Factors affecting housing prices in metropolitan regions: The case of Tehran, 2021

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This study aims to investigate the spatial distribution of housing prices and identify the factors (independent variable) affecting the cost of residential units (dependent variable). The method of the present study is descriptive-analytical and has an applied purpose. The statistical population used in this study is the residential unit prices in Tehran in 2021. For this purpose, the average per square meter of residential units in the city neighborhoods was entered in the Geographical Information System (GIS). Two techniques of ordinary least squares regression (OLS) and geographically weighted regression (GWR) were used to analyze housing prices and modeling. Then, the results of OLS and GWR models were compared using the housing price interpolation map predicted in each model and the accurate housing price interpolation map. Based on the results, the least-squares regression model poorly modeled housing prices in the study area. The results of the weight regression model show that the variables (access rate to sports fields, distance from gas station and water station) have a direct and significant effect. Nevertheless, the variable (distance from fault) has a nonsignificant impact on increasing housing prices at the city level. In addition, to identify the variables affecting housing prices, the results confirm the desirability of the GWR technique in terms of accuracy compared to the OLS technique in explaining housing prices. The results of this study indicate that the housing prices in Tehran are affected by the access level to urban services and facilities.

Introduction

In the early 1950s, the rapid growth of urban populations and migration increase (Ghaedrahmati–Zarghamfard 2020) changed the pattern of human settlement worldwide (Zarghamfard et al. 2019: p. 453). Lack of adequate housing is the first challenge posed by fast and unplanned urbanization (Meshkini–Zarghamfard 2020: p. 83) because housing is a durable, inhomogeneous, immovable, capital and consumer good that has a large share of the capital, lifelong assets of many households, costs and constant gross domestic investment (Roustaei et al. 2018: p. 86). This housing characteristic has made it a significant concern for experts and policy-makers (Zarghamfard et al. 2019, 2023b, Janakipour et al. 2022). Success in implementing housing policies requires accurate knowledge of consumers' preferences and, specifically, their housing preferences. Therefore, determining and estimating housing prices is crucial for planners and decision-makers (Malpezzi 2003: p. 69). Housing prices have significant economic and social importance, and adequate and affordable housing is essential in determining quality of life (Maher 1994: p. 13, Remenyik et al. 2021, Hakim et al. 2023). Price is one of the most fundamental variables in the land and housing sector that helps investors allocate economic resources, informing and providing the necessary signals (Roustaei et al. 2018: p. 86). Additionally, if estimating housing prices can demonstrate the share of factors affecting housing value, it should be considered in urban and regional planning and policies (Hai-Zhen et al. 2005: p. 907). There are many factors affecting housing prices in each region, but for several reasons, the importance and impact of these factors vary from region to region (Li et al. 2021, Nazemi–Rafiean 2020, Liang et al. 2018). Meanwhile, analyzing the spatial performance of the housing market is fundamental to studying the city's social and economic well-being. (Ozus et al. 2007: p. 708) In recent decades, GIS development has gradually made pricing Models a powerful tool. However, it has been less used in urban areas and environmental economies (Rahnama et al. 2014: p. 74). Affecting modeling factors for housing prices gives a clear view of the housing market system and a more accurate analysis of housing price fluctuations (Nazemi–Rafiean 2020, Karami et al. 2022, Zarghamfard et al. 2023a). One of the most practical methods of housing price modeling is based on linear regression methods and indicators such as land, area, and building orientation. The least-square method cannot accurately simulate all levels of housing prices due to the nonuniform spatial distribution of housing prices (Geng et al. 2011: p. 1). Thus, the GWR technique reflecting spatial heterogeneity is a more appropriate model for modeling housing prices (Saremi et al. 2018: p. 20).

Tehran Province has more than 20% of Iran's population. Accordingly, one of the main problems in Tehran is the lack of land for the construction of residential units. The lack of land in large cities such as the metropolis of Tehran has increased housing prices. In addition, since 2018, with an increase in inflation in Iran, housing prices have risen sharply. Today, housing prices have become a significant challenge for citizens and officials (Koohpayma–Argany 2020).

For this reason, controlling the increase in housing prices is one of the main goals of policy-makers and urban planners. The housing price index is one of the factors that planners cannot control; however, controlling this index is possible by spatial analysis of housing market performance to identify factors affecting its pricing (Saremi et al. 2018: p. 20). In different areas of Tehran, due to the diversity of environmental (Ghalehteimouri et al. 2021), physical, social, and economic characteristics, many fluctuations are observed in the housing market. Therefore, the wide fluctuations in housing prices can be considered the most prominent feature of this sector. In general, many factors play a role in determining the cost of land and housing in Tehran. Given what has been said, the primary purpose of this study is to investigate the spatial distribution of housing prices and identify the affecting factors (independent variable) on the cost of housing units (dependent variable). By examining the theoretical background on housing prices, we find that housing prices have always been considered in terms of their affecting factors, and less attention has been given to them in terms of spatial analysis. Additionally, the studies and research carried out around the research subject in the case study are more focused on the scale of neighborhood and region (Saremi et al. 2018, Koohpayma–Argany 2020, Abde Kolahchi et al. 2014), and on a larger scale, it has received less attention. Therefore, until now, there has been no research in the field of analyzing the spatial distribution of housing prices and identifying factors affecting housing prices in the Tehran metropolis using the two techniques of OLS and GWR. This study provides new research that has not been mentioned in any previous studies. Therefore, the current research was conducted to investigate the spatial distribution of housing prices and identify the variables (independent variables) affecting the price of residential units (dependent variable). To model housing prices and analyze the independent variables of housing prices, two techniques, GWR and OLS, were used. The main questions of this study are as follows: What is the spatial distribution of housing prices in the Tehran metropolis? What factors affect housing prices? Is the GWR method more explanatory than the OLS technique?

To date, several studies have been conducted in the field of housing and various aspects of its subject, especially the housing price index. It can be said that research on housing prices and the factors affecting them dates back to the 1970s. In 1970, people such as Kain and Quigley, in 1973, Estrazheim in San Francisco, and Hushak and Sadr in Ohio, in 1979, performed some studies in this area (Saremi et al. 2018: p. 24). Researchers have always considered housing prices and the factors that affect them. They have dealt with this issue in different ways. Rosen first used the hedonic model in 1974 to study and analyze many aspects of the housing market, such as taxes, commodity prices, public facilities, and housing quality (Akbari et al. 2004: p. 99). Gaspareniene et al. (2014) have compared the selected models of housing market factors and presented the principles of housing price formation in countries with economies in transition and had a critical view of housing market models. Wen–Goodman (2013) estimated the relationship between housing and land prices using a two-stage least squares. Wong and Jiang used the econometric model and seven explanatory variables of household income, land transaction price index, cost construction, urbanization rates, interest rates, housing consumer price index (CPI), and investment to find the factors affecting housing prices (Wang–Jiang 2016). Hu et al. (2012) used an improved spatial Durbin model to examine the impact of landscape on property value.

Some researchers have proposed the GWR model to address the weaknesses of the hedonic model, and they introduced the OLS technique (Brunsdon et al. 1996, 1998, Wheeler–Tiefelsdorf 2005). To date, this model has been used in many different subjects, such as environmental sciences (Gao et al. 2012, Wang et al. 2013), medical sciences (Goli et al. 2013, Liu et al. 2020), geographical phenomena (Nakaya 2001), financial resources and economics (Yrigoyen et al. 2007). In addition, some researchers have used the GWR model to study housing prices (Bitter et al. 2006, Geng et al. 2011, Wu et al. 2018). To date, several studies have been conducted on housing prices and their affecting factors. According to the conducted studies, some factors, such as internal direct factors (land price, construction costs, profits and taxes) and external indirect factors (residents' income, population and GDP) (Jiang–Qiu 2022), proximity to various facilities (Parks, lakes, shops, banks, secondary schools, and rail transportation (Liang et al. 2018), proximity to cultural and medical buildings (Kusan et al. 2010), housing supply and demand (Wang–Zhang 2014), macroeconomic factors (Gaspareniene et al. 2017), physical quality and spatial factors (Rahadi et al. 2014), access to railways (Debrezion et al. 2010), educational facilities (Wen et al. 2014b), natural landscapes such as lakes (Wen et al. 2014a), demographic changes (Mariadas et al. 2016), access index (Adair et al. 2000), local unit or block size (Law 2017), Liao residential unit floor area (Liao–Wang 2012), and the number of residential units (Gibler et al. 2014), had a positive and significant effect on housing price fluctuations. However, in other studies, some factors, such as power generation in wind farms (Sunak–Madlener 2015), National Railway Station, Airport, and Shipping Port (Efthymiou–Antoniou 2013), have negative effects on the value of surrounding housing due to various types of pollution. Studying and recognizing the factors affecting housing prices in any geographical area can be influential in urban planning and policy-making. In addition, at the national level, modeling the factors affecting housing prices can help policy-makers and urban planners control changes. The cost of the housing market and preventing the urban housing crisis in the city of Tehran will be beneficial. It will also lead to an increase in knowledge about the housing sector globally.

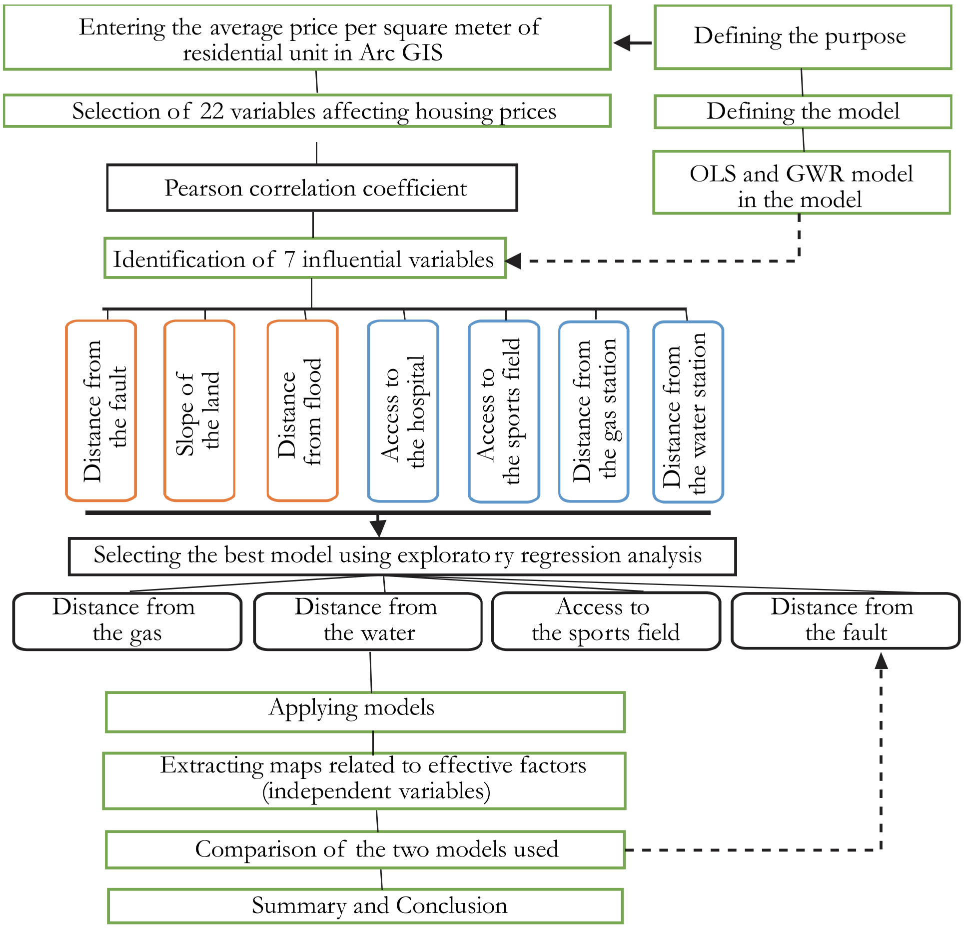
Theoretical findings

The land is the starting point of any urban development. Land is a commodity with unique characteristics that distinguish it from other commodities. Some of these characteristics are limitation on the surface, immovability, and dependence of human life on the earth's existence and immortality. (Saremi et al. 2018: p. 24) housing is a multidimensional concept (a buildable and destructible commodity, production and consumption, perception and experience, buying and selling) that indicates the most basic human need and greatly impacts human well-being (Nazemi–Rafiean 2020: p. 4). Housing also plays an important role in the economy (Bitter et al. 2006: p. 2). In general, housing prices are determined based on the supply and demand in the land and housing market and are affected by macroeconomic variables such as income, population, and construction costs (Wen–Goodman 2013: p. 10). The lack of proper planning and policy-making in the housing sector, especially in developing countries (Zarghamfard et al. 2019: p. 455), has highlighted spatial inequality in cities, accelerating spatial changes in housing prices. Rapid growth and spatial changes in housing prices have always interested managers, researchers, developers, and residents (Li et al. 2021: p. 1). On the other hand, a limited and almost constant supply of land for high demand will increase housing prices (Wen–Goodman 2013: p. 9). Home price is a function of the inherent characteristics that will bring the most profit to buyers. Some features, such as location, accessibility, physical structure, and neighborhood, lead to differences in housing prices in different parts of the city. These characteristics influence the decision of individuals and families to choose their home location (Cellmer et al. 2020: p. 3, Bitter et al. 2006: p. 8). Thus, understanding the affecting mechanisms of spatial changes in housing prices is essential for formulating scientific housing policies, segmenting submarkets, optimizing urban spatial plans, allocating public infrastructure, and standardizing spatial resources (Li et al. 2021: p. 1). In general, the spatial characteristics of a residential unit are closely related to its price (Wu et al. 2018: p. 1). It is important to study the spatial prices for accurate observation and to determine the affecting factor (Saremi et al. 2018: p. 24). affecting factors on housing prices can be divided into two categories: the first category is the fundamental factors that are determined by the forces of supply and market demand, and the second category is nonfundamental factors that are not related to the economic performance of housing but include the forces that affect housing prices outside of housing sector performance. The fundamental affecting factors on the housing market range from macro to micro. Factors such as monetary policies and interest rates on bank deposit returns are among the fundamental factors on a macro scale. At the microscale, factors such as building density also affect the housing pattern (Roustaei et al. 2018: p. 87). In preliminary studies, the factors affecting housing prices included location, neighborhood, and architectural features (Wu et al. 2018: p. 1). At the level of urban neighborhoods, some other factors can be considered: proximity to retail stores, a mixture of facilities, and its undeniable impact on housing prices (Abde Kolahchi et al. 2014: p. 73). Additionally, in traditional theories of housing prices, the change in distance from downtown and the main accesses are the main causes of the difference in housing prices. Accordingly, the distance from the city's commercial center causes spatial changes in housing prices. (Saremi et al. 2018: p. 24) Facilities and equipment such as transportation, educational, medical, commercial, etc., can increasingly affect the housing market (Liang et al. 2018: p. 2). Other factors that affect housing prices include environmental quality and pollution (Cellmer et al. 2020: p. 3, Thakur–Das 2022).

In general, the most important factors that affect the land and housing market are 1) Environmental factors: Housing location affects housing prices (Kamal et al. 2016: p. 1678); one of the important environmental and natural factors is the proximity or geographical location of land and its altitude, each of which has a special effect on housing and land prices. Therefore, one of the factors in housing price differences between northern and southern Tehran is environmental and natural factors. 2) Physical factors. Among the physical indicators that affect housing prices can be access to urban facilities and services, distance from downtown, type of use (commercial, residential, etc.), building quality, size, land access, a large number of houses vacancy, the rapid depreciation of housing, the continued use of old technologies and the rising prices of construction institutions, are some factors each of which will have a positive and negative impact on the land and housing market. 3) Economic factors: Economic factors affecting land and housing prices include the level of economic activity, the price of construction materials, the wage rate of manpower in the city, economic sanctions, wars and conflicts, inflation, banking facilities, investment, and capital accumulation, the lack of optimal allocation of financial resources, the existence of multilayered speculation and intermediation, the land hoarding phenomenon, the existence of deviations in banking facilities, and so on. 4) Sociodemographic factors. Social factors include the preference for social benefits such as the presence of a certain class concentration in a particular part of the city (Farhangian town or cultural class), social pollution (presence or absence of crimes and deviations in urban areas), high status and social position, migration (housing of migrant villagers in marginal or inadequate housing), the desire of young families to live in independent units, lack of public participation in housing planning, the existence of a psychological atmosphere based on the constant increase in housing prices, lack of a clear social policy and correctly pointed out in the field of urban housing (Khakpour–Samadi 2015: p. 25). 5) Office program. Factors such as lack of programs, the inefficiency of the Supreme Housing Council, lack of statistics and information, inconsistency of laws and policies, inconsistency between housing supply and demand, and competitive pressures on land and housing have affected housing prices (Kamal et al. 2016: p. 1678). Therefore, land and housing prices are affected by different conditions and factors, and at different times and places, prices will also be different (Nikpour et al. 2018: p. 94). Therefore, some points that have high or low prices can be analyzed and examined (Ozus et al. 2007: p. 707). It is possible to solve some issues related to housing by determining the effective factors and estimating the price of housing units and to facilitate policy-making in this area. On the other hand, by estimating the affecting factors of housing prices, a tool can be provided to the city authorities and officials to determine taxes and duties according to the impact of each feature of the housing unit on its price (Pourmohamadi et al. 2014: p. 88).

Figure 1

The theoretical framework of the research



According to the definitions presented in the theoretical section, to clarify the importance of the factors affecting housing prices, and to examine the results of the research carried out in the field of housing and its various aspects, this research has been conducted based on 4 variables. The spatial distribution of housing prices and the identification of factors affecting the prices of residential units in the Tehran metropolis should be investigated in the form of Figure 1.

Materials and methods

Research method

The method of the present research is descriptive-analytical, and it has an applied purpose. The statistical population used in this research is the price of residential units in Tehran in 2021:

1. The average square meter of residential units at the level of the city's neighborhoods, which was gathered through the database of 100 real estate consultant offices, was entered into the GIS.
2. By studying the relevant theoretical and experimental texts, the variables affecting housing prices were extracted, and after accessing information, 22 independent variables were identified.
3. The related maps were prepared and adjusted using Arc GIS software.

Since the impact of visual indicators in the urban environment is of considerable importance on housing prices, this study focuses on visual indicators with high reliability. Therefore, 22 variables affecting housing prices were extracted by studying related theoretical and empirical texts. The identified independent variables were derived using the Spatial Analyst Tools plugin and Surface, Interpolation, and Distance tools in Arc GIS software. Then, their relationship with the dependent variable of housing price was examined using the Pearson correlation coefficient in SPSS software, and seven influential variables were identified. The variables used are shown in Table 1 and are depicted in Figures A1 and A2 in the Appendix for better understanding. After reviewing the significance of the relationship between independent and dependent variables, exploratory regression tools were used to select the best regression line for housing price modeling. Accordingly, all possible and correct combinations of independent variables were extracted simultaneously with different tests, and the allowable values were determined for each test. After exploring the accepted regression models, the best model with the AdjR2 was selected, and its variables were used to construct a general regression model with the OLS technique and a local regression model with the GWR technique. Finally, the results of the OLS and GWR models were compared using the housing price interpolation map predicted in each model and the accurate housing price interpolation map.

Table 1

The variables used in housing price modelling in Tehran, 2021

Factor	Housing price (depended variable)	Average price per square meter of housing unit in the city neighborhoods in 2021
Environmental factors	Land slope	The extracted amount value from each sampled point generated from the zoned map of the land slope in the study area by the use of Slope method
	Distance from faults	The distance of a residential unit from the active faults in the city based on the Euclidean distance
	Distance from situations where floods are likely to occur	Distance of residential unit from situations where floods are likely to occur using Euclidean distance
Physical factors	Access to hospitals	Distance of residential unit from the nearest hospital based on Euclidean distance
	Access to sports fields	The distance of a residential unit from the nearest sports field based on the Euclidean distance
	Distance from the gas station	Distance of the residential unit from the nearest gas station based on the Euclidean distance
	Distance from water station	Distance of residential unit from the nearest water station based on Euclidean distance

Source: Tehran Municipality, 2021; Authors' calculations.

Geographically weighted regression (GWR)

Multivariate regression models are divided into two categories: local regression models and global regression models. One of the crucial general regression models is the OLS model, which has been widely used in housing price modeling. The most apparent problem with the OLS model happens when it is used in geographic and tangible spaces, such as housing prices. The problem is the assumption of fixed modeling environmental conditions that fit a general regression line without considering geographical distributions. However, the theoretical basis of the OLS technique is precise and attractive. However, its application in the field of housing due to the existence of two phenomena of spatial autocorrelation and spatial heterogeneity is often difficult to specify in housing statistical information (Saremi et al. 2018: p. 26). The GWR has many advantages in comparison to the OLS model. The GWR considers the coefficient of determining variables for the local difference by giving more weight in relation to geographical observations. Therefore, it quickly draws spatial patterns and is helpful and practical in calculating and evaluating spatial hypotheses (Rahnama et al. 2014: p. 76). Fotheringham provided the GWR model for the first time. He tried to study the spatial heterogeneity aspects. Then, Brunsdon and Fotheringham examined the relationship between housing prices and the areas, and they encountered several model issues that included the choice of variables, bandwidth, and spatial autocorrelation error. Zhang used this model to study altitude. The results showed that the technique (GWR) could better understand the OLS model's residual error (Geng et al. 2011: p. 1). In general, GWR is a statistical technique that pays much attention to geographical locations in regression parameters and considers the effects of an explanatory variable in different areas (Jun et al. 2018: p. 505). The GWR model can be shown as follows (Equation 1):

$$y_i=\beta_0(u_i.v_i)+\sum_k \beta_k (u_i.v_i)x_{ik}+\varepsilon_i \quad (1)$$

where $(u_i.v_i)$ is the coordinate of the sample space $\beta_0(u_i.v_i)$ in the value of i in the continuous function $\beta_k(u_i.v_i)$. If $\beta_k(u_i.v_i)$is the same for all places, it will be a global regression model. In the mentioned model above, an observation with proximity to i is defined. Thus, the weight of an observation changes with a change in i, and its equation is followed as follows (Equation 2):

$$\beta_0(u_i.v_i)=(X^T W(u_i.v_i)X)^{-1}x^T w(u_i.v_i)y \quad (2)$$

While:

$$X=\begin{bmatrix} 1 & x_{11} & \dots & x_{11} \\ 1 & x_{21} & \dots & x_{21} \\ \dots & \dots & \dots & \dots \\ 1 & x_{n1} & \dots & x_{n1} \end{bmatrix},\ Y=\begin{bmatrix} y_1 \\ y_2 \\ \dots \\ y_n \end{bmatrix}$$

$$W(u_i.v_i)=W(i)\begin{bmatrix} w_{i1} & 0 & \dots & 0 \\ 0 & w_{i2} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & w_{in} \end{bmatrix}$$

$$\beta=\begin{bmatrix} \beta_0(u_1.v_i) & \beta_1(u_1.v_i) & \dots & \beta_k(u_1.v_i) \\ \beta_0(u_2.v_2) & \beta_1(u_2.v_2) & \dots & \beta_k(u_2.v_2) \\ \dots & \dots & \dots & \dots \\ \beta_0(u_n.v_n) & \beta_1(u_n.v_n) & \dots & \beta_k(u_n.v_n) \end{bmatrix}$$

β_0 is the estimated value of β ، n is the number of samples, k is the number of variables, and $w_{in}$is the weight of n with respect to i. The GWR equation can be simplified as follows (Equation 3):

$$y=\beta_0+\beta_1x_1+\beta_2x_2+\ldots+\beta_nx_n+\varepsilon \quad (3)$$

In the above equation, Y is considered a dependent variable, β is a correlation coefficient, X is an independent variable and ε is a random error (Rahnama et al. 2014: p. 77, Geng et al. 2011: p. 1, Liang et al. 2018: p. 3).

The housing price situation and introduction to the study area

Tehran is the capital and the political/economic center of Iran. It is the most populous city in West Asia, with an area of 1,336 square kilometers, between 35 degrees and 30 minutes to 35 degrees and 57 minutes in north latitude and between

51 degrees and 4 minutes to 51 degrees and 46 minutes in the eastern side of the Greenwich meridian. The city is bounded by the Alborz Mountains from the north, east by Lavasanat, west by Karaj, and the south by Varamin. The current area of Tehran extends from an altitude of 900 to 1,800 meters above sea level. According to the last census in 2017, the population of Tehran was 8.8 million. Currently, Tehran is the capital of Tehran province and Tehran city and is divided into 22 districts, 123 regions, and 375 neighborhoods in terms of administrative divisions. In general, reputable Iranian companies and commercial centers are located in the northern regions of Tehran, and the wealthiest people live in this area. The city center, which is densely populated, includes Bazar, ministries, and government headquarters. The southern regions are also primarily residential neighborhoods, and city newcomers live in this area. The reason for choosing the Tehran metropolis in the present study is its construction diversity, residential pattern, and severe fluctuations in housing prices. Based on the average per square meter of a residential unit at the level of 375 urban neighborhoods in this area in 2021, the price per square meter of a residential unit with an average and deviation from the standard fluctuates between 32 and 16 million Tomans, respectively. The high standard deviation indicates excessive dispersion of housing prices in the study area. Based on this, the highest price per square meter of a residential unit is 90 million Tomans, and the lowest is 12 million Tomans (Figure A3 in the Appendix).

Analysis of research findings

After extracting 22 independent variables from the ArcGIS software, Pearson's correlation method was used in SPSS software to check the meaningfulness of their relationship with the dependent variable, intensity and type of relationship. Therefore, 7 independent variables were selected, and the variables that were not statistically meaningful and had a weak correlation were removed. Most independent variables have a significant linear relationship with the dependent variable at the 95% level. Regarding the coefficients and the direction of the effect of the variable, it can be said that the dependent variable is similar. Housing price has a direct and positive relationship with the other variables, such as access to the hospital and distance from the gas station, and there is an inverse and negative relationship with different variables, such as distance from places where there is a possibility of flooding, distance from faults, access to sports fields, land slope, and distance from water.

To determine the distribution pattern of all research variables, the Moran I spatial autocorrelation method was calculated. This index varies between 1 and –1, so a value close to 1 indicates a cluster pattern, a value smaller than zero indicates a scattered pattern, and zero indicates a random pattern. The results suggest that all the variables have a cluster distribution pattern, and the obtained Moran's I value is close to 1 (Table 2). In this way, the GWR method can be used to estimate the model.

Table 2

The variables used in housing price modeling and their spatial autocorrelation results in Tehran, 2021

Pattern	P value	z score	Expected I	Moran's I	Variable type	Variable
Clustered	0.0000	31.50	–0.002674	0.873872	Dependent	Housing price
Clustered	0.0000	20.31	–0.002674	0.556378	Independent	Land slope
Clustered	0.0000	33.29	–0.002674	0.926353	Independent	Distance from faults
Clustered	0.0000	32.15	–0.002674	0.894245	Independent	Distance from situations where floods are likely to occur
Clustered	0.0000	26.54	–0.002674	0.732218	Independent	Access to hospitals
Clustered	0.0000	31.43	–0.002674	0.870948	Independent	Access to sports fields
Clustered	0.0000	30.53	–0.002674	0.846204	Independent	Distance from the gas station
Clustered	0.0000	33.40	–0.002674	0.915219	Independent	Distance from water station

The exploratory regression analysis tool in Arc GIS software was used to choose the best linear regression model in the following part. According to the different tests and the allowed values mentioned in Table 3, the best model with the highest value of the adjusted determination coefficient of 0.62 was selected, and its variables (distance from the fault, access to sports fields, distance from the gas station and the distance from the water station) were used in building the general regression model with the OLS technique and the local regression model with the GWR technique.

Table 3

Allowed values used in exploratory regression, 2021

Denomination	Value
Adjusted R Square	0.5
Maximum coefficient p value cutoff	0.05
Maximum variance inflation factor (VIF) value cutoff	7.5
Minimum Acceptable Jarque-Bera p value	0.1
Minimum acceptable spatial autocorrelation p value	0.1

The results of the OLS regression model indicate that all of the variables' coefficients are 95% meaningful at the probability level. In general, this model (P value<0.05) is significant. VIF test values mean that there is no linear correlation between independent variables. The results of Koenker's test and the meaningfulness of this test (P<0.05) indicate the presence of heterogeneity in the distribution and instability of relationships in the model. The statistical meaningfulness of the Jarque-Bera test also shows the nonnormality of the distribution of the remaining values and the desirability of this model in modeling housing prices in the studied area (Table 4). Therefore, GWR weighted regression is necessary to solve this problem. Figure A4 in the Appendix, produced using the hot spot analysis method, indicates the areas where the OLS model did not perform well in explaining housing prices. The analysis results of the hotspot analysis map showed that the hotspots with a confidence percentage of 99% formed clusters of hotspot stains. The highest concentration of hotspots (the highest price) is in a part of the north of the city, i.e., in the neighborhoods of Niavaran, Jamaran, Chizar, Farmaniyeh, Ekhtiyarieh, Gholhak, etc. The yellow points, which are considered nonsignificant, cover a large part of the city's surface (including Mahallat Enghelab, Jamal Zadeh, Keshavarz, Kouhak, Ekbatan, Dehkade-Olympic, etc.). Additionally, the cold spots with 99% confidence formed cold stain clusters. The highest concentration of these (the lowest price) is observed in the eastern part of the city, such as Abuzar, Shahed, Afsarieh, Moshriyeh, and Hashemabad.

Table 4

The housing price modeling results using OLS, 2021

VIF[a)]	Probability	t-Statistic	Coefficient	Variable
1.48	0.000	–9.74	–16,560.9	Distance from faults
2.21	0.000	13.81	50,023.9	Access to sports fields
2.21	0.000	–6.58	–24,256.2	Distance from the gas station
1.14	0.000	–10.71	–29,218.2	Distance from water station
0.62		Multiple R-Squared		
0.61		Adjusted R-Squared		
–0.000145137		The sum of the remaining squares		
14,887.67		AICc[b)]		
0.000	Probability	91.36		Koenker Statistic
0.000	Probability	14.03		Jarque-Bera Statistic

a) Variance inflation factor.
b) R-Squared and Akaike's Information Criterion.

The first output from the GWR method is the general information related to the model. The most important values in this output are the R2, adjusted R2 and AICc, which determine the model's effectiveness. The closer the adjusted R2 values are to number one and the lower the AICc value, the more reasonably the used independent variables have been able to explain the changes in the dependent variable. The adjusted R2 and R2 values obtained in this research are 0.77 and 0.75, respectively, which indicate the acceptable accuracy of the research variables in modeling the factors affecting housing prices. Additionally, the greater the adjusted R2 increases and the residual sum of squares decreases, the error reduction and accuracy increase in the GWR model. In the following part of this method, model coefficients were calculated for each of the actual observed values. According to Table 5, the amount and direction of the independent variable's influence are different in various parts of the investigated area. A variable such as the distance from the fault and the distance from the gas station has positively affected housing prices in some parts of the area but has had a negative effect and reducing impact in others. The obtained results show that the two variables of access to sports fields and distance from the water station have less spatial heterogeneity than other independent variables due to the same direction of influence in all areas of the area.

Table 5

Results of housing price modeling by GWR, 2021

Variables	Coefficients				
	minimum	lower quartile	median	upper quartile	maximum
Intercept	126,987,174.8	371,013,436.3	448,957,960.6	526,902,485.0	770,928,746.4
Distance from the fault	–42,042.2	–23,500.7	–17,578.4	–11,656.04	6,885.8
The access to sport fields	2,7531.6	40,285.8	44,359.7	48,4333.5	61,187.8
The distance from gas station	–54,698.1	–30,774.6	–23,133.2	–15,491.8	8,431.6
The distance from water station	–41,257.5	–28,809.8	–24,833.9	–20,857.9	–8,410.2
Residual Squares			2.3		
Sum of residual squares			–629,013,766.4		
AICc			14,732.25		
R2			0.77		
R2Adjusted			0.75		

Suppose the estimated coefficients of the independent variables are positive. In that case, it indicates that the share increases of the independent variable in the investigated range lead to a rise in the share of the dependent variable. Suppose the estimated local regression coefficients are negative. In that case, by increasing the percentage of the independent variable, the share of the dependent variable will decrease in the desired range. Additionally, in some cases, the local coefficients are close to zero, which indicates that the studied variables do not affect the local fluctuations in the GWR model.

The estimated local regression coefficients for the variable distance from the fault and the housing price indicate that in most northern neighborhoods, such as Niavaran, Farmaniyeh, Darabad, Jamaran and Qeytariyeh, the land price will decrease with increasing distance from the active faults. Despite the location of districts 1, 2 and 3 on the eastern fault of Tehran, which is one of the most dangerous faults in Tehran, they have the highest housing prices. The high price of housing in these areas depends on several reasons, including the price of land, the quality of materials, the concentration of facilities, equipment, welfare and recreational services, the concentration of investment, the high quality of life, etc. In southeastern neighborhoods such as Moshiriyeh, Dolat-Abad, Ali-Abad and Northern Afsariyeh, housing prices increase due to the lesser distance from the fault. In justifying the high housing prices in these areas, we can mention the high population density and the concentration of commercial markets. In general, housing prices in the Tehran metropolis have not been affected by the factor of distance from the fault.

The estimated local regression coefficients for the variable of access to sports fields and housing prices indicate that in the north, south and center of the city, including districts 2, 10, 11, 12, 16, 17 and 19, the increase in access to sports fields will also increase housing prices. The existence of urban services and equipment, comfort, medical, educational facilities and the high concentration of population in these areas have been effective in increasing housing prices. Due to the lack of sports fields in the eastern and western areas of the city, with the increase in access to sports fields, the price of housing increases to a lesser extent. In general, access to sports fields in the studied area positively affects housing prices.

For the variable distance from the gas station and housing price in most of the northern neighborhoods such as Saadat-Abad, Evin, Darband, Zafaranieh, Qitariyeh, Farmaniye and Darabad, the price of housing increases as the distance from the gas station decreases. Due to the lack of gas stations in the southwestern areas, such as districts 12, 13, 14, 15, 16, and 20, housing prices increase slightly as the distance decreases. The slight increase in housing prices in these areas is probably due to the presence of undefended urban areas, visual disturbances, cement factories, sellers' waste, and the high level of old fabric.

For the variable of distance from the water station and housing price, the coefficients show that in the city center (districts 6, 7, 8, 10, 11, 12 and 13), we see an increase in the housing price as the distance from the water station decreases. Housing prices are lower in the peripheral areas of the northern neighborhoods of the city, such as Darband, Zafaraniyeh and Valenjak, and the southern regions, especially the neighborhoods of Sheikh Sadough, Beheshti, Abbas-Abad, Taghi-Abad, Shahid Avini and Estakhar, because of the increase in the distance from the water stations (Figure A5 in the Appendix).

Comparing the results of the GWR model with the OLS model

According to the results of the GWR model, the values of R2Adjusted and AICc from this model that was used with the 4 variables of the previous model were calculated at approximately 0.75 (14% improvement of the model) and 14,732.25 (155.42 unit reduction). A lower value of AICc indicates a better fit of the model, and a higher value of the adjusted determination coefficient is superior to other models. Therefore, it can be said that the GWR model has a higher efficiency than the OLS model. To perform a better comparison, the zoning method was used. In Figure A3 in the Appendix, using the kriging interpolation method, the housing price is zoned for all the observed values predicted by the OLS and GWR techniques. The results show that there is more objective similarity between the predicted values by the GWR model and the predicted values by the OLS model. For example, housing prices in the south and southeast parts of Tehran in areas such as district 14 (neighborhoods of Abuzar, Shahed, Chaharsad Dastgah, Taxirani and Qasr-e-firoozeh) and district 15 (neighborhoods of Mesgharabad, Masoudieh, Razaviyeh and Islamabad) and in the western part of the city, such as District 21 (neighborhoods of Esteghlal town, University town, Chitgar, Vard-avard, Vilashahr and Ghazali), are not well explained in the OLS method. In contrast, the GWR model has efficiently explained housing prices. In this model, housing prices in region 1 (Zafraniyeh, Tajrish, Mahmoudieh, Valenjak and Bagh Ferdous neighborhoods) are well shown. The highest housing prices are related to the northern part of the city, which is due to the concentration and accumulation of urban facilities and services, including welfare, medical, cultural, recreational and educational services, the existence of many public parks, lack of pollution, crime reduction, quality, suitability and standard of housing buildings in these areas is of high value. On the other hand, the price of housing in the southern parts of the city, such as districts 16, 17, 18 and 20, is low due to the low durability of materials and the long life of buildings, unfavorable visual quality, lack of fair and equal access to urban facilities and services, the presence of various types of pollution, delinquency and lack of security. As a result of this trend, a heterogeneous and unbalanced spatial organization has been formed in Tehran, which shows the disparity in the price of land and housing and the spatial gap between the north and south of the city. If efficient management and a systematic approach to housing planning and policies are not put in place, the problem of spatial inequalities in Tehran will not be solved.

Conclusion

The rapid growth of cities and the urban population increase in the last century have resulted in the transformation of the patterns and system of settlements. This evolution continues in the world's countries with a different rhythm and quality. Therefore, access to suitable and cheap housing is a common concern of all nations, especially third-world countries. Land is an intermediary commodity in housing, building and space production. Because of this, the price of land will significantly impact the cost of housing in areas where the intensity of land usage is very high. The supply and demand of land are also influential in housing valuation. Therefore, the limited and almost constant land supply against its high demand increases housing prices. However, housing prices are different from one point to another due to other economic, social, physical and environmental characteristics. Urban spatial characteristics are effective in housing price fluctuations at the city level. Thus, understanding the effective mechanisms of the spatial changes in housing prices is necessary for formulating housing policies, dividing submarkets, optimizing urban spatial plans, allocating public infrastructure and equalizing spatial resources. This research aims to investigate the spatial distribution of housing prices and identify the factors that affect residential unit prices in Tehran.

For this purpose, two regression models, OLS and GWR, were used, and finally, the two mentioned models were compared with each other. To follow the abovementioned goal, 22 housing price variables were extracted from related theoretical and experimental texts. Then, the meaningfulness of their relationship with the dependent variable (housing price) was investigated using the Pearson correlation test. Based on the results of this test, 7 influential variables are meaningful at the 95% probability level. In the following, the experimental regression method was used to select the best variables for building the model, and the best linear regression model was chosen using 4 out of 7 variables. Then, the linear regression model was created using both OLS and GWR techniques. The results show the following points:

1. The distribution of housing prices in Tehran will generally decrease with increasing distance from active faults in most northern neighborhoods, such as Niavaran, Farmaniyeh, Darabad, Jamaran and Qeytariyeh. Districts 1, 2 and 3, located on the eastern fault of Tehran (one of the most dangerous faults of this province), have the highest housing prices. The high price of housing in these areas depends on several reasons, including the price of land, the quality of materials, the concentration of facilities, equipment, welfare and recreational services, the concentration of investment, the high quality of life, etc. In southeastern neighborhoods such as Moshiriyeh, Dolat-Abad, Ali-Abad and Northern Afsariyeh, housing prices increase to a lesser extent as the distance from the fault decreases. In justifying the high housing prices in these areas, we can mention the high population density and the concentration of commercial markets. In general, housing prices in the Tehran metropolis have not been affected by the factor of distance from the fault. This result is inconsistent with studies such as Sunak–Madlener (2015) and Efthymiou–Antoniou (2013) and does not support them.

2. In the north, south and downtown districts 2, 10, 11, 12, 16, 17 and 19, housing prices will also increase with increased access to sports fields. The existence of urban services and equipment, comfort, medical, educational facilities and the high concentration of population in these areas have been effective in increasing housing prices. Due to the lack of some sports fields in the eastern and western areas of the city, with the increase in access to sports fields, housing prices increase to a lesser extent. In general, access to sports fields in the studied area positively affects housing prices. Based on the research results, the variable importance of access to sports fields in determining housing prices confirms the results of previous studies (Liang et al. 2018, Cho et al. 2009).

3. In most of the northern neighborhoods, including Saadat-Abad, Evin, Darband, Zafaraniyeh, Qeytariyeh, Farmaniyeh and Daraband, housing prices increase as the distance from gas stations decreases. Due to the lack of gas stations, housing prices

increase slightly as the distance decreases in southwestern districts such as 12, 13, 14, 15, 16, and 20. The slight increase in housing prices in these areas is probably due to the presence of undefended urban areas, visual disturbances, cement factories, sellers' waste, and the high level of old fabric.

4. In the downtown area (districts 6, 7, 8, 10, 11, 12 and 13), we see an increase in housing prices as the distance from the water station decreases. In the peripheral areas of the northern neighborhoods of the city, such as Darband, Zafaraniyeh and Velanjak, and the southern regions, especially the neighborhoods of Sheikh-Sadough, Beheshti, Abbas-Abad, Taghi-Abad, Shahid Avini and Estakhar, housing prices decrease with increasing distance from the water stations. Some research results, such as those (Li et al. 2019, Munshi 2020), are similar and consistent with the findings obtained in this study. In general, infrastructure and amenities significantly impact the value of land and housing.

To compare the two used models, various tests and methods were performed, such as the adjusted coefficient of determination, the value of the AIC index, and the comparison of the similarity of the housing price zoning maps used with both models with the housing price zoning map based on actual observations. Based on the OLS linear regression method, the adjusted coefficient of determination is 0.61, and the index value is 14,887.67. Nevertheless, using the GWR model in housing price modeling, an increase of 14 percent is adjusted in the determination coefficient of 0.75, and a decrease of 155.42 units is predicted in the AIC index. The values of 14,732.25 indicate that the GWR model is more favorable than the OLS model. The zoning that uses the kriging interpolation method also shows the similarity of the housing price zoning by the predicted values of the GWR model with the housing price zoning map based on the observed values.

In general, the findings are similar to the results of previous research (Bitter et al. 2006, Saremi et al. 2018, Nikpour et al. 2018, Geng et al. 2011). According to the present research results, housing prices in Tehran are affected by access to urban services and facilities. In this way, the imbalance in the availability of facilities has caused a significant difference in housing prices among neighborhoods. Therefore, paying attention to the mentioned variables in housing economic studies and preparing related plans and programs are necessary. In addition, housing prices are not affected by the distance from the fault factor. Many expensive houses are located on high slopes and near faults. The reason for this is rooted in the history of the city of Tehran. In the past, the presence of abundant water, many gardens, and various hunting grounds attracted the attention of Iranian kings to this region. Initially, the favorable weather in northern Tehran attracted countryside residents in the summer. Since it was impossible for all people to build houses in the countryside, prosperous families bought land and built villas in these areas. In this manner, villages were formed in northern Tehran. At that time, the suitable neighborhoods for living in Tehran were concentrated in the center of the city. However, gradually, with the population increase in the city center, the desire to live in northern Tehran inflated. With the migration of the people who lived in the center to the north of Tehran, rural life gave way to urban life, and the price of land and housing gradually increased and northern Tehran became the residence of the rich. Additionally, in the present, due to inefficient management, land prices, tolls, materials and wages, the concentration of facilities, equipment, welfare, and recreational services, the concentration of investment, high quality of life, and high social status of residents, housing prices in these areas are heightened. These conditions have brought spatial disparity between different areas of Tehran. Tehran city has developed rapidly without creating proper systems to prevent disasters caused by possible earthquakes. It should be noted that the southern areas of the city are at greater risk due to the insufficient strength of buildings, high population density, and fine-grained and compact texture. Therefore, it is necessary to prepare a plan to prevent disasters and damage caused by earthquakes. Securing and considering environmental conditions can prevent the occurrence of crises. Finally, paying attention to spatial factors and neighborhood relations at the neighborhood level effectively adjusts housing prices and increases residence quality. As a result, spatial factors and neighborhood relations effectively guide modernization processes in urban contexts.

Since the city is a system, changes and fluctuations in any aspect can affect other parts. Therefore, it is not beneficial to focus only on the development of one area, and all aspects need consideration and detailed planning. Identifying factors affecting housing prices helps create sustainable housing in Tehran. Sustainable housing is housing that is economically appropriate, socially acceptable, physically and technically feasible and solid, and compatible with the environment. Therefore, building sustainable housing represents spending less energy during the construction process together with the utilization phase, which ultimately provides housing at an acceptable price for all income deciles. In housing construction, the more you consider the sustainable housing principles, the more sustainable housing you provide, and you take a step toward sustainable development. Therefore, sustainable housing is an important planning factor for local authorities and developers. As a result, it is necessary to institutionalize an integrated vision based on the concepts of sustainable development in the field of housing.

Appendix

Figure A1

Variables of environmental factors in Tehran, 2021

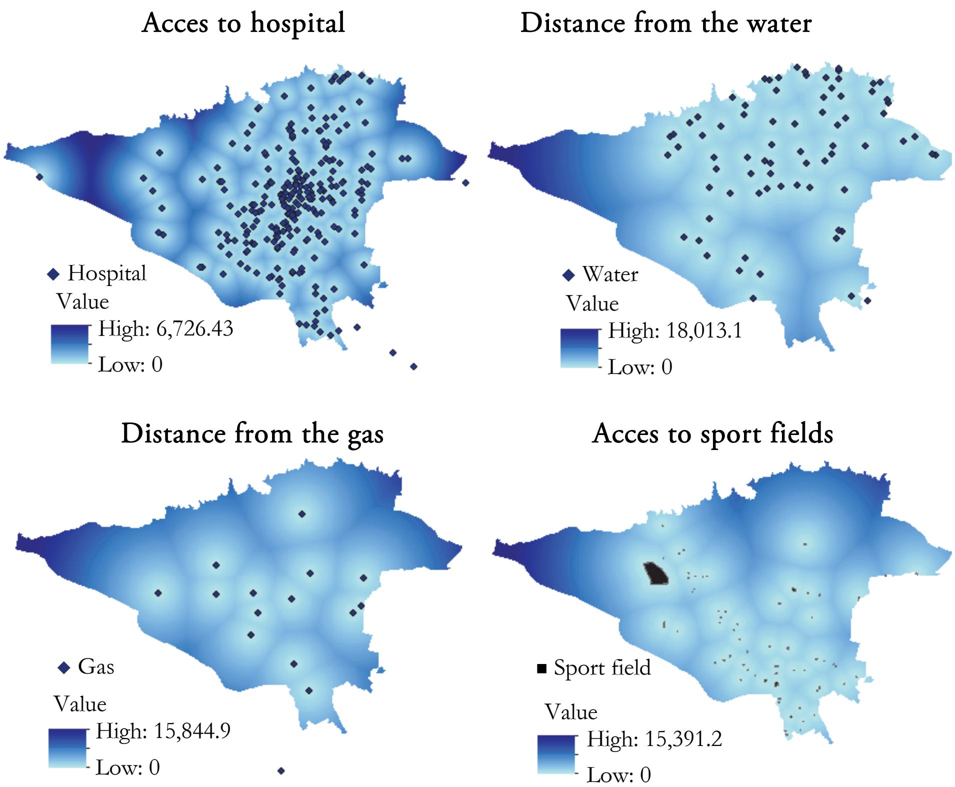


Figure A2

Variables of physical factors in Tehran, 2021

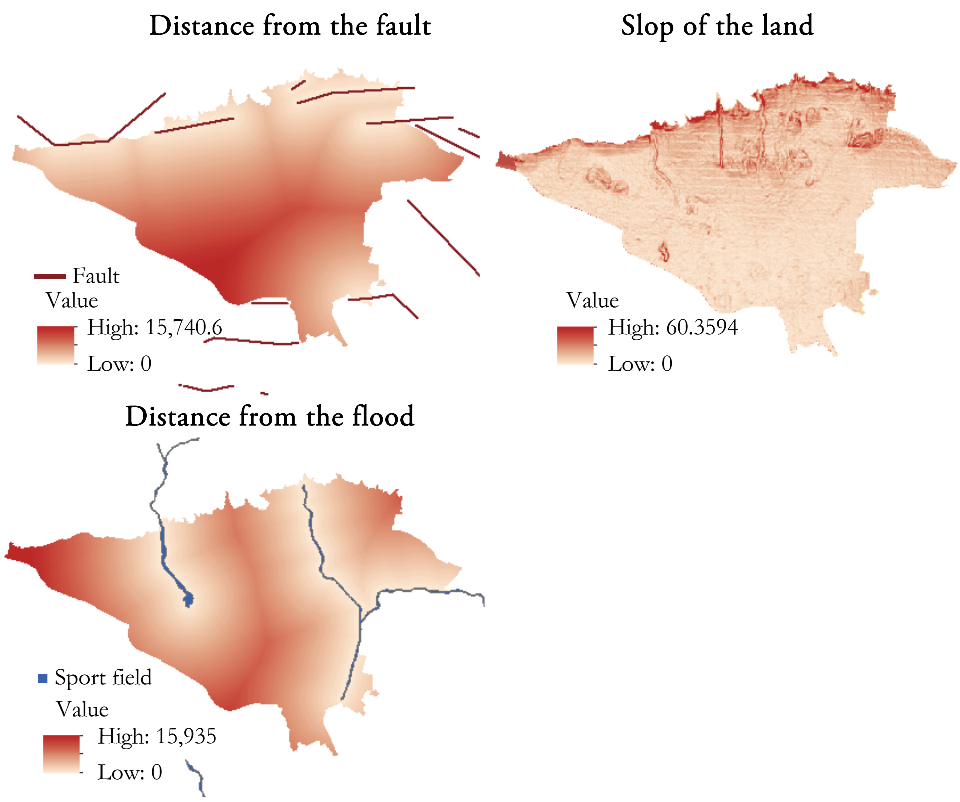


Figure A3

Geographical location of Tehran metropolis and the location of housing price value data, 2021

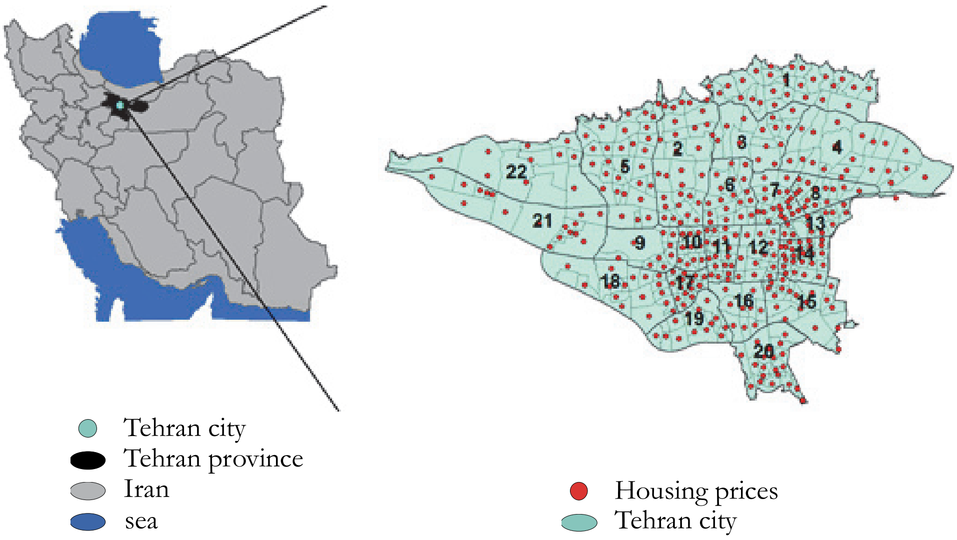


Figure A4

Identification of the remaining hot spots by the use of hot spot analysis in Tehran, 2021

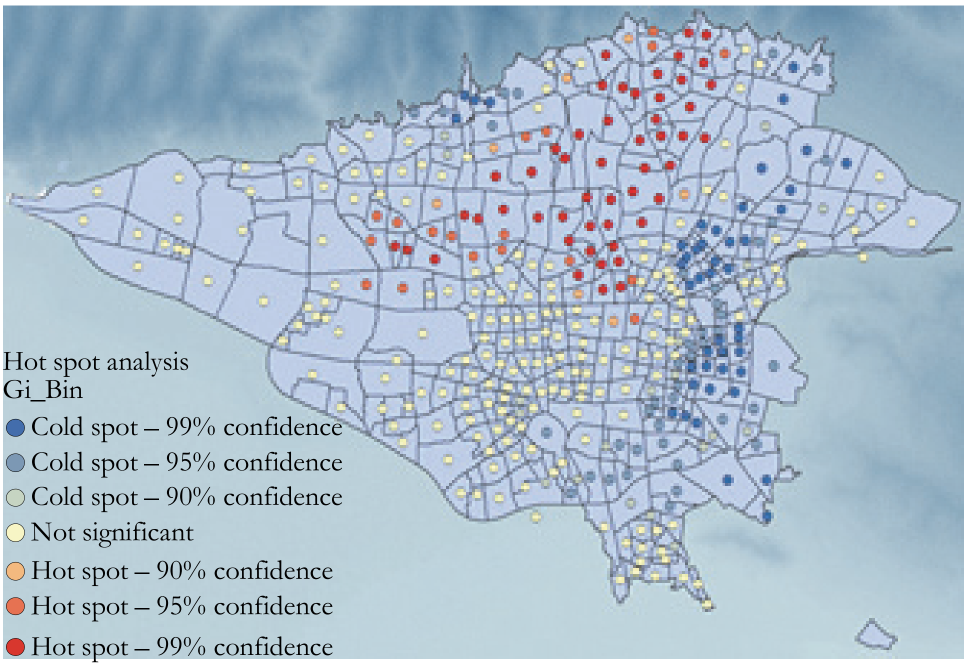


Figure A5

Estimated local coefficients for the independent variables used in the weighted regression model in Tehran, 2021

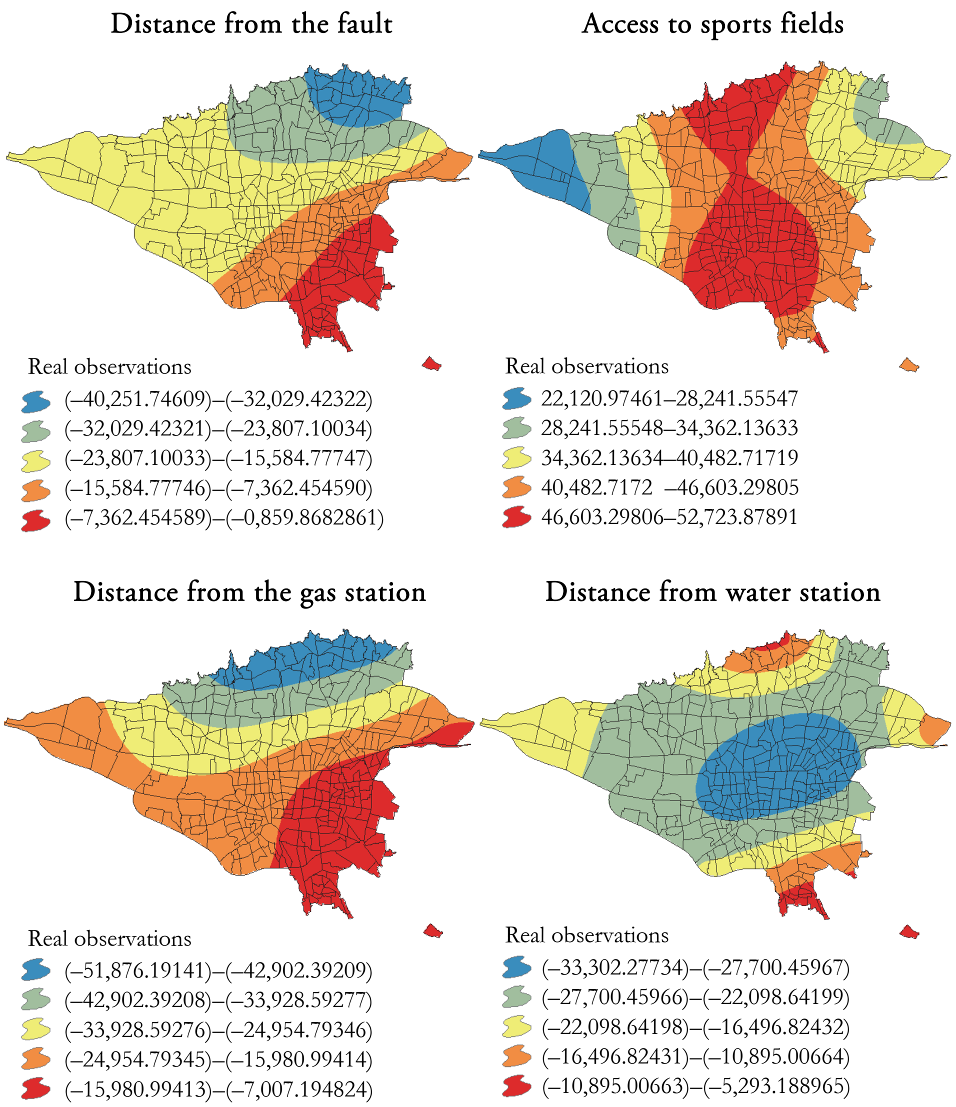
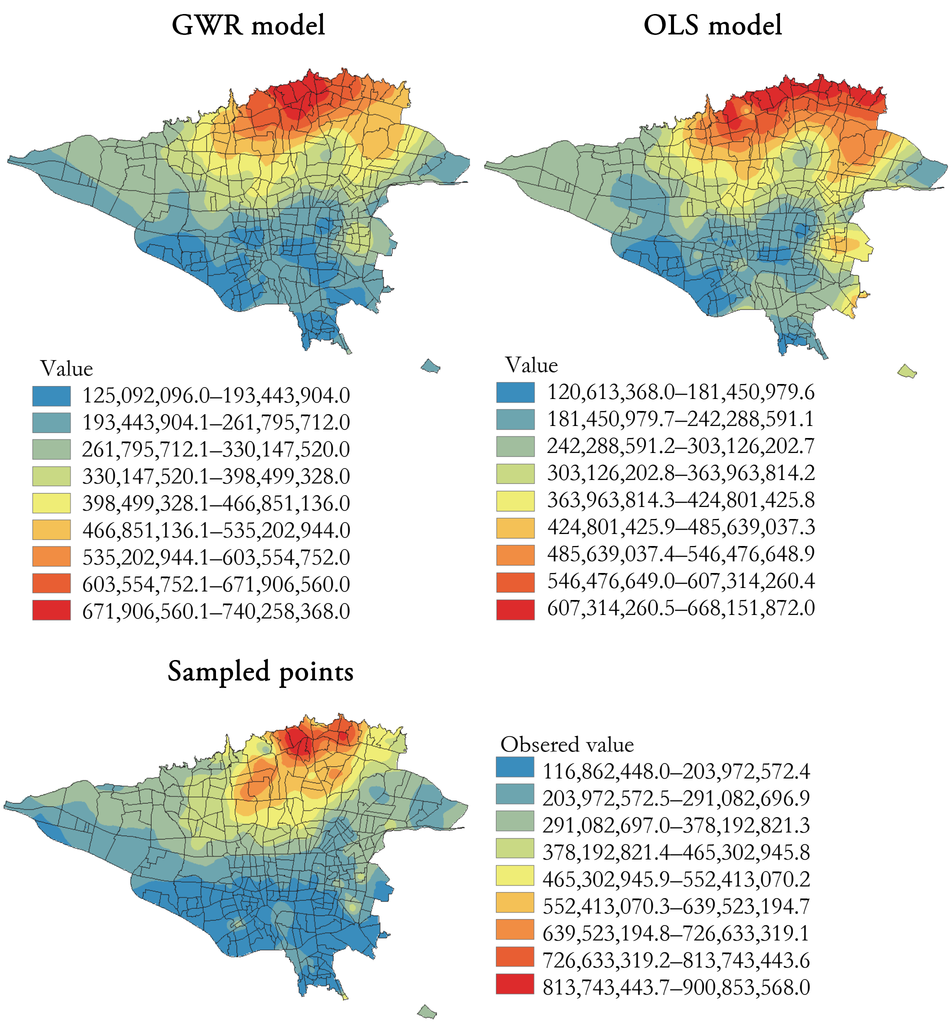


Figure A5

Zoning of real and predicted values of housing prices in Tehran city, 2021



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