KSCE Journal of Civil Engineering (2021) 25(3):1056-1065
DOI 10.1007/s12205-021-1250-z

pISSN 1226-7988, eISSN 1976-3808
www.springer.com/12205

Transportation Engineering

Comparative Analysis of Spatial Impact of Living Social Overhead Capital on Housing Price by Residential Type

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ARTICLE HISTORY

Received 14 July 2020
Accepted 1 November 2020
Published Online 22 January 2021

KEYWORDS

Living SOC
Residential type
Housing price
Spatial effect
GWR model

ABSTRACT

We examined 15,446 single-family detached houses and 2,494 apartment houses in Saha-gu, Busan Metropolitan City, to see whether the accessibility to social overhead capital (living SOC), influences housing prices spatially. Living SOC represents different types of essential facilities. We divided houses into single-family detached houses and apartment houses to perform a more accurate analysis. We used a geographically weighted regression (GWR) model for local-level analysis with a 200-m grid and 400-m grid as spatial units to consider spatial effects. The GWR model explained the price variation better than an ordinary least squares (OLS) model. The results provide a variety of implications to consider when establishing a business-and-action plan based on living SOC.

1. Introduction

Values that emphasize work-life balance are spreading in Korea, and interest in conditions for enjoying leisure is increasing. As a result, living social overhead capital (SOC), which represents essential facilities, has emerged as an important aspect of improving quality of life. SOC refers to the infrastructure necessary for smooth economic activities. Traditional SOC refers to the establishment of large-scale infrastructure centered on civil engineering, such as infrastructure for production and the economy, including roads, ports, and railroads, as well as ways to enhance utility, such as intelligent transportation systems, complex terminals, and user convenience facilities. However, living SOC focuses on creating social overhead capital centered on aspects of "people and use" to promote convenience, such as basic infrastructure (water, sewage, gas, electricity, etc.), culture, sports, childcare, and park facilities. Living SOC can be understood as essential facilities that encompass all the infrastructure necessary for everyday life for people to eat, sleep, raise children, support the elderly, work, and rest.

As one type of urban infrastructure, living SOC promotes convenience and safety, which is a basic premise for everyday life (Act on Public-Private Partnerships in Infrastructure Article 2-1). Living SOC facilities are neighborhood unit facilities that can be accessed by foot, and their functions can be divided into seven categories according to the Basic Living Infrastructure National Minimum Standards: education (kindergartens and elementary schools), learning (libraries), care (childcare centers, elderly welfare facilities, basic medical facilities), physical activity (community sport facilities), rest (neighborhood parks), convenience (residential amenities, retail stores), and transportation (public parking lots). The Korean government announced the Living SOC Three-Year Plan with plans to dramatically increase living SOC facilities, such as gymnasiums, libraries, and childcare facilities, by investing 30 trillion won by 2022. The Seoul Metropolitan Government also established the Ordinance on the Supply of Living SOC, the Ordinance on the Supply of Social Infrastructure in the Low-Rise Residences of Seoul, and an urban regeneration project called the 10-Minute Local Living SOC Project.

Many living SOC plans and projects are going to be implemented in the future, so it is necessary to empirically understand the impact of living SOC on residential and neighborhood environments. Thus, a scale is necessary to compare the levels of

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neighborhood environments. Housing prices can be used as a scale because they can increase in an area if the neighborhood environment improves (Guo et al., 2017). According to the 2018 Korea Housing Census, about 66% of the total population lives in multi-family houses. Accordingly, most of the research on housing prices in Korea targets apartment houses (Lee et al., 2018; Choi, 2019; Chun and Park, 2019; Lee and Suh, 2019; Lee et al., 2019; Kim and Kim, 2019). Single-family detached houses are also a residential type that must be considered, but research is insufficient compared to that on apartment houses due to difficulties in acquiring data. Therefore, it is essential to accurately analyze the impact of living SOC on housing prices by dividing types of residences.

This study analyzes how the accessibility of living SOC for different residential types affects housing prices. We used a geographically weighted regression (GWR) model that considers spatial effects of spatial autocorrelation and spatial heterogeneity. We examined the following research questions: 1) Does the impact of living SOC on housing prices have a spatial effect between residential environments? 2) Does the impact of living SOC on housing prices differ depending on the residential type? 3) Does the impact of living SOC on housing prices vary by spatial unit?

2. Literature Review

The main model used in studying housing prices is the hedonic model. The model was presented by Rosen (1974) as a method for estimating housing prices with the assumption that housing prices are determined by the sum of the benefits that can be achieved by the various characteristics of a home. Households pursuing utility maximization will pay the same price as they are willing to pay for environmental factors (Gao and Asami, 2001). In general, the factors that determine housing prices are determined by various attributes, such as housing characteristics, neighborhood characteristics, and accessibility (Choi et al., 2019).

Early housing studies mainly focused on identifying housing price factors based on physical characteristics such as size, age, and number of bedrooms (Evans, 1973; Richardson et al., 1974; Can, 1992; Archer et al., 1996). Studies focusing on the importance of facilities and accessibility have also been conducted (Graves and Linneman, 1979; Choi, 1999; Haider and Miller, 2000; Rosiers et al., 2011). In addition, it was proven that the natural environment and landscape have an influence on housing prices (Luttik, 2000; Mansfield et al., 2005; Hui et al., 2007; Sander et al., 2010). In this study, we looked at relevant studies on facility accessibility. As a result, we found that the effect of facilities on housing price is variable. For example, public transport infrastructure such as subways and buses can improve housing prices by improving access to opportunities and services (Habib and Miller, 2008; Seo et al., 2014; Bae et al., 2018). On the other hand, accessibility changes that increase noise pollution and traffic levels cause a decrease in housing prices (Tian et al., 2017).

Urban parks have also been found to be convenient facilities that have multiple effects on housing prices (Crompton, 2001; Netusil, 2013). Urban parks provide a wide range of benefits, such as aesthetic factors, sunlight, noise absorption, air purification, and health promotion (Dwyer and Miller, 1999). These various benefits have been found to have a positive effect on increasing housing prices around parks in most studies (Sander and Haight, 2012; Park et al., 2017b; Kim et al., 2019). On the other hand, in large urban areas like Salt Lake County, Utah, urban parks have had a negative impact, as many people prefer to drive to the parks (Li et al., 2010; Tian et al., 2017).

Medical facilities provide various services to improve quality of life and treatment. Kim et al. (2016) classified medical facilities into three categories and analyzed how they affect housing prices. The results showed that primary medical facilities have a significant impact on housing prices. However, being close to a secondary medical institutions mean being close to a commercial area that is different from a good residential environment, so it showed that it has a negative effect on the house price. In addition, since the tertiary medical institutions are specialized medical institutions, it showed that the effect on the house price is weak because it is not visited frequently. Jia et al. (2018) found that people who live in large houses go to hospitals by car, so hospitals have little effect on housing prices. Furthermore, people do not want to live very close to a hospital because of ambulance sirens and traffic jams (Tian et al., 2017).

Traditional hedonic models might not be appropriate for the analysis and modeling of geographical data because they rarely model spatial effects in regression equations (Basu and Thibodeau, 1998; Sunding and Swoboda, 2010). In the literature on spatial statistics and spatial econometrics, spatial effects are generally divided into two categories: spatial dependence and spatial heterogeneity (Anselin, 1988). The geographical data used in the housing price estimation model have structural characteristics of similar neighborhoods, and there is a high possibility that spatial autocorrelation exists because it uses a shared location amenity (Fik et al., 2003). In addition, spatial heterogeneity occurs because the instability of spatial structure — that is, the function type or parameter value — is not constant and varies depending on the region (Anselin, 1999).

Consequently, ignoring spatial effects violates the basic assumptions of the conventional OLS model, causes biased estimates of the parameters and their significance, and usually underestimates the true standard error, resulting in misleading assumptions about the model's significance (Can, 1992; Fotheringham et al., 2003; Gleditsch and Ward, 2008). Recently, research in connection with geographic information systems (GISs) and spatial measurement models has been actively conducted to analyze housing price models while considering spatial effects (Park et al., 2017a; Wu et al., 2017; Wen et al., 2018; Yuan et al., 2020). In this study, we used a suitable GWR model by empirically confirming spatial autocorrelation and spatial heterogeneity.

3. Methodology

3.1 Study Area

The aim of this study is to analyze the effect of living SOC accessibility on housing prices according to housing type and the spatial characteristics of a region, as well as to contribute to the improvement of living SOC projects and the establishment of action plans. We used Saha-gu, Busan Metropolitan City, as a study area (Fig. 1). Saha-gu is one of Busan's 16 municipalities and is located in the southwestern part of Busan. It has a population of 321,000 as of 2019, and its area is 41.75 km^2. Saha-gu is the only region in Busan that has been selected for the 'Urban Regeneration New Deal Project', a major project of the current government, for the third consecutive year and is carrying out many urban regeneration projects.

In addition, the “demonstration living area plan” has been implemented since 2015. This plan deviates from the basic maintenance plan centered on urban and residential environment maintenance zones and establishes a comprehensive plan for the entire residential area. These factors make the area suitable for research on the impact of living SOC.

Residential types were divided into single-family detached houses and apartment houses according to the Korean Housing Act. We used the official price data of 15,446 single-family detached houses and 2,494 apartment houses from 2019.

3.2 Data and Methods

Table 1 shows the variables used and their descriptive statistics. The dependent variable is the average official price of one housing building. The official price is the housing price announced by the Ministry of Land, Infrastructure and Transport on January 1 of each year. The independent variables are the housing and locational characteristics and living SOC accessibility. Living SOC refers to sports facilities, libraries, etc that are directly related to the quality of life, different from the large-scale SOC centered on space and development. The current government of the Republic of Korea is said to increase the quality of life and create effects such as local job creation, balanced development, and service industry development by increasing infrastructure close to people's lives through living SOC investment (Living SOC Three-Year Plan).

In this study, this living SOC was classified into 7 types based on the national minimum standards for basic living infrastructure: nursery facilities (kindergartens, childcare centers), elementary schools, public libraries, elderly facilities (senior centers, senior classrooms, elderly welfare facilities), basic medical facilities (medical clinics, drugstores), community sport facilities (swimming pools, fitness centers, gymnasiums), and urban parks (excluding cemetery parks). We constructed these as original data using the Ministry of Public Administration and Security’s GIS data, the Busan Public Data Portal, and the Local Data Portal.

Previous studies used the administrative *gu*/*gun* and *dong* as spatial units, but instead, we set spatial units of 200-m and 400-m grids after considering the scale effect of modifiable areal unit problem (MAUP) theory (Openshaw, 1984). This created 1287 and 371 grids, respectively. We wanted to show more detailed analysis results in smaller space units than the eight administrative *dong,* which have an average area of 5.21 km^2, as well as to confirm the existence of MAUP theory in different grid sizes.

The analysis included 15,446 single-family detached houses and 2,494 apartment houses. Many previous studies used OLS models for housing price analyses, which can distort the properties of the data as a result of globally analyzing the data attributes for hosing prices measured for each space. We first

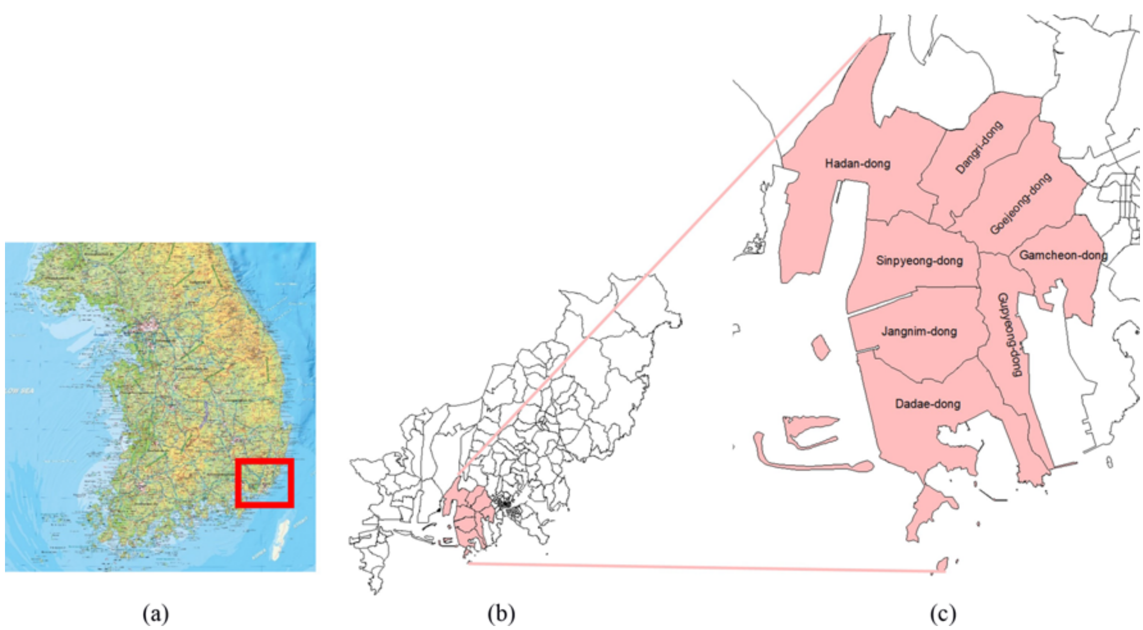

Fig. 1. Study Area: (a) South Korea, (b) Busan Metropolitan City, (c) Saha-gu

Table 1. Descriptive Statistics

S.F Detached house	Variable	Unit	Minimum	Maximum	Mean	S.D.
n = 15446	Dependent variable					
	Price	won	426,000	200,000,000	74,957,252.69	4,790,2291.74
	Independent variable					
Housing and locational characteristics	Area	m^2	10	200	97.3256	46.58399
	Sub	m	4.95	2467.71	707.7503	501.54956
	Bus	m	1.8	422.99	122.8965	67.28275
	Road	m	0.21	240.1	13.9878	10.1378
Living SOC accessibility	Nur	m	0.55	710.67	153.3296	92.11269
	Sch	m	3.13	1271.74	389.7345	183.63279
	Lib	m	2.92	1320.41	374.3932	221.17737
	Wel	m	0.31	683.86	121.9134	74.25955
	Med	m	0.58	894.67	203.2964	154.2221
	Spo	m	0.71	988.3	199.8958	128.39175
	Park	m	0	1,222.75	414.2005	271.29451
Apartment house	**Variable**	**Unit**	**Minimum**	**Maximum**	**Mean**	**S.D.**
n = 2494	Dependent variable					
	Price	won	11,364,285.71	342,250,000	87,109,255.79	50,080,635.55
	Independent variable					
Housing and locational characteristics	Area	m^2	11.48	195.94	63.1201	24.1131
	Sub	m	20.09	2470.95	571.2779	414.80127
	Bus	m	3.57	438.17	123.9093	71.81879
	Road	m	1.77	238.17	30.4604	29.11073
Living SOC accessibility	Nur	m	2.49	689.56	143.2397	91.64301
	Sch	m	38.62	1,174.92	359.1624	154.98997
	Lib	m	22.91	1,164.87	432.3226	207.30676
	Wel	m	0.98	463.3	137.7984	85.09743
	Med	m	2.04	763.38	202.1067	133.44424
	Spo	m	2.21	971.7	172.1369	102.13531
	Park	m	4.44	1,212.29	360.1304	243.21201

checked to see whether there was a spatial effect. The spatial autocorrelation was confirmed by Moran's I test provided by Arcgis 10.3, and the spatial heterogeneity was confirmed by the Koenker test provided by a macro written in SPSS syntax by Dr. Ahmad Daryanto. After that, we implemented a GWR model that reflects the spatial effect of the data using MGWR 2.0, which is provided by the Spatial Analysis Research Center at Arizona State University (Fig. 2).

3.3 Model Specifications

Brunsdon et al. (1996) and Brunsdon et al. (2002) proposed geographically weighted regression (GWR) as a local-variation modeling technique. The GWR model is a method of estimating regression coefficients by dividing an area into heterogeneous local spatial regions and reflecting their characteristics. The regression coefficients of the GWR model are obtained according to each geographical location i based on the effect of distance (Fotheringham et al., 2003). In the regression equation of the GWR model, different regression models are applied to estimate the regression coefficients, as shown in Eq. (1) with center-point coordinates (u_i, v_i) of space i.

$$Y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) X_{ik} + \varepsilon_i \qquad (1)$$

According to the First Law of Geography, the regression coefficient is weighted according to its position. The regression coefficient is determined by Eq. (2) based on the geographically weighted matrix $W(u_i, v_i)$ for other spaces in space i with center point coordinates (u_i, v_i).

$$\hat{\beta}(u_i, v_i) = (X^T W(u_i, v_i) X)^{-1} X^T W(u_i, v_i) Y \qquad (2)$$

Each element of the geographically weighted matrix $W(u_i, v_i)$ is determined by the kernel function, which can be considered to obtain a good reflection of an actual phenomenon by obtaining successive and smooth apparent weight values. The geographically weighted matrix $W(u_i, v_i)$ is shown in Eq. (3) using the bi-square kernel function:

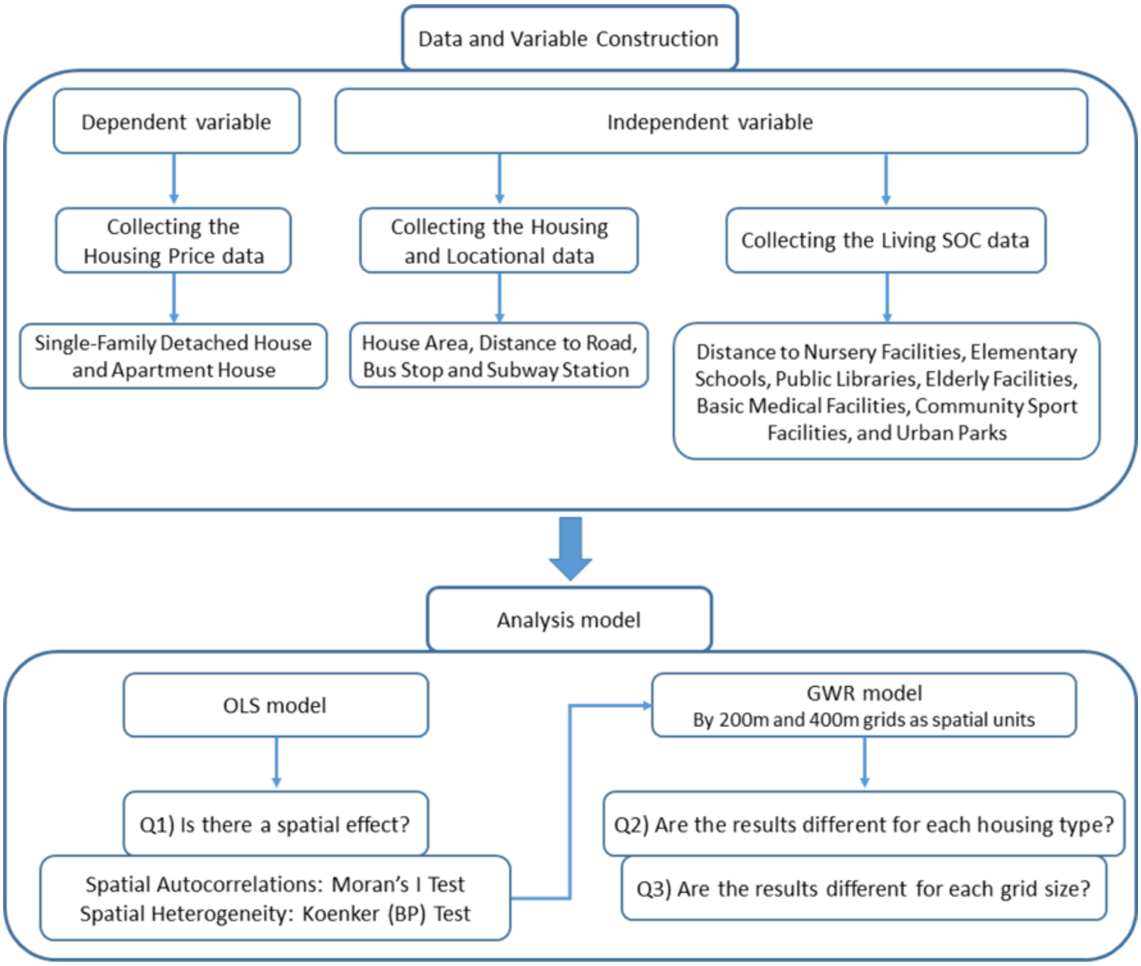

Fig. 2. Research Flowchart

$$W_{ij} = \begin{cases} \left[1-\left(\frac{d_{ij}}{h_i}\right)^2\right]^2, & if\ d_{ij} < h_i \\ 0 & , otherwise \end{cases}, \quad (3)$$

where h_i is the bandwidth. The GWR model tends to be more sensitive to bandwidth. The analysis results are changed by the weight function and bandwidth. If the bandwidth is inadequate, the slope is not sufficient to obtain an estimate and leads to a steep graph. Conversely, too much bandwidth results in a graph with a gentle slope, similar to the OLS model, which does not take into account spatial characteristics. Therefore, it is important to set an appropriate bandwidth for accurate results.

Fixed kernels have fixed bandwidth, and adaptive kernels have different bandwidths depending on the degree of data density. Adaptive kernels are typically used when determining the correct bandwidth. In addition, the Cross-Validation (CV) method and a Connected Akaike Information Criterion (AICc) method are commonly used to estimate the optimal bandwidth. In this study, the AICc method was used. The GWR model was used for the analysis by organizing a geographically weighted matrix with an adaptive kernel using the bi-square kernel function.

Table 2. Results of the OLS Model Using Living SOC

Variable		Single-family detached house	Apartment house
Intercept		49,825,520.03***	12,016,329.01***
Housing and locational characteristics	Area	518,493.735***	1,426,475.43***
	Sub	-20,078.5***	-12588.9***
	Bus	17,002.131***	11622.68
	Road	426,895.354***	271,417.455***
Living SOC accessibility	Nur	22,657.687***	-19,857.272***
	Sch	-37,344.219***	-9,985.283**
	Lib	17,438.768***	24,224.608***
	Wel	91,216.992***	8,306.944
	Med	741.96	-52,842.275***
	Spo	-39,851.513***	-15,275.22**
	Park	-43,300.88***	-25,934.57***
Adj-R^2		0.618	0.625
StdResid moran's I		0.277***	0.332***
Koenker		1,066.076***	577.307***

***Level of significance 1% ($p < 0.01$), **Level of significance 5% ($p < 0.05$), *Level of significance 10% ($p < 0.1$)

4. Results

Table 2 shows the results of analyzing the relationship of living SOC by housing type using the OLS model. The values of Adj-R^2 for single-family detached housing prices and apartment housing prices were similar at 0.618 and 0.625, respectively. Next, in terms of housing and location characteristics, the variable representing the distance to a bus stop was found to affect only single-family detached houses, but the housing area, distance to a subway station, and distance to a road were found to have a common effect on single-family detached houses and apartment houses. Therefore, in terms of housing and location characteristics, there is no significant difference between housing types.

In terms of accessibility of living SOC facilities, there were some differences between housing types. In the case of distance to childcare facilities, there was a positive correlation with single-family detached housing prices, but there was a negative correlation with apartment housing prices. In addition, the distance variable to elderly welfare facilities only affects the single-family detached housing prices, while the distance to basic medical facilities only affects apartment housing prices.

However, when analyzing using spatial data, it is necessary to verify the presence or absence of spatial effects. The spatial effect has spatial dependence and spatial heterogeneity (Anselin, 1988). If the OLS model is used while ignoring spatial effects, the basic assumptions are violated, the parameters and estimates are biased, and in general, the actual standard error is underestimated, resulting in false assumptions about the significance of the model. Thus, Moran's I test was used to check spatial dependence, and the Koenker (BP) test was used to check spatial heterogeneity.

As a result, Moran's I values of standardized residuals were 0.277 and 0.332, which were statistically significant at the 1% level. This means that the residuals have high static spatial autocorrelation. In addition, the Koenker (BP) value was also found to be significant, suggesting that there is spatial heterogeneity. Therefore, the global-level OLS model is not suitable for analyzing the data in this study, and the local-level GWR model is more suitable. Thus, the GWR model was used to set the spatial units as 200-m and 400-m grids.

As a result of using the GWR model, the Adj-R^2 values of 200 m

Table 3. Results of the GWR Model for Single-Family Detached Housing Price

200-m grid		Mean	Min	Max	Std
Intercept		52,856,010.986	-1,506,716.489	100,959,985.940	17,963,212.252
Housing and locational characteristics	Area	564,366.003	141,549.166	898,889.311	131,738.472
	Sub	-13,028.491	-51,621.648	64,286.428	24,138.391
	Bus	-23,341.638	-162,642.020	170,719.174	53,060.585
	Road	-211,140.360	-1,043,169.895	743,346.371	304,685.719
Living SOC accessibility	Nur	10,276.205	-100,033.988	77,512.900	29,608.938
	Sch	-11,737.970	-87,619.159	61,868.513	37,583.476
	Lib	16,927.450	-42,261.895	69,344.249	26,829.938
	Wel	36,848.383	-81,971.433	127,485.785	41,674.048
	Med	-35,399.416	-152,317.955	92,567.863	61,467.850
	Spo	10,641.786	-93,575.764	164,685.795	56,561.789
	Park	-28,260.087	-72,909.353	20,939.916	16,800.307
Local R^2		0.754	0.526	0.902	0.079
Adj-R^2			0.774		
400-m grid		**Mean**	**Min**	**Max**	**Std**
Intercept		22,625,475.359	-29,619,315.639	101,621,718.278	33,114,751.445
Housing and locational characteristics	Area	712,246.544	159,461.018	1,129,695.311	276,192.785
	Sub	-5,029.087	-40,045.426	47,865.789	15,611.161
	Bus	3,147.981	-62,697.166	73,896.134	30,590.733
	Road	41,471.891	-808,945.081	1,809,381.039	778,717.412
Living SOC accessibility	Nur	3,097.434	-46,472.712	41,233.311	17,319.981
	Sch	-6,578.675	-46,917.078	40,780.116	20,581.324
	Lib	26,683.299	-11,615.975	66,368.401	18,687.260
	Wel	5,3735.795	-18,801.123	119,873.046	30,138.003
	Med	-5,912.433	-103,719.229	85,308.868	44,719.040
	Spo	-20,087.428	-101,891.141	44,363.953	40,459.538
	Park	-37,091.179	-58,125.935	-21,842.024	9,083.543
Local R^2		0.805	0.704	0.880	0.046
Adj-R^2			0.771		

Table 4. Results of the GWR Model on Apartment Housing Price

200-m grid		Mean	Min	Max	Std
Intercept		978,296.228	-32,595,362.753	30,030,474.466	13,254,298.131
Housing and locational characteristics	Area	1562,371.687	918,585.591	1,989,488.014	249,769.345
	Sub	-6,705.439	-42,221.868	80,007.564	24,168.217
	Bus	-10,461.099	-103,857.469	132,458.573	43,039.051
	Road	237,549.503	-103,465.708	543,541.447	167,668.269
Living SOC accessibility	Nur	-21,610.717	-94,995.469	51,356.284	34,560.966
	Sch	-11,443.539	-67,515.445	63,620.965	29,488.705
	Lib	21,322.783	1,216.564	58,477.190	13,997.140
	Wel	-40,555.484	-151,355.504	71,097.048	61,504.861
	Med	-55,912.056	-141,849.723	3,407.248	28,498.400
	Spo	13,445.048	-71,270.723	131,705.289	53,540.497
	Park	-17,568.042	-39,637.768	7,331.154	9,308.026
Local R^2		0.832	0.715	0.921	0.039
Adj- R^2				0.838	
400-m grid		**Mean**	**Min**	**Max**	**Std**
Intercept		-3,631,636.251	-16,984,055.416	11,072,314.615	8,355,334.546
Housing and locational characteristics	Area	1,538,915.079	1,314,621.426	1,741,739.501	111,604.254
	Sub	-8,491.897	-20,440.202	27,893.318	12,437.896
	Bus	688.708	-62,148.813	45,000.412	26,894.175
	Road	314,521.428	214,118.619	421,668.289	70,152.581
Living SOC accessibility	Nur	-39,256.263	-64,292.885	-13,587.448	14,356.396
	Sch	4,725.492	-10,497.462	25,647.187	10,704.157
	Lib	20,760.712	10,438.986	26,834.703	4,477.870
	Wel	40,387.322	-24,719.427	102,482.261	30,299.374
	Med	-54,763.987	-73,955.077	-34,324.564	11,366.794
	Spo	-30,673.333	-65,523.800	28,279.027	26,018.012
	Park	-26,101.126	-41,278.666	-12,566.676	7,906.878
Local R^2		0.819	0.781	0.856	0.018
Adj-R^2				0.797	

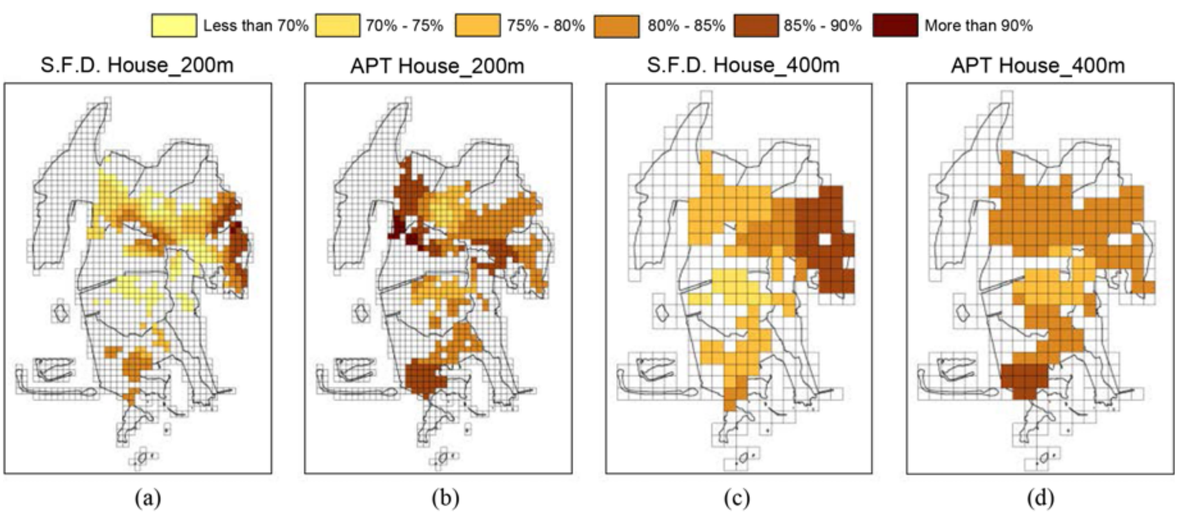

Fig. 3. GWR Local Model with 200-m Grid and 400-m Grid of Single-Family Detached and Apartment Houses: (a) S.F.D. House_200-m, (b) APT House_200-m, (c) S.F.D. House_400-m, (d) APT House_400-m

Fig 4. Results of the Local Coefficients of GWR Model for Each Living SOC

and 400-m grids were 0.774 and 0.771 for single-family detached houses and 0.838 and 0.797 for apartment houses, respectively, as shown in Tables 3 and 4. These were higher than the Adj-R^2 values of the OLS model (0.618 and 0.625), indicating that the GWR model is more suitable. As shown in Fig. 3, the range of local R^2 in the 200-m grid was up to 0.376 in the case of a single-family detached house and up to 0.176 in the 400-m grid. For apartment houses, the 200-m grid showed a larger local R^2 range than the 400-m grid, which confirms that the results for each grid size were different. Next, based on the standardized regression coefficient, the map in Fig. 4 shows how living SOC affects housing prices under a 90% significance level, and the sizes and signs of the regression coefficients vary by grid.

In some areas of Gamcheon-dong and Gupyeong-dong, in the east part of Saha-gu, a regression coefficient of (+) appeared the single-family detached housing prices with a 400-m grid, but a regression coefficient of (–) was shown in the apartment housing prices. In the case of Dadae-dong, in the north of Saha-gu, the distance to welfare facilities for the elderly did not affect the single-family detached housing prices with a 200-m grid, but a regression coefficient of (–) appeared in the apartment housing prices. Thus, it was confirmed that there is a difference in the effect of living SOC on housing prices between housing types as there are cases where the living SOC has the same effect on both housing types in a specific grid, but there are also cases where the effect is opposite or zero.

Subsequently, in some areas of Dadae-dong, in the south of Saha-gu, the distance of apartment houses to elementary school showed a regression coefficient of (–) in the 200-m grid, but they were not affected in the 400-m grid. In addition, in some areas in Hadan-dong, in the north of Saha-gu, a regression coefficient of (+) was found in the 200-m grid for the distance of detached houses to the living and sports facilities, but there was no effect in the 400-m grid. As such, it was confirmed that there are cases in which the effect of living SOC by grid size on housing prices differs.

5. Conclusions

In this study, we tried to understand the effect of accessibility of living SOC on housing prices. We tried to find a more rational plan through comparison between single-family detached houses and apartment houses, and living SOC was divided into 7 categories. This study was based on housing prices in one area, so it has limitations in generalization and applicability to other regions. Furthermore, we did not consider other critical variables in housing prices due to difficulties of data acquisition and the limited size of the study area. But despite these limitations, this study has some implications.

The three hypotheses were confirmed regarding the spatial effects, differences by housing type, and differences by space unit. To confirm the first hypothesis, the presence or absence of spatial autocorrelation was checked through the Moran's I test, and the presence or absence of spatial heterogeneity was confirmed through the Koenker (BP) test. As a result, it was confirmed that Moran's I value and the Koenker (BP) value were statistically significant for both the detached house prices and the apartment prices, indicating that there was a spatial effect.

To confirm the second hypothesis, looking at the basic medical facilities of the 400-m grid, the effects on the single-family detached housing prices and apartment housing prices in Gamcheon-dong, east of Saha-gu, were reversed. This happened because in Gamcheon-dong, where the ratio of the elderly population is high, most of the elderly live in single-family detached houses and prefer to have basic medical facilities close to their homes, and those who live in apartment houses prefer to go to large hospitals by car. For this reason, it is judged that opposite result occurred depending on the housing type. Therefore, urban planners should consider the asymmetry effect of each type of housing when establishing living SOC projects and action plans.

The third hypothesis confirmed that the results for each grid size were different because the regional determination coefficients of single-family detached houses and apartment houses were evenly distributed across the 400-m grid rather than the 200-m grid. Specifically, in the case of public libraries in Dadae-dong, the 200-m grid had negative regression coefficients for single-family detached housing prices, but the 400-m grid had no significant regression coefficients. Therefore, since the impact of living SOC on housing prices depends on the size of the grid, living SOC projects and action plans should be comprehensively analyzed and established using a variety of spatial units, not just on administrative units or districts. if we develop this research in the future and identify living SOCs, it could help us determine facilities and locations that are suitable for living SOC complex projects, which are currently focused on Smart City Urban Regeneration Projects in Korea.

Acknowledgments

This work was supported by a 2-Year Research Grant of Pusan National University.

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References

Anselin L (1988) Spatial econometrics: Methods and models (Vol. 4). Springer, Heidelberg, Germany, 16-31, DOI: 10.1007/978-94-015-7799-1

Anselin L (1999) The future of spatial analysis in the social sciences. *Geographic Information Sciences* 5(2):67-76. DOI: 10.1080/10824009909480516

Archer WR, Gatzlaff DH, Ling DC (1996) Measuring the importance of location in house price appreciation. *Journal of Urban Economics* 40:334-353, DOI: 10.1006/juec.1996.0036

Bae SY, Chung EC, Lee SY (2018) Effects of urban railway transportation services on housing prices: Case of apartments in gyeonggi province. *Journal of the Korea Real Estate Analysts Association* 24(3):85-98, DOI: 10.19172/KREAA.24.3.6 (in Korean)

Basu S, Thibodeau TG (1998) Analysis of spatial autocorrelation in house prices. *The Journal of Real Estate Finance and Economics* 17(1):61-85, DOI: 10.1023/A:1007703229507

Brunsdon C, Fotheringham AS, Charlton ME (1996) Geographically weighted regression: A method for exploring spatial nonstationarity. *Geographical Analysis* 28(4):281-298, DOI: 10.1111/j.1538-4632.1996.tb00936.x

Brunsdon C, Fotheringham AS, Charlton M (2002) Geographically weighted summary statistics — A framework for localised exploratory data analysis. *Computers, Environment and Urban Systems* 26(6):501-524, DOI: 10.1016/S0198-9715(01)00009-6

Can A (1992) Specification and estimation of hedonic house price models. *Regional Science and Urban Economics* 22(3):453-474, DOI: 10.1016/0166-0462(92)90039-4

Choi Y (1999) Perception and evaluation for residential environment conditions and public and neighborhood facilities between single detached unit dwellers and apartment dwellers. *Journal of Korea Planning Association* 34(2):79-91 (in Korean)

Choi CS (2019) A study on the relationship between house price and housing regulation policy. *Asia-Pacific Journal of Multimedia Services Convergent with Art, Humanities, and Sociology, The Convergent Research Society among Humanities, Sociology, Science, and Technology* 9(9):1031-1040, DOI: 10.35873/ajmahs.2019.9.9.088 (in Korean)

Choi Y, Seo MJ, Oh SH (2019) The correlates between walkable environments and housing price using multi-level model. *KSCE Journal of Civil Engineering* 23(10):4516-4524, DOI: 10.1007/s12205-019-1894-0

Chun HJ, Park HS (2019) A study on the expected growth rate in housing prices in metropolitan areas of Korea. *Korea Real Estate Academy Review* 76:35-44

Crompton JL (2001) The impact of parks on property values: A review of the empirical evidence. *Journal of Leisure Research* 33(1):1-31, DOI: 10.1080/00222216.2001.11949928

Dwyer MC, Miller RW (1999) Using GIS to assess urban tree canopy benefits and surrounding greenspace distributions. *Journal of Arboriculture* 25:102-107, DOI: 10.5849/jof.11-052

Evans AW (1973) The economics of residential location. Macmillan, London, UK, 59-71

Fik T, Ling D, Mulligan G (2003) Modeling spatial variation in housing prices: A variable interactions approach. *Real Estate Economics* 31(4):623-646, DOI: 10.1046/j.1080-8620.2003.00079.x

Fotheringham AS, Brunsdon C, Charlton M (2003) Geographically weighted regression: The analysis of spatially varying relationships. John Wiley & Sons, Hoboken, NJ, USA, 1-26

Gao X, Asami Y (2001) The external effects of local attributes on living environment in detached residential blocks in Tokyo. *Urban Studies* 38(3):487-505, DOI: 10.1080/00420980120027465

Gleditsch KS, Ward MD (2008) Spatial regression models. SAGE Publications, Newbury Park, CA, USA , 8-10

Graves P, Linneman P (1979) Household migration: Theoretical and empirical results. *Journal of Urban Economics* 6(3):383-404, DOI: 10.1016/0094-1190(79)90038-X

Guo Y, Tang Q, Gong DY, Zhang Z (2017) Estimating ground-level $PM_{2.5}$ concentrations in Beijing using a satellite-based geographically and temporally weighted regression model. *Remote Sensing of Environment* 198:140-149, DOI: 10.1016/j.rse.2017.06.001

Habib MA, Miller EJ (2008) Influence of transportation access and market dynamics on property values: Multilevel spatiotemporal models of housing price. *Journal of the Transportation Research Board* 2076(1):183-191, DOI: 10.3141/2076-20

Haider M, Miller EJ (2000) Effects of transportation infrastructure and location on residential real estate values: Application of spatial autoregressive techniques. *Journal of the Transportation Research Board* 1722(1):1-18, DOI: 10.3141/1722-01

Hui EC, Chau CK, Pun L, Law MY (2007) Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix. *Building and Environment* 42(6):2333-2343, DOI: 10.1016/j.buildenv.2006.05.004

Jia S, Wang Y, Fan GZ (2018) Home-purchase limits and housing prices: Evidence from China. *The Journal of Real Estate Finance and Economics* 56(3):386-409, DOI: 10.1007/s11146-017-9615-2

Kim MY, Kim EJ (2019) Does the access to neighborhood environment affect multi-family housing prices?: Comparison between Gangnam 3 districts and gangbuk 3 districts in Seoul. *Journal of The Korean Regional Development Association* 31(2):229-250 (in Korean)

Kim HS, Lee GE, Lee JS, Choi Y (2019) Understanding the local impact of urban park plans and park typology on housing price: A case study of the Busan metropolitan region, Korea. *Landscape and Urban Planning* 184:1-11, DOI: 10.1016/j.landurbplan.2018.12.007

Kim BG, Ryu SK, Hong SJ (2016) The effect of medical service accessibility on the housing price - Focused on apartment complex in Gyeonggi-do, Korea. *Korea Real Estate Academy Review* 66:188-201 (in Korean)

Lee WM, Kim KM, Kim JS (2019) A study on the housing market of seoul districts in responses to housing policies. *Journal of the Economic Geographical Society of Korea* 22(4):555-575, DOI: 10.23841/egsk.2019.22.4.555 (in Korean)

Lee CM, Ryu KM, Choi K, Kim JY (2018) The dynamic effects of subway network expansion on housing rental prices using a repeat sales model. *International Journal of Urban Sciences* 22(4):529-545, DOI: 10.1080/12265934.2018.1487331

Lee KB, Suh JY (2019) A study on improvement of disclosure pricing confirmation using housing market and urban characteristics. *Korea Real Estate Academy Review* 79:118-134, DOI: 10.31303/krear.2019.79.118 (in Korean)

Li SM, Hou Q, Chen S, Zhou C (2010) Work, home, and market: The social transformation of housing space in Guangzhou, China. *Urban Geography* 31(4):434-452, DOI: 10.2747/0272-3638.31.4.434

Luttik J (2000) The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and Urban Planning* 48(3-4):161-167, DOI: 10.1016/S0169-2046(00)00039-6

Mansfield C, Pattanayak SK, McDow W, McDonald R, Halpin P (2005) Shades of Green: Measuring the value of urban forests in the housing market. *Journal of Forest Economics* 11(3):177-199, DOI: 10.1016/j.jfe.2005.08.002

Netusil NR (2013) Urban environmental amenities and property values: Does ownership matter? *Land Use Policy* 31:371-377, DOI: 10.1016/j.landusepol.2012.07.016

Openshaw S (1984) The modifiable areal unit problem concepts and techniques in modern geography. Geobooks, Norwich

Park S, Kim M, Baek J (2017a) Application of geographical and temporal weighted regression model to the determination of house price. *Journal of the Korean Data and Information Science Society* 28(1):173-183, DOI: 10.7465/jkdi.2017.28.1.173

Park JH, Lee DK, Park C, Kim HG, Jung TY, Kim S (2017b) Park accessibility impacts housing prices in Seoul. *Sustainability* 9(2):185-198, DOI: 10.3390/su9020185

Richardson HW, Vipond J, Furbey RA (1974) Determinants of urban house prices. *Urban Studies* 11(2):189-199, DOI: 10.1080/00420987420080341

Rosen S (1974) Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy* 82(1):34-55, DOI: 10.1086/260169

Rosiers FD, Dube J, Theriault M (2011) Do peer effects shape property values? *Journal of Property Investment and Finance* 29(4-5):510-528, DOI: 10.1108/14635781111150376

Sander HA, Haight RG (2012) Estimating the economic value of cultural ecosystem services in an urbanizing area using hedonic pricing. *Journal of Environmental Management* 113:194-205, DOI: 10.1016/j.jenvman.2012.08.031

Sander H, Polasky S, Haight RG (2010) The value of urban tree cover: A hedonic property price model in Ramsey and Dakota Counties, Minnesota, USA. *Ecological Economics* 69(8):1646-1656, DOI: 10.1016/j.ecolecon.2010.03.011

Seo K, Golub A, Kuby M (2014) Combined impacts of highways and light rail transit on residential property values: A spatial hedonic price model for Phoenix, Arizona. *Journal of Transport Geography* 41:53-62, DOI: 10.1016/j.jtrangeo.2014.08.003

Sunding DL, Swoboda AM (2010) Hedonic analysis with locally weighted regression: An application to the shadow cost of housing regulation in Southern California. *Regional Science and Urban Economics* 40(6):550-573, DOI: 10.1016/j.regsciurbeco. 2010.07.002

Tian G, Wei YD, Li H (2017) Effects of accessibility and environmental health risk on housing prices: A case of Salt Lake County, Utah. *Applied Geography* 89:12-21, DOI: 10.1016/j.apgeog. 2017.09.010

Wen H, Xiao Y, Hui EC, Zhang L (2018) Education quality, accessibility, and housing price: Does spatial heterogeneity exist in education capitalization? *Habitat International* 78:68-82, DOI: 10.1016/j.habitatint.2018.05.012

Wu C, Ye X, Du Q, Luo P (2017) Spatial effects of accessibility to parks on housing prices in Shenzhen, China. *Habitat International* 63:45-54, DOI: 10.1016/j.habitatint.2017.03.010

Yuan F, Wei YD, Wu J (2020) Amenity effects of urban facilities on housing prices in China: Accessibility, scarcity, and urban spaces. *Cities* 96:102433, DOI: 10.1016/j.cities.2019.102433