國土計劃
pISSN: 1226-7147, eISSN: 2383-9171
https://doi.org/10.17208/jkpa.2024.02.59.1.121

Journal of Korea Planning Association Vol.59, No.1 (2024)
대한국토·도시계획학회지 「국토계획」 제59권 제1호 pp.121-142

The Effects of Subjective Residential Environment Based on Civil Complaints Data and Objective Residential Environment Factors on Housing Price

: Using LDA Topic Modeling*

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Abstract

This study analyzes the impact of subjective residential environment factors based on civil complaints data and objective residential environment factors on housing prices. To this end, LDA topic modeling was utilized to factorize this environment, and multiple regression analysis was also conducted. Based on the results, this study derives the following conclusions. First, categorization of the civil complaints revealed occurrences of such complaints had an impact on house sale and rent prices. In particular, not only traffic-related civil complaints but also traffic safety characteristics in the objective residential environment exerted significant effects. This indicates that the civil complaints reflect the residents' perception of the residential environment and housing price, which functions as a subjective residential environment indicator. Second, based on a complex perspective that considers both objective and subjective aspects, the effect of residential environment on housing sale and rent prices was identified at the microscopic level of the 100m grid. Lastly, in addition to the subjective residential environment such as physical inconvenience, civil complaints affected housing prices owing to a combination of prospects for future urban planning policy and other factors. The results suggest that when a policy is established, the impact on the housing market can be proactively predicted and problems responded to by analyzing the residential environment derived from civil complaints.

Keywords Subjective Residential Environment, Objective Residential Environment, Civil Complaints, Housing Price, LDA Topic Modeling

주제어 주관적 주거환경, 객관적 주거환경, 민원, 주택가격, LDA 토픽모델링

Ⅰ. Introduction

1. Research Background and Purpose

Since the 1960s, rapid urbanization exacerbated the problem of aging and inadequate housing both within and outside cities. Consequently, urban redevelopment projects were initiated in wornout areas (Yi et al., 2009). By the late 1990s, there was a significant increase in quantitative housing supply, including the construction of new towns. Even in

* This paper is part of a research project supported by a 2023 joint grant from the Ministry of Education and National Research Foundation of Korea (NRF-2023S1A5A2A0308586611), and a grant from the Korea Agency for Infrastructure Technology Advancement (RS-2022-00143404).

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recent times, policies have predominantly focused on quantitative housing supply, evident in the construction of the second and third generation new towns and the redevelopment of first generation new towns (Ministry of Land, Infrastructure and Transport, 2022). However, discussions about the qualitative improvement of housing have been lacking. Issues regarding qualitative residential welfare, specifically the residential environment, have emerged as crucial social concerns (Shin and Nam, 2012). In the field of housing policy, there is a growing need for policies addressing how housing supply can meet housing demands based on changing residential environments (Lee et al., 2022). The transformation of the residential environment manifests in the value of housing, reflected through housing prices (Kim and Hong, 2013). Understanding the relationship between residential environments and housing prices is crucial for enhancing qualitative residential welfare.

Factors determining housing prices can vary depending on the values of urban residents in the housing market (Choi and Song, 2006). Recently, due to improvements in living standards, urban residents worldwide have shown a trend of preferring not only individual aspects of housing but also various elements of the residential environment (Hartig et al., 2016). This trend indicates that consumers in the housing market are willing to pay extra for favorable residential environment factors when choosing a residential location (Benson et al., 1998). Consequently, research on the impact of the residential environment on housing prices in the housing market has been conducted from various perspectives (Lee and Youn, 2013; Chun et al., 2021). The majority of these studies have utilized the hedonic price model (HPM) to identify factors affecting housing prices (Miranda et al., 2021; Oh and Seo, 2023). These studies have used macro-scale objective (physical) residential environment characteristics, such as education levels and land use, as variables to determine factors influencing housing prices.

However, the determinants for homebuyers' decisions cannot be fully explained solely by objectively measured factors and often are influenced significantly by subjective elements such as unique social experiences and residents' perceptions (Kang et al., 2021). The consideration of subjective residential environment factors has led to research that relies on surveys or interviews for data collection (Buonanno et al., 2013; Yang et al., 2023; Yoon and Park, 2003). One drawback of surveys is the subjectivity arising from individual perspectives and items, making data processing less efficient in terms of time and cost (Zhang et al., 2018).

Generally, studies on residential environment in the housing market have predominantly been conducted from the perspective of housing suppliers. However, as the interest in qualitative aspects has increased, researchers have expanded their analysis to include the perspective of housing demand (Oh and An, 2011). Understanding the opinions of residents, who are the actual consumers of housing, is considered a crucial factor in measuring subjective residential environment and its subsequent impact on housing prices (Zhang et al., 2018; Jang and Go, 2021). Some studies have utilized civil complaints as a proxy for subjective residential environment. Civil complaints contain detailed location information, making them conducive for analysis, and they enable a comprehensive evaluation of urban issues and neighborhood environments through reports of physical discomfort like illegal parking or violations in disabled parking spaces (Kim and Kang, 2019). Moreover, dissatisfaction with residential environments is closely associated with civil complaints and is reflected in residential satisfaction (Kim, S.J. et al., 2020). Lower residential satisfaction can act as a factor for residents to consider moving from their current residences (Barreira et al., 2019), and such satisfaction levels, depending on their degree, have influenced housing prices positively or negatively (Ahmadi et al., 2022). Hence, areas where civil complaints representing subjective residential environments are frequent may signify lower residential satisfaction, potentially exerting a negative influence on housing prices. While existing research related to housing prices has identified the significant role of objective residential environment factors, few studies have considered both subjective and objective residential environment factors in determining housing prices.

Against this backdrop, the aim of this study is to empirically analyze the factors influencing housing prices based on subjective residential environment factors, utilizing civil complaints, and objective residential environment factors[1] indicating physical living conditions. Specifically, it seeks to categorize civil complaints as a representative proxy for subjective residential environment factors and determine which types of civil complaints are closely related to the

housing market. The findings of this research are expected to serve as valuable data for future policymaking in the housing sector.

2. Scope of Research

The scope of the study is as follows: Temporally, it spans the year 2020, and spatially, it covers Incheon's Yeonsu District. These temporal and spatial boundaries were set based on the availability of key indicators such as civil complaints data, allowing for the acquisition of residential environmental factors. This period coincides with the period of stabilized housing transaction price index (Korea Real Estate Board, 2020)[2], and includes all housing transactions and civil complaints that occurred in Yeonsu District in 2020. In addition, Incheon Metropolitan City ranks third in civil complaints, following Gyeonggi Province and Seoul (Anti-Corruption and Civil Rights Commission, 2023), and within the Seoul metropolitan area, it has the highest civil complaints per capita.[3]

Furthermore, Incheon's Yeonsu District has undergone rapid changes in residential environments due to continuous housing supply and development in Songdo International City. It is an area where the average housing price has continuously fluctuated. According to Statistics Korea, the average year of construction completion for apartments in Yeonsu District is 17.4, suggesting no apparent issues. However, in reality, the proportion of aged buildings in the original city center exceeds 78%, indicating a difference in the physical residential environment between the vulnerable original city center and the newly developed Songdo International City, which belongs to the new city center. Therefore, it was deemed a suitable region for identifying determinants of housing prices based on differences in residential environments, even within a single area, from a microscopic scale of the 100 m grid.[4]

II. Theory and Literature Review

1. Objective Residential Environment and Housing Price

In cities, the residential environment encompasses the entirety of the living environment surrounding residences and activity areas. In a narrow sense, it refers to the physical environment around housing, while in a broader sense, it includes social, economic, and cultural aspects (Kang et al., 2003). The meaning of residential environment has been discussed extensively, ranging from the urban environment at the regional level to the indoor and outdoor environments of houses. The term has various definitions depending on economic/social environments and physical/non-physical aspects (Park, J.O. et al., 2009). While the definition of residential environment depends on the scope of analysis and data, a more comprehensive approach is needed. The value of the residential environment and satisfaction among residents influence consumers' willingness to pay and choice in the housing market, thereby impacting housing prices in that area.

Research on the influence of the residential environment on housing prices has primarily relies on the Hedonic Price Model (HPM), utilizing objective residential environment factors representing the physical residential environment of houses and surroundings. The HPM is a model inferring the determinants of housing prices for three main groups of explanatory variables, describing the structure, location, and neighborhood characteristics of houses using Ordinary Least Squares (OLS) (Rosen, 1974). Park and Rhim (2010) analyzed the factors affecting housing prices using HPM, assuming differences in perception between buyers and sellers regarding the value of homes. They distinguished explanatory variables into household characteristics, estate characteristics, location characteristics, school characteristics, and environmental characteristics, utilizing actual transaction prices of high-end and low-end apartments in Seoul and Busan from 2006 to 2009. The results revealed different factors influencing housing prices for different regions and high-/low-end apartments, attributed to the differing valuation standards for apartments in different areas.

Furthermore, studies have been conducted using HPM to elucidate the impact of residential environment factors on housing prices (Lee and Choi, 2016). However, HPM assumes spatial homogeneity of housing prices and price invariance, making it difficult to fully reflect the structural characteristics of housing prices (Chun, 2016). Additionally, in South Korea, where apartments with a fixed structure and group housing styles are prevalent, there is a possibility

of spatial autocorrelation (Kim and Jung, 2010). To address this, non-parametric methods like Geographically Weighted Regression have been utilized. However, these methods have limitations such as challenging hypothesis testing, the need for increased samples with additional explanatory variables, and minimal improvements in analysis results (Seo, 2019). As such, HPM, which also offers ease of interpretation, is commonly utilized.

In relation, research has been conducted to ascertain the factors affecting housing prices using spatial models for the purpose of model comparison. Chun et al. (2021) analyzed the impact of the residential environment on housing prices by comparing HPM with various spatial models across 25 autonomous districts in Seoul. Independent variables were set to reflect physical residential environments as well as social and economic residential environments. The analysis of spatial autocorrelation revealed a positive spatial autocorrelation of 0.460 in the house sale price index, with the GWR model identified as the most superior based on the AIC evaluation criterion. However, the difference in AIC values was less than 2, and the Spatial Autoregressive Model (SAR) showed lower values compared to OLS.

While studies considering spatial autocorrelation have been carried out, most have been predominantly performed at a macroscopic analysis unit, such as administrative districts, or have expanded the measurement range for spatial autocorrelation analysis. However, other than macroscopic regional factors, factors at the level of neighborhood environments surrounding residences also play a role in determining housing price (Kim and Kim, 2019). Moreover, while past studies focused on regional elements due to technological and data limitations, recent advancements in big data technology, analytical models, and technological and social changes have increased interest in micro-level neighborhood living environments.

As a result, studies involving observations at the neighborhood unit have been conducted (Kim, J.N. et al., 2020; Gong and Kim, 2022). Gong and Kim (2022) confirmed the influence of walkable neighborhood environments on housing prices in Daegu Metropolitan City. The study analyzed housing types separately, dividing them into apartments and multi-family housing. The research indicated that subway accessibility was an important factor for both housing types, and variables representing the safety of pedestrian environments such as streetlight density and crosswalk density positively influenced housing prices, indicating that housing prices reflected the value of pedestrian environments. Kim, J.N. et al. (2020) investigated the polarization of housing prices and the consistency between neighborhood residential environments in Seoul. According to the analysis, evaluations of the residential environment confirm a long-term demand for residential environment improvements, suggesting that improved conditions may allow accurate estimations of housing prices and emphasizing the need to consider qualitative indicators alongside quantitative ones.

2. Subjective Residential Environment and Housing Price

Reviewing the relationship between residential environment and housing prices in related studies confirmed the significance of the residential environment as a critical factor influencing housing prices. Additionally, it was found that various external factors, not only internal or individual factors of housing, exert a complex influence. Thus, previous studies hold significance in estimating housing prices through objective residential environment indicators. However, they overlooked the fact that housing price determination is significantly influenced by subjective factors such as social experiences and residents' perceptions (Kang et al., 2021). It is essential to consider not only objective factors but also diverse subjective factors, such as expectations for redevelopment during that period, installation of undesirable facilities, and social and neighborhood environments to fully comprehend the determinants of housing prices.

Subjective residential environments have primarily been studied through surveys and analyzed across various sectors. In domestic research, Yoon and Park (2003) conducted a survey based on the Likert scale regarding preferences for 29 subjective residential environment factors in the Bundang and Ilsan areas. Using these results, they constructed independent variables and established a housing price determination model. The outcomes revealed that preference factors for street layout, communal spaces, property value, outdoor environment, and neighborly relationships significantly influenced housing prices. The housing price deter-

mination model that incorporated subjective residential environments exhibited superior explanatory power compared to the existing models.

However, surveys measuring subjective perceptions of residential environments have faced criticism for being subjective based on individual evaluators and items, causing inefficiency in terms of time and cost for data processing, and posing difficulties in interpreting results (Zhang et al., 2018). Consequently, in urban planning, there is an increasing use of data to objectively reflect subjective residential environment factors (Jang and Go, 2021). Both domestically and internationally, research utilizing various data to measure subjective residential environments has been conducted.

In South Korea, studies utilizing civil complaints data (Kim and Kang, 2019; Kim, S.J. et al., 2020; Park and Lee, 2022) and research utilizing housing reviews on the real estate platform Zigbang (Kim and Lee, 2020; Jang and Go, 2021) have been carried out. Internationally, studies using Google Street View's street landscape data and computer vision methodologies to assess the perception of street environments have been conducted (Zhang et al., 2018; Verma et al., 2020).

These previous studies mainly investigated the correlation between subjective residential environment factors and residential satisfaction. However, they were focused on the macro level of administrative districts, and failed to analyze the micro-scale neighborhood environments perceived by residents. Other limitations include the exclusion of non-apartment housing types and the utilization of only male household heads as samples.

Moreover, residential satisfaction goes beyond mere evaluation, acting as a factor that can cause residents to move from their existing residences (Barreira et al., 2019). If the factors determining satisfaction provide substantial value, they can influence housing prices significantly (Ahmadi et al., 2022). In South Korea, despite a tendency to equate residential satisfaction and the determinants of housing prices (Choi and Min, 2008), subjective residential environment factors were only considered as influencing residential satisfaction.

Studies considering subjective residential environments as factors influencing housing prices have been conducted abroad (Buonanno et al., 2013; Qiu et al., 2022). Buonanno et al. (2013) analyzed the influence of housing environment factors, focusing on residential security, on housing prices in Barcelona. They conducted surveys after controlling for local characteristics such as local public spending and immigration. Based on this, they divided residents' perceptions of security and crime into urban and non-urban areas, and constructed variables. The analysis showed that perceptions of crime induced additional increases in housing prices, and regions perceived as less secure exhibited lower housing prices.

Meanwhile, Qiu et al. (2022) surveyed Shanghai, China, and used computer vision and machine learning alongside surveys to analyze the impact of residential environments on housing prices, and compared their performance. They found that subjective residential environments had a greater impact on explaining housing prices than objective residential environments, such as the individual characteristics of housing and demographic/sociological features. However, they highlighted that the correlations between subjective residential environment factors were relatively high, emphasizing the need for complementary relationships between objective and subjective residential environment factors, rather than solely relying on subjective factors for analysis.

3. Distinctiveness of Research

Through the review of theory and prior research, it has been confirmed that residential environment is a major factor in determining housing prices. As interest in the qualitative aspects of housing increases, research has expanded beyond the internal and individual factors of housing to include external factors. Moreover, moving beyond macro-level analysis based on administrative districts, data focusing on micro-level neighborhood environments has become available, enabling more detailed consideration of citizens' living environments. While residential environment-related research has traditionally been approached from the perspective of housing suppliers, recent considerations of housing as a residence rather than an investment highlight the importance of a demand-oriented perspective, specifically focusing on actual homeowners. In most studies, despite the emphasis on qualitative indicators like subjective residential environments, their utilization has been limited due to data acquisition constraints.

Therefore, this study's distinctiveness is framed as follows: First, the characteristics of subjective residential environments have been shown to significantly influence housing prices, reflecting residents' actual perceptions and attitudes in local areas. Yet, despite this understanding, prior studies exploring determinants of housing prices have relied solely on objectively constructed indicators using GIS or field data collection, overlooking subjective residential environment characteristics. This research aims to examine the impact on housing prices by considering both objective and subjective residential environments, thus standing out in its comprehensive approach.

Second, prior studies considering subjective residential environments mainly reflected residents' perceptions based on evaluation scores derived from surveys and interviews. However, surveys are subjective and can yield varied results depending on individual characteristics of evaluators and items. They are also limited in processing large volumes of data due to time and cost constraints, and pose challenges in result interpretation. In contrast, this study uses civil complaints data reflecting actual residents' opinions rather than researchers' subjective survey-based questions. This dataset encapsulates not only physical inconveniences but also the issues pertinent to that period, allowing for comprehensive considerations. In particular, the use of around 30,000 samples of civil complaints data supports more refined interpretations compared to survey data.

Third, past research often focused on administrative districts or output areas within the whole city of Seoul. However, this only considered a macro approach from the perspective of regional living areas, not explore micro-level neighborhood aspects. Additionally, civil complaints primarily occur near residential areas and exhibit spatial clustering rather than evenly distributed patterns across administrative districts, necessitating a micro-level approach. This study distinguishes itself by investigating the impact of micro-level residential environmental factors on housing prices by subdividing the spatial scope into neighborhood units, employing a grid-based approach based on neighborhood living environments.

Ⅲ. Analysis Methodology

1. Overview of Analysis

To achieve the research objectives, this study aims to analyze the impact of subjective residential environment characteristics based on civil complaints data and objective residential environment characteristics on housing prices in Incheon's Yeonsu District in 2020. Housing prices were categorized into sale prices and rental prices, utilizing real transaction data provided by the Ministry of Land, Infrastructure, and Transport.

The flow of the analysis is as follows (see 〈Figure 1〉). First, the Latent Dirichlet Allocation (LDA) topic modeling technique is employed to categorize the occurrence data of civil complaints and extract multiple topics. This is a statistical technique used to discover latent topics within extensive unstructured document sets (Park et al., 2017). Second, the derived topics are structured as subjective residential environment variables, while objective residential environment variables are constructed based on residents' primary concerns identified from civil complaints. Third, multiple regression models are applied with the constructed variables

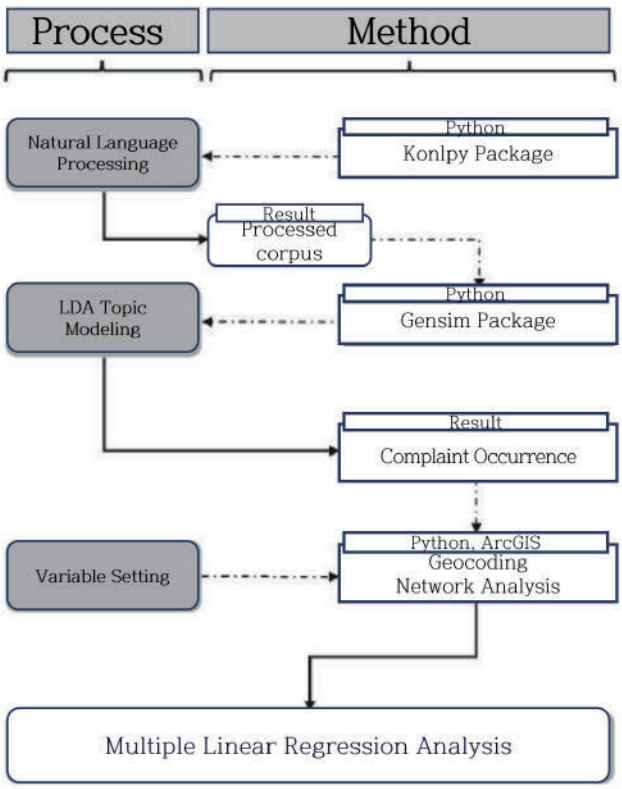

Figure 1. Analysis flow

as independent variables and housing prices (sale and rental) as dependent variables.

2. Categorization of Civil Complaints Data through LDA Topic Modeling

1) LDA Topic Modeling

LDA topic modeling is one of the text mining techniques used to extract meaningful topics from a collection of text-based documents and identify subtopics related to these topics. This model is a probabilistic algorithm that assumes relatedness among words within the same document, iteratively identifying clusters of words that co-occur and defining topics based on this assumption. Topic modeling is primarily applied in text analysis and other unstructured data analysis, enabling data acquisition from various documents such as news articles and social media.

The topic modeling technique utilized in this study, employing the LDA algorithm, is based on the hypothesis that clusters of words share common topics, analyzing topics present in documents based on the proportions of words. Unlike clustering analysis assigning one word to only one topic, this probabilistic method allows a single word to relate to multiple topics, making it a useful technique among various topic modeling approaches (Lim and Hwang, 2022).

The LDA algorithm infers document structure and hidden variables based on words within documents, generating a designated number of topics through the Dirichlet distribution for the words in a document set. The process of the LDA algorithm is depicted in 〈Figure 2〉, a reconstruction of Ruozzi's (2019) data. This represents the process of finding latent variables through the appearance of a unique observation: the nth word, *wd*,n, in the dth document. Each variable in the generation process carries specific meanings: D refers to the total number of documents in the corpus, K represents the total number of topics, and N signifies the number of words in the dth document. β k is the vector corresponding to the kth topic, having the length of the entire corpus's word count, while α and η are hyperparameters directly specified by the user during the model configuration.

2) Process of Categorization of Civil Complaints Data

LDA topic modeling was employed for the categorization of civil complaints in Incheon's Yeonsu District, aiming to identify subjective residential environment elements based on the analysis results. The utilized data was the grid mapping information of civil complaints in Yeonsu District in 2020. Python's Konlpy and Gensim packages were used for frequency analysis and topic modeling. The total civil complaints reported were 33,516, and for preprocessing, special characters, foreign languages, spaces, and non-informative stopwords were removed. To maintain the reliability of type analysis (Kim and Jeon, 2022), the tokenization process focused solely on general nouns crucial for understanding the context while eliminating less significant adjectives or adverbs that could be extracted when considering all units.

Initially, frequency analysis was conducted to determine the core keywords of frequently occurring civil complaints, visualizing them through a word cloud (see 〈Figure 3〉). Frequency analysis is an effective method of comprehending the current status and trends. Keywords with high frequencies in civil complaints represent focal points of concern for residents. Among the grid-based civil complaints, the most mentioned keywords were "illegal parking-related reports", which occurred 11,384 times. Other top keywords were "safety", "crosswalk", and "library".

Establishing the optimal number of topics is crucial to ensure the study's reliability during the model setup. An

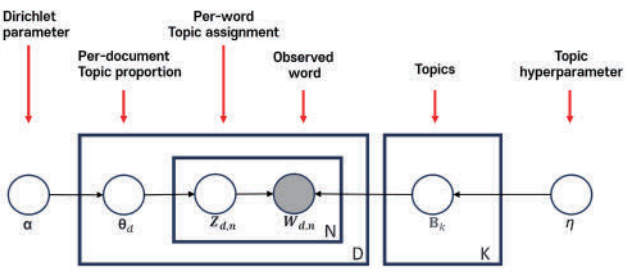

Figure 2. LDA algorithm process

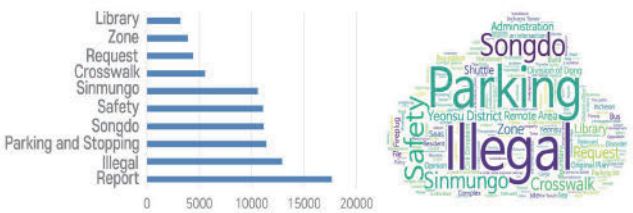

Figure 3. Frequency analysis and word cloud of complaint occurrence

insufficient number of topics can result in broad subject matters, while an excessive number can lead to over-clustering of data. To determine the optimal number of topics, there are two primary methods: the researcher's subjective selection and an unsupervised learning-based approach using machine learning. As the subjective selection method may vary in determining the number of topics depending on background knowledge and perspectives, this study estimated the optimal topic number based on unsupervised learning.

This method primarily utilizes coherence and confusion concepts. A higher coherence score signifies that each topic comprises coherent and interrelated words. Meanwhile, the confusion score represents the probability of topic occurrence and word occurrence within a topic; a lower value indicates a more appropriate model. Since the confusion score mainly indicates the model's adequacy in learning the target documents, it is more appropriate to use coherence (Cho, 2022). By prioritizing coherence and considering confusion as a secondary factor, the optimal number of topics was determined to be 9 (see 〈Figure 4〉).

The summary of topics derived from the categorization of civil complaints is presented in 〈Table 1〉 and visualized in 〈Figure 5〉. A total of nine topics were identified, with the topic having "Songdo" as the top keyword addressing facility installations and direct administrative demands of the residents. Other topics highlight issues like illegal parking problems, inconveniences within residential complexes, and demands for additional infrastructure. In 〈Figure 5〉, each circle represents an individual topic, with the circle's size indicating the proportion it holds within the entire set of topics. The distance between circles signifies the similarity between topics (Chehal et al., 2021). That is, closer circles denote more related topics.

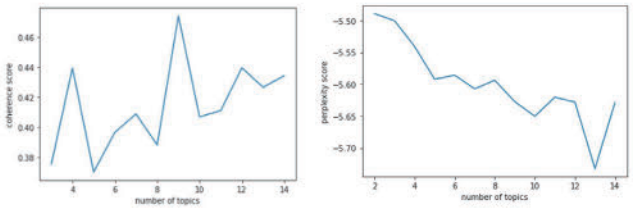

Figure 4. Process of setting the optimal number of topics (left: coherence, right: perplexity)

Topic 1 revolves around civil complaints concerning the division of Songdo 4-dong and 5-dong, as revealed through keywords such as "Songdo", "administration", and "division of Dong". During the process of dividing Songdo 4-dong, with over 50,000 inhabitants, into 4-dong and 5-dong, there was a dispute between residents and Yeonsu District when a newly proposed plan conflicted with the existing administrative district plan.

Topics 2 and 5 exhibited keywords such as "site", "nation", "relation", and "request". Unlike other topics, these did not explicitly present inconveniences within residential environments but were identified as complex civil complaints. Civil complaints regarding daily life may indicate specific policy demands or issues related to particular areas, resulting in complex civil complaints, as noted in Lee and Kim's (2021) study. Specifically, Topic 2 civil complaints were found to be concentrated in Songdo-dong in terms of spatial distribution. While this tendency may not be directly linked to

Table 1. Results and top keywords for LDA

Topic		Top keywords				
1	Request for division of administrative districts	Songdo	Administration	Division of Dong	Opinion	Yeonsu District
2	Other complaints	Civil Complaint	Site	Nation	Effort	Report
3	Opposition to cargo yard	Zone	Cargo	Coal yard	Demand	Gu office
4	Illegal parking report	Report	Illegal	Parking	Safety	Sinmungo
5	Other complaints	Relation	Request	Yeonsu	Review	Policy
6	Disabled parking area vehicle violation	Zone	Boundary	Resident	Disorder	Parking
7	Require additional bus station installation	Bus	Bus Station	Region	Progress	Jurisdiction
8	Problems with wide-area express railways	Build	Incheon Tower	Plan	Tram	Railroad network
9	Songdo beach bus request complaint	Songdo	Request	Bus	Remote area	Sea

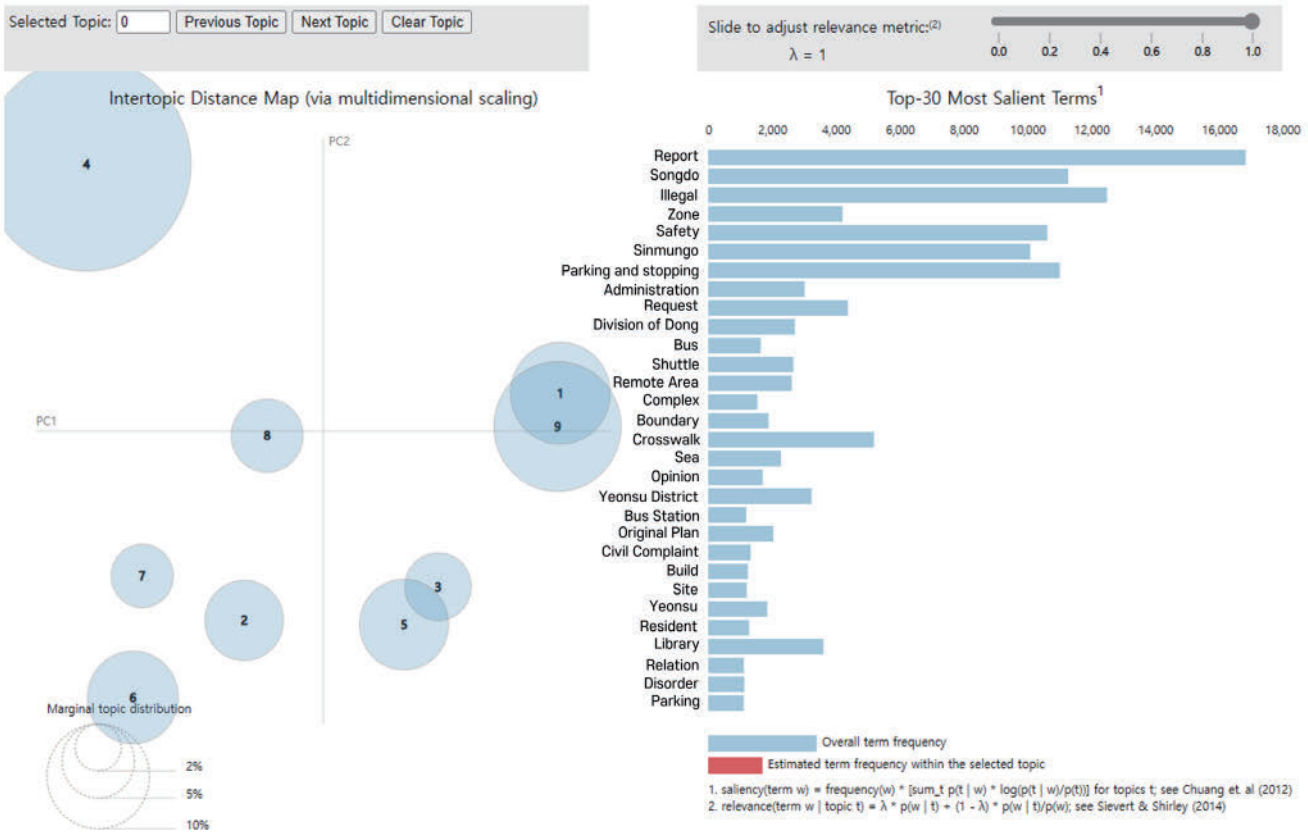

Figure 5. Visualizing the results of an LDA

keywords, the region-specific complex civil complaints could have had an influence.

Topic 3 primarily revolves around civil complaints centered on the installation issue of the cargo yard within Songdo Zone 9 in 2020. The installation of the cargo yard in Zone 9 was planned back in 2006 to address the shortage of hinterland areas in Incheon Port and facilitate smooth cargo handling. However, contrary to the initial plans, the influx of around 30,000 households into the adjacent Zone 8 led to changes in the residential environment, triggering concerns among residents regarding safety, traffic, and aesthetics. Consequently, numerous civil complaints have been raised within the affected area by the residents of Songdo to protect their residential environment.

The most frequent Topic 4 presents keywords such as "illegal", "parking", and "report". This indicates that public safety was significantly affected by illegal parking within Yeonsu District at the time of investigation. A closer examination of civil complaints showed that there was a high frequency of reports related to illegal parking at the crossroads within Yeonsu District.

Topic 6 is characterized by keywords like "zone", "disorder", and "parking", suggesting civil complaints primarily related to violations of parking in areas designated for disabled individuals. Topic 7 encompasses issues concerning the addition of bus stations, highlighted by keywords such as "bus", "bus station", and "facility". It also addresses illegal parking problems in the vicinity of bus stations. Topic 8 revolves around civil complaints related to the wide-area express railway system in Yeonsu District, indicated by keywords like "build", "tram", "railroad network", and "wide-area express railway". Topic 9 primarily involves requests concerning a circular bus service along the coastline in Songdo-dong.

3. Analysis Data and Variable Setting

The dependent variables consist of the price per square meter for both sale price and rent price, forming two separate models (see 〈Table 2〉). To construct these dependent variables, transaction data for actual sales and monthly rents[5] occurring in Yeonsu District, Incheon in 2020 were utilized. Individual transactions were spatially aggregated based on the analysis unit of 100 m grids. Eventually, the

Table 2. Variables for analysis

Variables		Unit	Explanation	Source
Dependent variable				Molit Korea
Unit housing price	Unit housing sale price	10k won/m^2	Housing price divided by housing size was averaged in grid	
	Unit housing rent price			
Objective housing environment				
Housing characteristics	Housing size	m^2	Average exclusive area in grid	
	Housing year	Year	Average housing year in grid	
	Floor	Floor	Average floor in grid	
Regional characteristics	Number of households	Number	Number of households in grid	SGIS
	Rate of old age	Rate	The elderly/total population in grid	
	Number of house	Number	Number of house in grid	
	Type of city center	Dummy	New city center=1 Old city center=0	LH COMPAS
Safety characteristics	Number of crosswalks	Number	Number of grid center points within 500 m	Smart Incheon System
	Car ownership ratio		Number of cars/household in the grid	LH COMPAS
	Number of police reports		Number of reports in grid	
Accessibility characteristics	Shortest distance to park	m	Shortest distance based on walking network*	Public Data Portal
	Shortest distance to library			
	Shortest distance to bus station			
	Shortest distance to hospital			
	Commercial facilities within 500 m	Number	General restaurants and convenience stores only	LH COMPAS
Subjective housing environment				
Complaint occurrence	1) Request for division of administrative districts	Number	Number of complaints in grid	
	2) Other complaints			
	3) Opposition to cargo yard			
	4) Illegal parking report			
	6) Disabled parking area vehicle violation			
	8) Problems with wide-area express railways			

* ArcGIS Network Analysis was used to calculate the shortest distance from the center point of the grid where housing transactions occurred to the target.

average sale price and average rent price for each grid were used in the final analysis.

Since the deposit amounts vary widely for monthly rent, a standardized conversion can be used to facilitate comparison between monthly rent and lump-sum deposit rent. Hence, the monthly rent was converted into lump-sum deposit rent using the rental conversion rate[6] by housing type in Yeonsu District for 2020. The rental conversion rate, publicly disclosed annually by the Korea Real Estate Board, has been used to standardize variables in past research using rent as a dependent variable (Ha and Jin, 2021; Kim and Yoo, 2022).

The independent variables were categorized into objective residential environment and subjective residential environment (see 〈Table 2〉). For the subjective residential environment variables, the frequency of civil complaints by topic type at the grid level was used. Utilizing the nine topics derived from the categorization of civil complaints data, topics with Variance Inflation Factor (VIF) values exceeding 10 were removed to address multicollinearity. The selected variable was the frequency of civil complaints for six civil

complaint topics: 1) request for division of administrative districts, 2) other civil complaints, 3) opposition to cargo yard, 4) illegal parking report, 6) disabled parking area vehicle violation, and 8) problems with wide-area express railway.

In constructing the objective residential environment variables, the criteria were based not only on the literature review but also on the key concerns identified in the categorization of civil complaints by residents. As a result, 15 variables were developed, classified into housing characteristics, regional characteristics, safety, and accessibility.

The variables under housing characteristics comprised the average area, average housing year, and floor within the grid. The area and housing year are significant factors affecting housing prices, and different studies have shown varying outcomes depending on researchers' analyses (Gong and Kim, 2022). Moreover, the floor of a house is known to positively influence the residential environment, as higher floors tend to provide better privacy and a sense of openness (Bae et al., 2018).

The variables under regional characteristics consisted of the rate of old age within the grid, the number of households, the number of houses, and the type of city center (new or old city center). According to the housing filtering theory, as housing ages, its quality deteriorates, leading to an influx of lower-income populations and ultimately resulting in a decline in housing prices (Jun and Jung, 2021). However, in the case of Yeonsu District, there is an ongoing increase in housing prices and an upward trend in the rate of old age, as reported by the Ministry of the Interior and Safety of South Korea in 2020. Therefore, the outcomes may not necessarily align with theory.

The number of households and number of houses generally have a positive impact on housing prices. However, in the case of Incheon, particularly in Songdo-dong, due to the increase in housing supply within the new city center, there may be a different trend in household and housing counts compared to the original city center, where housing supply has stabilized. The type of city center is a variable that distinguishes between the old and new city centers in Yeonsu District. It is a dummy variable coded as 1 for the presence of a new city center. The city center status is expected to have a positive impact on housing prices as it reflects ongoing development in Songdo New City.

Safety-related variables include the number of crosswalks, car ownership ratio, and the number of police reports within the grid. These variables reflect elements related to traffic safety, such as "safety" and "crosswalks", which were identified as focal points of interest for residents during the categorization of civil complaints.

Particularly in Yeonsu District, there are frequent civil complaints demanding additional installations of bus stations and transportation facilities. This indicates that residents place significant importance on pedestrian environments, and thus, the density of crosswalks is deemed an important variable. Gong and Kim (2022) also mentioned in their research that the presence of crosswalks is a crucial factor in terms of traffic safety and has a positive impact on housing prices.

The car ownership ratio is based on the ratio of cars per household within each grid. This, along with the number of police reports, was adopted considering the occurrence of numerous civil complaints related to traffic issues like illegal parking and violations in disabled parking areas during the categorization of civil complaints. While Lee (2011) speculated that a higher car ownership ratio might indicate affluent residents and positively influence housing prices, this observation was not statistically significant. Nonetheless, given the prevalence of civil complaints related to cars in Yeonsu District, the results of this study may be different.

Accessibility-related variables include the proximity to parks, libraries, bus stations, shortest distance to hospitals, and the number of commercial facilities within 500 m from the grid center. This selection aligns with the categorization and frequency analysis of civil complaints, where requests for library construction and various traffic-related civil complaints were prominent. Furthermore, prior research suggests that open spaces like parks provide a pleasant environment for residents, positively impacting housing prices. Commercial facilities, limited to convenience stores and general restaurants located near residential areas, were also considered.

4. Analysis Model

Multiple regression analysis was conducted as shown in Eq. (1) to examine the influence of the frequency of civil complaints by type, a surrogate for subjective residential environment factors, along with objective residential envi-

ronment variables on housing prices. Here, Y represents the dependent variable, X denotes the explanatory variables, εi stands for the stochastic disturbance term, and i represents the ith observation. The coefficient β represents the partial regression coefficient, indicating the net effect of a one-unit change in the explanatory variable on the mean value of Y (Park and Hong, 2009).

In this study, a multiple regression model with 21 independent variables was constructed to explain the dependent variable (average transaction price of housing per unit area). Multiple regression analysis, commonly used in economic and social science analyses, offers the advantage of accurately assessing the effect of individual independent variables by controlling for the influences of other variables (Park and Han, 2015). Furthermore, the analysis was conducted for both sale prices and monthly rent prices. Rental prices reflect the demand for housing services, representing the use value. Sale prices, on the other hand, encompass both use and investment values, acting as a composite indicator that reflects both aspects (Sung and Park, 2014). Therefore, in this study, the aim is to explore how subjective residential environment factors based on civil complaints data and objective residential environment factors affect both rent and sale prices.

$$Y_i = \sum_{j=0}^{m} \beta_j x_{ij} + \epsilon_i \quad (1)$$

Ⅳ. Analysis Results

1. Descriptive Statistics Analysis

The multiple regression model was categorized into sale and rent models based on the dependent variables, and before conducting the analysis, descriptive statistics were performed for each model (see 〈Table 3〉).

The average of the dependent variables was observed to be KRW 3.65 million per square meter for sale price and KRW 2.36 million for rent price.

In housing characteristics, the floor and average area exhibited relatively high standard deviations, likely due to differences in housing types.

Under regional characteristics, instances where the number of households and number of houses had a minimum value of 0 indicated partially missing data in the grid statistics. The maximum value of 1 for the rate of old age, meaning a grid where the entire population consists of elderly individuals, was observed. Areas with a rate of old age of 0.5 or higher were mostly located in the old city center, indicating a probable association with housing prices.

Regarding safety aspects, the number of police reports displayed an extremely high standard deviation, hinting at potential law enforcement blind spots in vulnerable areas. Meanwhile, the car ownership ratio showed a higher mean value in the sale price model compared to the rent price model, accompanied by a substantial standard deviation.

In terms of accessibility, significant standard deviations were evident across all variables. This likely indicates certain blind spots in accessibility due to limited infrastructure supply compared to the continuous supply of new housing in Songdo New City.

Regarding the occurrence of civil complaints by type, the mean value in the sale price model was notably higher than in the rent price model. Additionally, there was a substantial difference between the maximum and minimum values. The original data suggests that for some types of civil complaints, certain individuals consistently filed similar complaints, leading to the clustering of multiple reports in specific areas.

2. Analysis of Housing Price Determinants

The analysis results, as shown in 〈Table 4〉, reveal an Adjusted R-squared of 0.882 for the sale price model and 0.720 for the rent price model. Factors influencing housing price in the objective residential environment indicated significant individual characteristics in both models. In regional characteristics, variables such as the number of households, number of houses, and type of city center were consistently significant across both models. In the rent price model, the rate of old age emerged as an additional significant factor. Regarding safety, the number of crosswalks was consistently significant across both models, while for the rent price model, the number of police reports stood out significantly. In terms of accessibility, distance to park was consistently significant, and in the sale price model, the number of commercial facilities showed significance. As for subjective residential environment factors, different signifi-

Table 3. Descriptive statistics

Parameter		Unit	Sale price model (249 grids)				Rent price model (270 grids)			
			Min	Max	Mean	SD	Min	Max	Mean	SD
Dependent variable										
Unit housing price		10k won/m²	122.88	1,075.00	365.68	204.55	50	524	236.04	103.37
Objective housing environment										
Housing characteristics	Housing size	m²	22.13	196.83	74.65	29.87	12	186	64.79	29.33
	Housing year	Year	0	40	20.13	9.97	0	41	17.20	9.93
	Floor	Floor	0	29.52	7.20	5.98	0	31	5.83	6.20
Regional characteristics	Number of households	Number	8	911	145.25	105.54	0	911	94.36	99.90
	Rate of old age	Rate	0	1	0.28	0.15	0	1	0.22	0.19
	Number of house	Number	11	928	127.15	97.26	0	928	62.02	80.97
	Type of city center	Dummy	0	1	0.25	0.43	0	1	0.26	0.44
Safety characteristics	Number of crosswalks	Number	0	97	34.82	21.94	0	97	37.70	23.69
	Car ownership ratio		0.01	11.54	1.11	0.85	0	4.88	0.86	0.70
	Number of police reports		2	284	47.97	41.78	0	1,362	61.50	112.18
Accessibility characteristics	Shortest distance to park	m	8.15	1,941.96	230.18	214.65	0.39	2,573.39	370.81	313.67
	Shortest distance to library		7.11	2,701.13	401.42	393.44	54.81	3,922.23	608.15	500.30
	Shortest distance to bus station		4.38	550.49	143.82	85.39	2.36	762.89	214.13	142.07
	Shortest distance to hospital		10.30	1,097.93	227.81	160.67	0	1,642.53	327.46	256.58
	Commercial facilities within 500 m	Number	62	3,441	952.58	567.08	0	3,441	1,123.51	725.90
Subjective housing environment										
Complaint occurrence*	1) Request for division of administrative districts	Number	0	653	2.98	41.46	0	6	0.20	0.68
	2) Other complaints		0	21	0.92	2.45	0	23	0.64	2.04
	3) Opposition to cargo yard		0	35	1.44	4.22	0	22	0.69	2.50
	4) Illegal parking report		0	307	13.38	35.57	0	1,172	12.44	73.56
	6) Disabled parking area vehicle violation		0	39	1.36	4.08	0	29	0.87	2.99
	8) Problems with wide-area express railways		0	19	1.01	2.72	0	19	0.52	1.91

* Variables with a VIF greater than 10 have been removed to solve the multicollinearity problem.

cant variables appeared depending on the model.

The variables in individual characteristics significantly impacted both models. The average area showed a negative influence, indicating that smaller areas correlated with higher average housing prices per square meter. This trend likely stems from the recent increase in single-person households, retirement among baby boomers, and increased demand for smaller homes due to escalating price burdens on larger residences. Indeed, according to KB Real Estate (2020) and Statistics Korea (2020), comparing the first and fourth quarters of 2020, Incheon Metropolitan City experienced more significant price increases for smaller-sized properties, with a substantial surge in the average price per square meter for smaller homes. However, for homes exceeding 102 square meters, the change was comparatively minimal.

The average housing year had a negative influence on both sale and rent prices. Despite the tendency in Yeonsu

Table 4. Analysis results

Parameter		Sale price model (249 grids)				Rent price model (270 grids)			
		β	SE	Sig	VIF	β	SE	Sig	VIF
	(intercept)	459.273	34.876	0.000***		253.308	20.685	0.000***	
Objective housing environment									
Housing characteristics	Housing size	-0.688	0.205	0.001***	1.891	-0.503	0.132	0.000***	1.342
	Housing year	-5.155	0.791	0.000***	3.135	-1.888	0.469	0.000***	1.953
	Floor	17.575	1.634	0.000***	4.798	9.244	0.844	0.000***	2.468
Regional characteristics	Number of households	-0.370	0.101	0.000***	5.744	-0.120	0.064	0.060*	3.633
	Rate of old age	-43.423	42.972	0.313	1.947	-36.756	21.598	0.090*	1.527
	Number of house	0.272	0.104	0.009***	5.119	0.134	0.080	0.093*	3.738
	Type of city center	131.258	18.699	0.000***	3.279	55.228	12.917	0.000***	2.885
Safety characteristics	Number of crosswalks	0.679	0.356	0.058*	3.069	0.518	0.261	0.048**	3.447
	Car ownership ratio	-8.988	5.815	0.124	1.235	-5.331	5.205	0.307	1.187
	Number of police reports	-0.110	0.131	0.402	1.500	-0.068	0.032	0.035**	1.172
Accessibility characteristics	Shortest distance to park	-0.070	0.032	0.032**	2.421	-0.049	0.018	0.006***	2.715
	Shortest distance to library	0.017	0.017	0.327	2.336	0.002	0.010	0.865	2.391
	Shortest distance to bus station	-0.097	0.066	0.139	1.582	-0.020	0.029	0.498	1.565
	Shortest distance to hospital	0.010	0.037	0.777	1.768	0.022	0.019	0.250	2.105
	Commercial facilities within 500 m	-0.058	0.013	0.000***	2.833	-0.005	0.008	0.542	3.362
Subjective housing environment									
Complaint occurrence	1) Request for division of administrative districts	0.231	0.158	0.144	2.153	2.867	9.528	0.764	3.772
	2) Other complaints	13.664	4.987	0.007**	7.517	4.251	4.021	0.292	6.040
	3) Opposition to cargo yard	1.247	2.073	0.548	3.858	3.384	2.337	0.149	3.063
	4) Illegal parking report	-0.045	0.269	0.867	4.595	-0.173	0.094	0.068*	4.344
	6) Disabled parking area vehicle violation	-9.108	2.615	0.001***	5.722	-0.384	2.756	0.889	6.124
	8) Problems with wide-area express railways	-0.214	3.161	0.946	3.713	-6.371	3.563	0.075*	4.146

***p<0.01, **p<0.05, *p<0.1

District for the rate of old age to increase with housing price (Ministry of the Interior and Safety of South Korea, 2020), the analysis results support the conventional housing filtering theory. Furthermore, this aligns with preferences among consumers, as lower housing years generally ensure better living environments (Kim and Yoo, 2022), which aligns with Kim and Kim's findings in 2019. Additionally, within the regional context, distinctions between Yeonsu District's new city center and old city center can be identified. In particular, the new city center primarily received newer residences with a lower building-to-land ratio and higher comfort, whereas older housing concentrated in the old city center, characterized by lower housing prices per square meter, exerting a negative impact on housing prices.

Housing floor showed a positive impact on both sale and rent prices. This is consistent with the findings of Bae et al. (2018), indicating that higher floors secure better views and privacy, positively influencing the residential environment. Overall, housing characteristics have proven to be significant factors in previous studies conducted at the administrative district level. However, this study, which examined the micro-level characteristics at a 100 m grid scale, also verified their significance. This underscores the continued importance of individual factors in influencing housing prices.

Regional characteristics showed significance in the sale price model for variables excluding the rate of old age, while

in the rent price model, all variables were significant. The number of households had a negative impact on both sale and rent prices, contrary to the findings of Chang et al. (2021). This inconsistency may be due to the clear differences in the spacing and building-to-land ratio between the new city center and old city center within Yeonsu District (National Geographic Information Institute, 2020). Spatially uneven distribution is likely to have led to these results. The grid-based number of households reflects population density and is presumed to be associated with the pleasantness of the residential environment.

It was only in the rent price model that the rate of old age showed a significant negative impact. This aligns with the findings from Hong (2015), where both sale and rent prices exhibited a reverse U-shaped trend concerning age, with a notable decline in rent among the elderly. This similarity suggests that aging populations might lead to decreased economic activity (Seong, 2009). Elderly individuals tend to avoid residential relocations, leading to relatively infrequent housing transactions. Indeed, transaction frequencies within grids with a high rate of old age were predominantly low. Therefore, the infrequent housing transactions arising from the elderly's reluctance to move may reflect a negative impact on housing prices in those areas (Lee, 2011).

The type of city center exhibited a positive influence, indicating that sale and rent prices were higher in the new city center compared to the old city center. This aligns with previous research indicating that city centers with higher functional roles in commerce or business tend to have higher land and housing prices (Park and Kim, 2019). In reality, this area shows a clear distinction between the declining old city center and the growing new city center. Therefore, this highlights the need for analyses at the individual housing and complex level to identify differences based on the type of city center, even within the same administrative district.

In terms of safety characteristics, some variables showed significant effects. The number of crosswalks exhibited a positive impact on both sale and rent prices. Crosswalks not only contribute to walkable residential environments but also, numerous complaints have been filed regarding additional supply of transportation and infrastructure facilities like bus stops (Lee and Kim, 2021). Some instances of damage were observed due to illegal parking near crosswalks. As such, the presence of crosswalks is considered a significant factor in housing prices.

The number of police reports showed a negative impact solely on rent prices, aligning with the findings of Buonanno et al. (2013), indicating that security vulnerabilities and crime rates affect the decrease in housing prices. In addition, it correlates with the focus areas identified through civil complaints, which revealed numerous reports of traffic accidents and illegal activities within the target region. In Songdo International City, many intersections have widths exceeding 1.5 times that of standard intersections, meaning that vehicles have to wait for 3 to 4 minutes if they miss a signal (Cha, 2019). This leads to instances of speeding vehicles passing through, increasing the risk of accidents. It can thus be inferred that areas prone to accidents, leading to multiple reports, can influence rent prices negatively.

Under accessibility characteristics, shortest distance to the park exhibited a negative impact on both sale and rent prices. This aligns with the findings of Lee, J.S. et al. (2013), indicating that better accessibility to parks leads to an increase in housing prices. This can be attributed to the growing significance of natural elements such as parks and rivers in housing selection, evident from the emergence of terms like "supsegwon", which literally means "forest adjacent housing" (Kim and Jang, 2020).

The number of commercial facilities within 500 m exhibited a negative impact on sale prices. This aligns with the findings of Youn and Jeong (2013). Generally, better accessibility to commercial facilities tends to increase housing prices. However, commercial facilities can also lead to problems such as parking issues or disruptions in the educational environment (Lee, 2007). In the case of apartment complexes, the presence of commercial facilities within the complex might lower the attractiveness of accessibility to nearby commercial facilities when it comes to housing selection (Gong and Kim, 2022).

This study's key variable, the occurrence of civil complaints by type, resulted in two significant variables each for the sale price model and the rent price model. Regardless of statistical significance, both positive and negative impacts were mixed, indicating a complex relationship between civil complaints and housing prices.

Among the significant variables, "other civil complaints" was the only one that exhibited a positive impact. This signifies

the multifaceted nature of civil complaints. Typically, civil complaints are associated with a negative perception, suggesting a potential negative influence on housing prices. However, civil complaints manifest not only as expressions of discomfort in the residential environment but also encompass policy demands and specific regional issues (Lee and Kim, 2021). Even in the categorization of civil complaints by type using keywords and spatial distribution analysis, "other civil complaints" appeared to be related more to policy and regional issues than discomfort in the residential environment. While residents may not have explicitly expressed discomfort, their subjective perceptions reflect policy-related factors that could influence the residential environment. This is evident in the distribution of civil complaints across specific areas.

In the sale price model, "disabled parking area vehicle violation" civil complaints showed a negative impact. These violations often occur in areas with insufficient parking spaces, leading to traffic congestion in nearby regions and prolonged time spent finding parking facilities, thus deteriorating the residential environment and reducing residential satisfaction (Kim, S.J. et al., 2020). Incheon Metropolitan City ranks sixth among seven metropolitan cities with a low parking availability rate relative to registered vehicles, and this was more so in residential areas (Park, 2023). This outcome is presumed to be a consequence of the insufficient parking spaces in the residential environment, leading to violations that, in turn, degrade the quality of the residential environment in a vicious cycle.

Illegal parking-related civil complaints exhibited a negative impact on rent prices. Keywords such as "report", "illegal", "parking", "safety", "fire hydrants", and "sidewalks" dominated these complaints reported through the Sinmungo. Particularly, Okryeon-dong and Cheonghak-dong experienced numerous cases, where the presence of large business vehicles illegally parked at fire hydrants and sidewalks has endangered the safety of citizens and disturbed the residential environment. In a similar study utilizing civil complaints data, Kim, S.J. et al. (2020) empirically demonstrated that the shortage of parking spaces in residential areas exacerbates illegal parking problems, leading to a decline in the residential environment and satisfaction. In the case of the old city center, the 1,172 recorded civil complaints occurred in areas concentrated with low-rise housing and commercial facilities, where illegal parking threatens vehicular and pedestrian movement.

The issues related to wide-area express railways showed a negative impact on rent prices. Keywords such as "construction", "tram", "railway network", and "wide-area express railway" highlighted concerns regarding the Songdo Tram and stations for the wide-area express railway B within Yeonsu-gu. Incheon city aimed to address transportation problems within the Songdo International City by initiating the Songdo Inner Loop Tram project, intending to incorporate it into the second phase of the Incheon Metropolitan Railway Network. During this process, residents from the original city center within Yeonsu-gu raised objections, claiming that the tram route was favoring the new city center. They requested additional stops for the wide-area express railway in the original city center, but these requests were not acknowledged (Kim, 2020). Directly affected regions saw civil complaints due to concerns about development plan delays. This ongoing dispute has resulted in conflict between the new city center and the original city center.

Generally, the introduction of a wide-area express railway brings positive effects on urban infrastructure formation and housing prices. In the metropolitan area, regions within the influence of the railway enjoyed an increase in housing prices upon its opening (Kim and Han, 2020). This is attributed to the broader housing choices for consumers due to the introduction of new regional transportation options. As a result, areas previously lacking efficient transportation witnessed an increase in housing consumption. Similarly, Yeonsu-gu, where the new city center is experiencing a concentration of the wide-area express railway Line B, has become the subject of numerous civil complaints. This indirectly indicates issues with the transportation infrastructure, contributing to a negative impact on housing prices.

Ⅴ. Conclusion

This study analyzed the factors influencing housing prices in terms of sale prices and monthly rent prices based on housing transactions in Yeonsu District, Incheon Metropolitan City, in 2020. To achieve this, a detailed spatial analysis was conducted using a 100 m grid unit. Both objective residential environment factors and extensive civil complaint

data were considered as subjective residential environment factors to emphasize their impact on housing prices. The key findings and implications of this research are as follows.

First, it was observed that the occurrence of civil complaints by type in Yeonsu District, Incheon Metropolitan City, had an association with housing prices. Despite controlling for the influence of objective residential environment characteristics, certain types of civil complaints showed significant impact. Particularly, there was a statistically consistent alignment between transportation-related civil complaints and variables describing transportation and safety within the objective residential environment. This suggests that the data on civil complaints utilized as subjective residential environment characteristics reflect residents' perceptions of the residential environment or housing prices. Consequently, future housing policies aiming at enhancing qualitative residential welfare may utilize information on the occurrence of civil complaints as a subjective indicator of residential environment.

Second, the impact of residential environment factors on housing prices was examined from a comprehensive perspective taking into account the micro-level objective/subjective residential environment. Previous studies have typically focused on the influence of objective residential environment factors at the level of administrative districts or neighborhoods. However, this study examined the relationship between the residential environment and housing prices at the microscopic scale of 100 m grids. The findings revealed variations among regions within the same administrative area, an aspect that was not identifiable in models based on administrative boundary divisions. In addition, the subjective residential environment factors used in this study concentrated densely in residential areas, rather than being uniformly distributed across administrative divisions. Hence, the localized analysis method using grid units employed in this study is deemed valuable for measuring housing prices. Particularly, it can be useful in tailoring policies for improving residential environments by government agencies and local authorities, targeting micro-level characteristics. This signifies that urban residents can efficiently benefit from customized residential welfare, and policymakers, by devising and implementing policies tailored to local characteristics rather than administrative boundaries, can save time and economic resources. This approach is anticipated to contribute not only to stabilizing housing prices in the region but also to enhancing the quality of life for residents.

Third, it was found that civil complaints not only represent subjective residential environment characteristics such as immediate physical inconveniences and reports, but also influence housing prices through a complex interplay of future urban planning prospects and other factors. Apart from factors directly impacting the current residential environment, civil complaints encompass demands and dissatisfaction related to specific regional issues and future urban planning elements, including the wide-area express railway B line and Songdo Tram. Particularly noteworthy is that empirical analysis has confirmed the influence in certain areas, which were expected to be directly impacted. This implies that residents' expectations or perceptions regarding urban planning elements serve as factors shaping housing prices. In the future, the impact on the local housing market can be predicted when planned policies are implemented, allowing for preemptive responses to issues arising from the housing policy-making process.

This study aimed to identify the factors influencing housing prices in Incheon's Yeonsu District, focusing on various factors, including the subjective residential environment reflecting residents' perceptions. However, there are certain limitations to this research. First, it did not account for differences in housing types where transactions occurred, implying that future studies considering both regional factors and differences in housing types in analyzing housing price influences may yield more accurate results. Second, while the consideration of subjective factors in addition to objective factors improved results, the high correlation among subjective factors was not fully reflected. The civil complaints data used in this study can be constructed on a monthly and yearly basis, suggesting that subsequent time-series research incorporating panel models may provide insights into housing policies for qualitative improvements in residential welfare.

Note 1. Quantitatively measured residential environment factors were defined as physical and objective factors, and civil complaint-based environmental factors as non-physical and subjective factors.

Note 2. The distributions of lump-sum deposit price index and sales price index in Yeonsu District, Incheon are as shown below.

Note 3. The civil complaints per unit population are 0.175 cases in Seoul, 0.236 cases in Gyeonggi, and 0.392 cases in Incheon, indicating a higher frequency of occurrences in Incheon.

Note 4. The 100 m grid units utilized in this study were based on grids provided by SGIS and the National Geographic Information Institute. The grid's origin (starting point) is defined as 300 km west and 700 km south from the UTM-K projection origin.

Note 5. Actual transaction data was obtained for detached multi-unit housing, multi-family housing, and apartments as classified in the nationwide population and housing census.

Note 6. The conversion rate was used to convert the monthly rent into the lump-sum deposit for detached multi-unit housing, multi-family housing, and apartments in Incheon's Yeonsu District.

Note 7. The number of transactions occurring in grids with a rate of old age above 0.5 were mainly in the low range of 1 to 5, except for one grid with 78 transactions.

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Date Received	2023-09-05
Reviewed(1st)	2023-10-18
Date Revised	2023-11-08
Reviewed(2nd)	2023-12-07
Date Accepted	2023-12-07
Final Received	2023-12-18