.18 (0.35)
FU	626.71 (0.61)	301.26 (0.23)	98.48 (0.08)	-15.83 (-0.01)	224.95 (0.22)	321.60 (0.34)	102.85 (0.10)
Constant	59329.83** (4.92)	79733.46** (5.25)	75721.11** (5.32)	66197.89** (4.15)	69339.01** (5.92)	52510.87** (4.17)	56764.21** (4.53)
R^2	0.38	0.03	0.06	0.07	0.37	0.52	0.35
Adjusted R^2	0.32	-0.07	-0.03	-0.02	0.31	0.43	0.28

Note: * and ** represent the 0.05 and 0.01 significance levels, respectively. C denotes the correlation coefficient between the independent and dependent variables; T denotes the t statistical value.

indoor environmental factor, the integrated ILE of residential buildings can reflect whether it can satisfy the requirements of homebuyers in terms of physical health, comfort, and productivity. Evidently, residents usually do not consider only one aspect of the indoor environment in their housing preference but rather the impact of long-term living on work, study, and life. A high ILECI also indicates that the overall living environment is good, effectively satisfying the residents' pursuit of a happy life and thus driving up housing prices.

4. Discussion

ILE is an important consideration in the public's housing choices. To explore how it affects housing prices, we constructed a framework of ILE factors that influence housing price differences and proposed a method for the quantitative evaluation of ILE in residential buildings. Based on existing studies, we compared and analyzed the differences between single ILE factors and combined factors on housing prices and attempted to solve the problem raised in the introduction.

4.1. Conceptual Framework of ILE. This study presents a conceptual framework for the influence of ILE on housing price differences. Compared with previous research frameworks on the influencing factors of housing price, our framework integrates multiple ILE factors that most intuitively affect human visual, auditory, olfactory, gustatory, and tactile senses on the basis of previous research (single ILE factor), which is more suitable for explaining and analyzing price differences among different housing units within the same residential quarter. Wright et al. [65] empirically studied the impact of indoor temperature changes on the social and behavior of family members in 46 residences in Arizona (a U.S. state) and found that indoor heat exposure is the strongest driving factor for residents to use air conditioners to adjust the temperature distribution. It is also an important aspect that influences the choice of housing for residents. Frontczak et al. [66] proposed that the development of ILE control systems can begin with improving thermal and visual comfort and air quality satisfaction. Our conceptual framework for ILE was constructed on the basis of summarizing previous studies, considering the residents' purchasing culture, i.e., the Chinese custom of selecting the appropriate home according to traditional cultural rules. For example, in terms of orientation, buyers consider the traditional culture, such as directions indicating good and bad luck and north-south permeable housing; in terms of apartment layout, they tend to prefer "square and regular" without missing corners or sharp corners, as well as houses that attract fortune and good luck; in terms of view, people prefer to see beautiful things or landscapes, which is considered good "feng shui." These traditional cultures of livability influence residents' housing preferences and are fully reflected in the selection of indicators within the conceptual framework of ILE. The advantage lies in its ability to comprehensively and systematically reflect the residents' house purchase considerations. Of course, the construction of the conceptual framework of ILE can provide theoretical guidance for subsequent related research.

4.2. Quantitative Evaluation of ILE. ILE is the primary consideration in housing choice. Brunsgaard et al. [67] mentioned that the comfort of ILE is considered to be the highlight of future housing purchases. The choice of housing by residents can be seen, to some extent, as a choice of the quality of ILE. In China, where most people live, study, and work indoors every day, indoor habitats reflect not only human activities but also their reciprocal relationships with residents [68], and achieving and maintaining an ideal ILE is an important item in the construction and housing process [69].

At present, in view of the difficulties related to data collection and processing, the integrated ILE research framework is not yet mature, and there is no uniform standard for the quantitative evaluation of ILE. Through field research, we quantitatively evaluated the orientation, natural light, ventilation, view, and acoustic environment conditions of 57 housing units for sale in the Taojinjiayuan Residential Quarter in Guangzhou by scoring and attempted to develop a set of scoring criteria suitable for the quantitative evaluation of ILE conditions, which opens up a new way of thinking for subsequent quantitative evaluation studies of microlevel ILE and has strong reference significance.

4.3. Single-Factor Correlation Evaluation. In performing the evaluation of linear relationships, we found a low correlation between OR and AE and housing prices and no direct relationship between NL, VE, and VI and housing prices. This finding indicates that, although there is some association between a single ILE element and housing prices, the closeness of the association is low. A single ILE element does not adequately reflect housing price changes. Consistent with this, single elements such as orientation and acoustic environment had significant positive effects on housing prices, respectively, while natural light, ventilation, and view were not significantly related to housing prices. This reaffirms our view that the influence of a single ILE component on prices is minimal and that occupants are more likely to look at the impact of integrated ILE factors in their housing choices. This is because people's perception of the environment is multifaceted and comprehensive. It is impossible to determine the perception of the living environment by a single environment. Only the combined effect of multiple ILE elements will affect people's perception and judgment of the environment and, thus, the price of housing. This idea is currently not present in other studies.

4.4. Integrated ILE Impact. According to the results in Section 3.3, integrated ILE has a comparatively stronger effect on property prices than individual factors. In addition to macrolevel factors, residents also consider the ILE conditions within a home to ensure that they are buying a comfortable, healthy, and cost-effective home. As such, ILE becomes a crucial aspect to take into account when choosing between the different housing units within a residential quarter. In our study, integrated ILE conditions such as orientation, view, and acoustic environment were found to be closely related to property prices, while the association between natural light and ventilation and property prices

was not significant. The reason for these findings, which were rarely discussed in past research, maybe that the Taojinjiayuan Residential Quarter covers an area of 86,400 m^2, with a noncompact layout of 12 residential buildings and relatively large spacing between buildings, which ensures good natural lighting conditions for housing without building obstructions. This layout also ensures that the interior of the building achieves daytime ventilation and nighttime cooling, which provides the owners with sufficient fresh air and improves the thermal comfort inside the building [70]. These results are consistent with Edwards and Li's [40, 71] findings that a lack of natural light or an obstructed view may make housing units slightly less valuable. In the absence of building obstructions, the effect of ventilation on housing prices is insignificant. Although the 57 housing units differ in terms of layout type, they have roughly the same number and size of windows.

In real life, residents' dissatisfaction and complaints about housing are related to uncomfortable environmental conditions inside the housing, such as poor thermal climate (too hot, too cold, and no ventilation), inadequate lighting conditions (glare, reflection, and low contrast) [69], and an excessively noisy living environment. These are also mainly due to ILE quality issues, such as poor housing orientation, natural light, ventilation, view, and acoustic environment. Therefore, in terms of housing choice, residents usually consider whether the quality of ILE can meet their lifestyle and behavioral needs, and housing units that provide a healthy, safe, and quiet living environment are clearly more competitive in the market. This is consistent with the investigation of Patino et al. [72]. Of course, our study is not only applicable to China but also to cities in the global South with similar ILE characteristics. In the future, real estate developers, building designers, and residential users should focus on the comprehensive impact of ILE factors such as orientation, natural light, ventilation, view, and acoustic environment on housing prices when designing, building, evaluating, and purchasing housing.

4.5. Limitations and Future Prospects. This study focuses on the impact of ILE quality on housing prices for different housing units within the same residential quarter on a microscale. Only 57 housing units were listed for sale in the Taojinjiayuan Residential Quarter during the survey time period. Therefore, the study can only use the data from 57 housing units for analysis, which represents the main limitation of this study. In addition, we will further track the survey and expand the sample to make up for this deficiency. Second, the quantitative evaluation of the ILE of housing is difficult. Our study only considers the influence of ILE factors (orientation, natural light, ventilation, view, and acoustic environment) that remarkably affect human senses and require long-term monitoring. The contribution of indoor living factors affected by the behavior of the residents is also considered. This condition plays an important role in residents' housing selection but is difficult to evaluate in light of the data from the current survey. In the future, the following two areas should be addressed: (1) we should start with long-term door-to-door air monitoring using air quality testing equipment ($PM_{2.5}$ meters and formaldehyde meters); (2) we should conduct a more comprehensive and refined indoor environmental assessment centered on the contribution of indoor living factors. Third, the age, gender, and education of individuals are different, resulting in different housing choice preferences and varying needs. Thus, the characteristics of the housing choice preferences of different types of people could be further analyzed by means of questionnaires or interviews in future studies. This could help explore the elements that affect property prices and the internal mechanisms of action among the factors from multiple perspectives.

5. Conclusions

This study explores the influence of ILE on housing prices from a microscopic perspective by constructing a conceptual framework for ILE covering orientation, natural light, ventilation, view, and acoustic environment. It examines 57 housing units in the Taojinjiayuan Residential Quarter in Guangzhou, China, as examples. The following main conclusions are drawn. First, housing prices are highly correlated with ILE, and the influence of integrated ILE on housing prices is far more than that of a single factor. Second, different ILE factors have different intensities of influence on housing prices. Orientation, view, and acoustic environment are the core factors affecting housing prices and are also the primary indoor factors that residents consider when purchasing a home. Our study not only helps quantitatively understand the value of ILE but also identifies which elements of the subsystem of ILE are more important in influencing housing prices. It also provides a reference for real estate developers, building designers, and residential users in designing, building, evaluating, and purchasing housing.

Abbreviations

ILE: Indoor living environment
ILECI: Indoor living environment composite index
OR: Orientation
NL: Natural light
VE: Ventilation
VI: View
AE: Acoustic environment
FL: Floor
NB: Number of bedrooms
AL: Apartment layout
FU: Furnishing
HP: Housing prices
IAQ: Indoor air quality
$PM_{2.5}$: Fine particulate matter.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Authors' Contributions

Yang Wang provided substantial contributions to the theoretical analysis, writing—original draft, data curation, investigation, and funding acquisition. Min Wang was assigned to the writing—review and editing, conceptualization, and visualization. Yingmei Wu was responsible for the formal analysis and resources. Xiaoli Yue worked on the methodology and software. Xueying Li contributed to the data curation and investigation. Hong'ou Zhang was in charge of supervision and validation.

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Supplementary Materials

The data that support the findings of this study are available in the supplementary material of this article. *(Supplementary Materials)*

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