ISTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

ANALYSING THE EFFECT OF URBAN FORM ELEMENTS ON HOUSE PRICES IN ISTANBUL BY GEOGRAPHICALLY WEIGHTED REGRESSION

Ph.D. Thesis by
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Department : Urban and Regional Planning

Programme : Urban and Regional Planning

FEBRUARY 2012

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Date of submission : 30 September 2011
Date of defence examination: 15 February 2012

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FEBRUARY 2012

İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

İSTANBUL'DA KONUT FİYATINI ETKİLEYEN KENT FORMU ELEMANLARININ COĞRAFİ AĞIRLIKLANDIRILMIŞ REGRESYON YÖNTEMİ İLE İNCELENMESİ

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Tezin Enstitüye Verildiği Tarih : 30 Eylül 2011
Tezin Savunulduğu Tarih : 15 Şubat 2012

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FOREWORD

There are so many people to thank during this long and tough study. I would like to start to express my appreciation to my advisor Prof. Dr. Vedia Dökmeci who was always with me to share her enormous knowledge and endless support.

I also would like to thank my second advisor Assoc. Prof. Dr. Ferhan Gezici Korten who was so generous to me in terms of the knowledge, effort and time during this period.

The other important person to thank is Prof. A. Stewart Fotheringham who introduced the model that is used in this study and provided me a friendly working environment in NCG (National Centre for Geocomputation, NUIM) and useful comments which helped to develop the thesis. I really appreciate the time and effort he put into this study.

The Jury members added much to the thesis with their valuable suggestions and comments. So, I would like to thank to Prof. Dr. Mehmet Ocakçı and Prof. Dr. Gülay Kıroğlu for their tolerance and help during this period.

I should thank my department members in ITU for the good academic environment and ITU for the support for this research project. Thanks to TUBITAK for the support during this study.

I also have to thank all my friends/collegeues in NCG for the great, productive and happy eightteen months. Especially thanks to Fergal Walsh who was always willing to help me solve any problem I had.

It is really good to have a huge number of good friends. It makes eveything easier. However, makes it difficult to mention all the names here. So, thank you all my friends, you all know who you are.

I would like to conclude with special thanks to my mum and dad, as well as to my extended family members. For sure, it would be much more difficult without them.

September 2011

Burçin Yazgı

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ABBREVIATIONS

GWR	**:** Geographically Weighted Regression
GIS	**:** Geographic Information Systems
CBD	**:** Central Business District
SAR	**:** Spatial Autoregressive Model
SEM	**:** Spatial Error Model
Loess	**:** Locally Weighted Regression
BGWR	**:** Bayesian Geographically Weighted Regression
GTWR	**:** Geographically and Temporally Weighted Regression
OLS	**:** Ordinary Least Squares
MWR	**:** Moving Windows Regression
CV	**:** Cross-Validation
AIC	**:** Akaike Information Criterion
BIC	**:** Bayesian Information Criterion
RSS	**:** Residual Sum of Squares
TL	**:** Turkish Lira
VIF	**:** Variance Inflation Factor
ANOVA	**:** Analysis of Variance
DF	**:** Degrees of Freedom
MS	**:** Mean Square

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ANALYSING THE EFFECT OF URBAN FORM ELEMENTS ON HOUSE PRICES IN ISTANBUL BY GEOGRAPHICALLY WEIGHTED REGRESSION

SUMMARY

Urban form elements play an important role in urban dynamics and in urban analysis with respect to their transparent structure. Istanbul, having a long and rich historical background, displays various urban form characteristics. However, this multi-dimensional structure of urban form elements has generally not been used in urban studies especially for the quantitative ones. One of the reasons for that is, urban form elements are not in the measurable and comparable forms required in order to use them in urban analysis. Therefore, there is a missing link between urban economy dynamics and urban studies in the sense of urban form elements. There is also a lack of studies focusing on the spatial interaction interpretations within the city of Istanbul.

Related to the problems stressed above, the purpose of the study is to make the main components of the city (urban form elements) measurable and comparable in order to analyse the effect of these components on other urban systems, with the aim of developing a comprehensive understanding of the city. So, the impacts of the urban form elements (urban density attributes, urban morphological attributes, urban accessibility attributes) on house prices are investigated with this study. While focusing on these purposes, the goal is to understand the local variations in this relationship in the city of Istanbul rather than the global scale similarities. The results of the study support the purposes and present the spatial variation of the relationships across the Istanbul metropolitan area.

In order to analyse the relationship between urban form elements and house prices in Istanbul this study has the following content: a development of the theoretical background; a review of the literature and methods used; an investigation of the structure of the selected model; an application of this model within the research framework; and an evaluation and discussion of the outcomes of the research process.

This research includes five different chapters. The first chapter which is the introduction part of the research contains the theoretical background as well as the purpose, content, method and the hypothesis of the research.

In the second chapter, the urban form concept and some related issues are discussed. Discussions are made through the aspects and the elements of urban form. Later, a review of the studies related to urban form is conducted. The chapter is concluded with an examination of the historical development of urban form in Istanbul.

There are various methods to examine house price determinants in the literature. The third chapter gives general information about these alternative modeling techniques through the structure of the models and their theoretical backgrounds. Both global

and local spatial regression and hedonic price models are evaluated with their advantages and disadvantages. The last section of this chapter focuses on geographically weighted regression (GWR) as the local regression modeling technique used in this research.

After defining the structure of the GWR model, the selection of the variables that are included in the study and sample distribution of the research are described in the fourth chapter. For the statistical evaluation of the data, descriptive statistics and multicollinearity tests results are presented. Following these, the application of GWR, a local regression model, is described. The results and the visual maps of the outcomes are discussed in order to analyse the effective determinants on house prices. Evaluation of all these steps and the results constitutes the last part of this chapter.

In the concluding chapter, a general evaluation of the whole process of the research and the discussion of the results is presented. Moreover, the limits and potentials of the research and suggestions for the further studies will be put forward.

İSTANBUL’DA KONUT FİYATINI ETKİLEYEN KENT FORMU ELEMANLARININ COĞRAFİ AĞIRLIKLANDIRILMIŞ REGRESYON İLE İNCELENMESİ

ÖZET

Kent formu elemanları gerek bileşenleri gerekse de saydam yapıları dolayısıyla kent dinamikleri ve kent analizleri açısından büyük öneme sahiptirler. İstanbul uzun ve zengin geçmişi ile çok farklı kent formu karakteristiklerini bünyesinde barındırmaktadır. Bu çok yönlü yapılarına rağmen, kent formu elemanlarının kent çalışmalarında özellikle de kantitatif çalışmalarda kullanımı pek tercih edilmemiştir. Bunun nedenlerinden biri, kent formu elemanları, her ne kadar kent analizleri için güçlü bileşenler olsalar da, ölçülebilir ve karşılaştırılabilir yapıda olmamalarıdır. Bu nedenle de kentsel ekonomik dinamiklerle kentsel çalışmalar arasında, kent formu elemanları odaklı bazı açıklıklar bulunmaktadır. Diğer eksikliği duyulan konu ise İstanbul’da mekansal etkileşim üzerine yoğunlaşan çalışmaların azlığıdır.

Belirtilen bu problemlere bağlı olarak, kentin daha kapsamlı anlaşılabilmesi için, şehrin ana bileşenlerinin ölçülebilir ve kıyaslanabilir yaparak bu bileşenlerin kent sistemi içerisindeki diğer değişkenler üzerindeki etkilerini analiz edebilmek çalışmanın amacını oluşturmaktadır. Buna bağlı olarak, kent formu elemanlarının (kentsel yoğunluk özellikleri, kentsel morfolojik özellikler ve kentsel ulaşılabilirlik özellikler) konut fiyatı üzerindeki etkisi bu çalışmada incelenmektedir. Bu amaca yoğunlaşılırken, hedeflenen İstanbul’da global ölçekteki benzerliklerdense lokal bazlı farklılaşmaları anlayabilmektir. Çalışmanın sonuçları belirlenen amaçları desteklemekte aynı zamanda da İstanbul metropolitan alan sınırları içerisindeki ilişkilerin mekansal farklılaşmalarını ortaya koymaktadır.

Bahsedilen problemler ve amaçlar doğrultusunda, İstanbul’da kent formu elemanları ve konut fiyatları arasındaki ilişkinin irdelenebilmesi için çalışmanın kapsamı şu şekildedir; teorik altyapının oluşturulması; literatürün ve kullanılan yöntemlerin gözden geçirilmesi; seçilen modelin yapısının incelenmesi; modelin araştırmanın çerçevesi kapsamında uygulanması; analiz sonuçlarının elde edilmesi; ve de araştırma sürecinin çıktılarının değerlendirilmesi ve tartışılması.

Çalışma beş farklı bölümden oluşmaktadır. Giriş niteliğinde olan ilk bölüm teorik altyapıya ilişkin bilgileri ve aynı zamanda da çalışmanın amacını, içeriğini, yöntemini ve de hipotezlerini ortaya koymaktadır.

Çalışmanın ikinci bölümünde ise, kent formu kavramı ve ona ilişkin farklı konular tartışılmaktadır. Tartışmalar kent formunun farklı yönleri ve kent formu elemanları üzerinden gerçekleştirilecektir. Daha sonra ise, kent formuna ilişkin yapılmış çalışmalar ortaya konulmaktadır. İstanbul’da kent formunun tarihsel gelişimi ile bu bölüm son bulmaktadır.

Konut fiyatını tayin eden değişkenleri incelemeye yönelik literatürde çok farklı yöntemler yer almaktadır. Üçüncü bölüm, bu alternatif modelleme teknikleri hakkında genel bilgiyi modellerin yapıları ve teorik altyapıları üzerinden vermektedir. Hem hedonik fiyat modelleri hem de global ve lokal mekansal regresyon modelleri avantajları ve dezavantajları ile değerlendirilmiştir. Bu bölümün son kısmı ise çalışmanın yöntemi olan, lokal regresyon modelleme tekniği olan coğrafi ağırlıklandırılmış regresyon (CAR) modeline yoğunlaşmaktadır.

CAR modelinin yapısı açıklandıktan sonra, çalışmada kullanılan değişkenler ve çalışmadaki örneklem dağılımı dördüncü bölümde açıklanmaktadır. Verinin istatistiki açıdan değerlendirilmesi, açıklayıcı istatistikler ve de çoklu doğrusallık testlerinin sonuçları sunulmaktadır. Bunları takiben, sonuçlar ve onlara bağlı görsel haritalar konut fiyatı üzerindeki etkili ögelerin analizi için tartışılmaktadır. Bütün bu basamakların ve bulguların değerlendirilmesi bu bölümün son kısmını oluşturmaktadır.

Sonuç bölümünde ise, bütün çalışma sürecinin genel değerlendirmesi ve de sonuçların yorumları sunulmaktadır. Buna ek olarak, çalışmanın potansiyelleri ve kısıtları üzerinde durularak bundan sonraki çalışmalar için öneriler öne sürülmektedir.

1. INTRODUCTION

Cities, based on their historical background, contain different characteristics in their urban structure. The qualitative and the quantitative properties of these structural elements vary based on the developments that the city confronts. Not only the physical developments but also the social, cultural, economic and technological trends are the issues that can have an effect on the city structure. The problems and the potentials can be examined through the built and the social environment. The level of recognition of these influences in the cities, districts and neighbourhoods will vary through the components of the city and the combination of these components. It is easy to notice these influences especially in the cities that have a long history.

The situation can be also described with an alternative approach. The alternative way is to consider the interaction of place, space and people. The reflections of the interactions between place and people will be recognised on daily life, policies and especially on the urban environment. Changing experiences combined with the varying preferences of residents result in different applications in the built environment as well as in the socio-cultural environment.

All these approaches have the common issue that a city is a composition of several different systems. For a better understanding of the city, since it is a composite of many systems, investigations should be aware of all these different stages of the all systems in the urban history. Moreover, not only the components but also the reasons or aspects of these components will give the comprehensive examination opportunity. On the other hand, the systematic approach is definitely needed especially for the cities which have a long and rich historical background.

Although it is possible to mention the importance of urban form in the early settlements in the history, the published studies focusing on the urban form concept are in the literature only for the last four decades. The concept and the content of the urban form is varying based on the purpose and the scale of the research as well as the discipline guiding the study. In general, it is possible to summarise them in two different groups; the ones that adopt a qualitative and the ones that adopt a quantitative perspective. For the two main purposes of this research, first making the urban form elements measurable in order to use these powerful components of the city for any kind of city related investigation and second to examine the interaction between the urban form elements and house prices, it is necessary to describe the urban form elements that might affect house prices. With the guidance of a literature review, the urban form characteristics included in this study are: urban density attributes, urban morphological attributes and urban accessibility attributes. Moreover, to have a comprehensive analysis, the socio-economic characteristics and also housing physical characteristics are included for the variable selection procedure.

The city of Istanbul is a good example of a complex system. As the capital of three empires (Roman, Byzantine and Ottoman) Istanbul, has a very rich urban structure due to its historical background. Transformations during this long period caused the city to have different urban dimensions. Not only in the past but also today it is possible to talk about the live urban life of Istanbul. As Kuban (1996) mentioned, not only because of its unique history but also with socio-economic, cultural and technological developments, the city keeps its existence as a dynamic city today as well. According to the latest population census conducted in 2007 Istanbul is the largest city in Turkey with a population of 12,573,836, 2042 p/km population density, in 39 districts; fourteen in the Asian and twenty five in the European side. As a result, it is possible to mention as Kiray (1998) did that today Istanbul is a metropolitan city with different economic, administrative, social and cultural relations.

The activities taking place in cities are not only part of urban life they are also part of the urban transformation process. Under the influence of three different ownership and trends, the story of Istanbul's urban structure is interesting to discover. The evolution of Turkey's cultural and financial centre starts by the 4th century. Since that time, the settlement that started at the Halic area, expanded to different dimensions with mixed characteristics. Modernisation parallel to Westernisation, industrialisation, migration, rapid urbanisation, decentralisation, modification of the central business districts and the old neighbourhoods and suburbanisation were the concepts that are all experienced in the city until today.

These transformations in different stages had a large effect on Istanbul's various urban characteristics. Istanbul's city structure changed with the shifting preferences of the varying users of the city over time. Several aspects such as physical, social, cultural and traditional values, economic conditions, technological developments, political issues, laws and regulations also had an effect on the differentiation of the urban fabric. Today, different urban form compositions, varying pattern characteristics are represented in the city. As a result, a better understanding of the city structure can be obtained through the investigation of the urban form elements, their aspects and their interaction with the other components of the other systems that exist in the city.

In Istanbul, parallel to the changing dynamics, the other term/concept popular in the city's agenda is the housing. It is also possible to talk about the varying urban patterns related to the different physical attributes of the housing especially in the big cities where social, physical and economic transformations are common. Varying housing types and environments expose the terms like needs and preferences. As a next step, changing preferences introduce the new social, physical and economic dynamics. House prices, a popular topic in real estate dynamics, vary in part as a result of this cycle.

With all these varying urban form elements, for the settlements there is not a system approach that can organise and use the potentials and the strengths of the city for any type of urban analysis in an efficient and effective way. As a tradition from the past decades, the partial planning alternatives are the most favourite activity of the local and the governmental authorities. Although the adequate importance to the urban form concept is given for developed countries, it is noticeable in Turkey that there are relatively few studies on urban dynamics. A major purpose of this study is therefore to understand the economic dynamics of the Istanbul house market through its powerful components of urban form elements.

There are several different methods to examine the relationships between spatial variables. For the house price model, the most frequently used one is the hedonic price regression model. One of the main important outcomes of these studies is that location matters. Parallel to this awareness, new model attempts, policies and applications were focusing on the spatial characteristic. Therefore, after realising the effect of the spatial issues on the house prices there are several attempts to include the location variable in housing studies. Spatial regression models were introduced based on this idea. After some time, it was the era of the local spatial regression models since they provide advantages for the studies to eliminate the problematic issues such as spatial heterogeneity and spatial autocorrelation.

Being a big city with thirty nine districts and having an area of 5000 km^2, settled on two continents with a distance of 160 km from west to east, spatial properties of house prices are very important for Istanbul. Furthermore, different areas of the city have their own dynamics such as Bosphorus, Halic, historical peninsula and the two sides: Asian and European, which further cause location to gain more importance.

In a city like Istanbul, rather than the understanding the global relationship between any two variables it is also important to be aware of possible spatial variations in such relationships. If there are lots of dynamics controlling the city, it is not easy to find out the right results with a global perspective. In order to accomplish the right interpretations of the relationship between the urban form elements and house prices, geographically weighted regression (GWR), a local regression modeling technique, is preferred for use in this research.

To take into consideration the varying spatial issues based on the locations of the samples and doing this research based on the GWR model rather than the global regression modeling techniques is another strength of this study since there has not been done any study using any local modeling technique in the urban studies for Istanbul and Turkey. GWR as a model differs form the other local regression models in the sense of better understanding and usage of the spatial data, providing the opportunity of the link between itself and the other geographical information systems, presenting specific results based on the specific locations, catching the spatial differentiations and giving the option to focus in the varying spatial patterns.

To sum up there are some studies focusing on the house prices but these limited number of studies mostly focus on the physical properties of housing in order to understand the economic aspects of the housing. However, none of these studies uses urban form elements as the main determinant of house prices. Moreover, none of the studies uses local regression modeling techniques to investigate the interactions in the urban system which is an effective and efficient way of examining spatial variations in the determinants of house prices. With the guidance of all these issues, this research offers a multi-perspective approach for urban spatial analysis in Istanbul. The results and the interpretations of the outcomes of this research will be helpful for urban studies/applications as well as to urban planners, architects, local and governmental authorities, decision makers and developers.

1.1 Purpose of the Research

Related to the problems described above, the aim of the study is to make the main components of the city measurable and comparable in order to analyse them as parts of urban systems. Therefore, to investigate the impacts of the urban form elements (urban density attributes, urban morphological attributes, urban accessibility attributes) on other urban systems' elements like house prices is the main purpose of this study. While focusing on these purposes to get a comprehensive understanding of the city, the goal is also describe and understand any local variations in these relationships across Istanbul.

1.2 Content of the Research

Related to the stated problems and the purposes of this thesis, in order to analyse the relationship between urban form elements and house prices in Istanbul this study has the following content: developing the theoretical background; reviewing the literature and methods used; investigating the structure of the selected model; application of this model within the research framework; obtaining the results of the analysis; and evaluating and discussing the outcomes of the research process.

This research includes five different chapters. The first chapter which is the introduction part of the research contains the theoretical background as well as the purpose, content, method and the hypothesis of the research.

In the second chapter, the urban form concept and some related issues are discussed. Discussions are made through the aspects and the elements of urban form. Later, a review of the studies related to urban form is conducted. The chapter is concluded with an examination of the historical development of urban form in Istanbul.

There are various methods to examine house price determinants in the literature. The third chapter gives general information about these alternative modeling techniques through the structure of the models and their theoretical backgrounds. Both global and local spatial regression and hedonic price models are evaluated with their advantages and disadvantages. The last section of this chapter focuses on geographically weighted regression (GWR) as the local regression modeling technique used in this research.

After defining the structure of the GWR model, the selection of the variables that are included in the study and sample distribution of the research are described in the fourth chapter. For the statistical evaluation of the data, descriptive statistics and multicollinearity tests results are presented. Following these, the application of GWR, a local regression model, is described. The results and the visual maps of the outcomes are discussed in order to analyse the effective determinants on house prices. Evaluation of all these steps and the results constitutes the last part of this chapter.

In the concluding chapter, a general evaluation of the whole process of the research and the discussion of the results is presented. Moreover, the limits and potentials of the research and suggestions for the further studies will be put forward.

1.3 Method of the Research

The model that is selected to apply to the research is that of geographically weighted regression. In order to achieve the goals the method is used following the seven steps mentioned below.

1. Theoretical background about the 'Geographically Weighted Regression' model:

The first step of the process is generally to understand the extent of the GWR model which is a local spatial analysis tool introduced recently. For this purpose, the theoretical and empirical studies on this model are reviewed from the literature. To have a better understanding, attention is not only given to the model itself but also to the other alternative local modeling techniques as well as to the global ones. Pros and cons are all discussed in order to have an extensive perspective about the all possible methods. Geographically Weighted Regression is used to examine spatial heterogeneity in the processes determining house prices.

2. The structure of the 'Geographically Weighted Regression' model:

The next step is to deal with the structure of the model to be able to understand the capabilities of this local modeling technique. The general structure is examined through the basics and the statistical details of the model with the help of the sources (books, papers, manuals, etc.) and the software itself. The extensions of the model are examined before moving to the further steps.

3. Variable selection and sample distribution for the model:

Since the selected model will be used to analyse the house prices differentiation through the urban form elements, different groups of variables are selected to represent the urban form elements. The decisions regarding which variables are included int he model are described. For symbolising the urban form elements some structural elements of the housing, urban density attributes, urban morphological attributes and urban accessibility attributes are selected. Based on the purpose of the research, other characteristics such as socio-economic characteristics and physical characteristics of housing are also included. To be able to consider all issues inclusively with these variables, the larger metropolitan area of Istanbul is selected as the boundary of the study area. The research is based on the samples that potentially give the clues about the various urban form characteristics in Istanbul. The distribution of these samples are important both for the model to work in a better way and to cover the study area.

4. Collection and the evaluation of the data used in the model:

The main important part of the fourth step, after the selection of the variables, the decision about sampling and the collection of the data, is the evaluation of the obtained data. The tests to understand the data is important before the fifth step which is the application of the model. In order to evaluate the data, in this step, some descriptive statistics and some multicollinearity tests are done. The way of understanding the content of the data and the interaction of the variables is as important as the interpretation of the results of the research.

5.Application of the model:

Following the earlier steps, the application of the model is a somewhat easier process. The important point is to apply the model with the right guidance. The model application consists of several sub-steps that can affect the outcomes of the study. That is why it is important to be fully aware of the earlier steps of the methodology.

6.Visual analysis and the discussion of the model results:

One of the potentials of the GWR model is the opportunity of mapping the results of the study. Therefore, visualising these varying outcomes of the study is an important step of the research process. The level and the power of the interpretations can be higher with the help of each variables' spatial interaction maps across the study area. The discussions can be more detailed based on the final visualised maps, as a result of the structural property of the GWR model.

7. Evaluation

By using the initiatives that the model shows, the outcomes of the model will be discussed and the hypotheses test will be done at this last step.

1.4 Hypotheses

Hypothesis I: Urban form elements have measurable and comparable economic values.

Hypothesis II: The urban form elements affect house prices.

Hypothesis III: The type and the strength of the relationship will differ based on the varying urban form components.

Hypothesis IV: The relationship between the house prices and the urban form elements will vary with respect to location.

2. URBAN FORM AND RELATED ISSUES

Urban form and related issues such as aspects of urban form, elements of urban form, historical development of urban form in Istanbul and the urban form studies done in the literature with qualitative or quantitative perspectives will be discussed in this chapter.

2.1 Urban Form Studies

Urban form is an important topic in and of itself and is the main focus of many studies done in the literature. There are several alternative approaches dealing with the urban form topic. With the perspectives of qualitative and quantitative, the studies related to urban form will be discussed in this section.

2.1.1 Urban form studies with a qualitative perspective

Urban form is such an important concept that it is possible to it even with the first settlements. With the changing historical, physical, cultural, economic, technological and social developments urban form content has changed through time. Related to that, various aspects of urban form were studied by several different fields. Urban structure, urban pattern, settlement type and urban morphology are the terms that can be thought as the reflections or expressions of urban form. Even though the history of the urban form concept is old, research/studies done related to it are mostly in the last four decades. The questions starting with ‘what is good city form’, continue with the more explanatory studies based on the varying components of urban form. After these discussions, the focus is mainly on the urban form as a criterion in planning policies and transportation acts. Later discussions continue with sustainable urban forms. After all these steps which are mostly based on the qualitative approach, urban form started to become a popular topic in quantitative research.

With a qualitative perspective, there were some urban design studies that were focusing on design principles through urban pattern and urban components in the late 70s and early 80s (Alexander et al., 1977; Krier, 1984). Although these studies are mentioning the urban pattern, Lynch's (1984) book on good city form is the preliminary work for the urban form studies. In this book Lynch states the values of form through the urban history and tries to describe what is form, in order to set a background information before his theory of good city form. According to him there are five basic performance dimensions of a good city form;

1. Vitality: the level of the collaboration of the settlement's form with the vital functions, people's capabilities and biological requirements
2. Sense: the level of the perception (perceiving, processing and finding the connections with his/her own values) of the users of a settlement
3. Fit: the adequacy level of the relation of settlement's size and capacity with pattern and quantity of user's actions
4. Access: the degree of reaching all different types of necessities such as services, information, people, resources etc.
5. Control: the level of usage and management of the spaces and activities by its users

In addition to these dimensions he adds two meta-criteria to the good city form theory;

6. Efficiency: the cost of creating and maintaining the settlement
7. Justice: the equal level of the distribution of costs and benefits between the users

The aspects of these dimensions will differentiate according to the user and the combination of the dimensions. It is possible that these dimensions can measure the quality of the settlement and can help to judge the goodness of the place. Unfortunately, there is a gap in the 90's with only a limited number of studies focusing on urban form issues. Some studies are based on urban morphology (Whitehand, 1994; Mesev et al., 1995) and some are focused on economic aspects (Vandell and Lane, 1989; Asabere et al., 1989; Anas et al, 1998). Furthermore, some of the limited examples from the 90's (Ibarz, 1998; Hakim, 1998; Duany and Plater-Zyberk, 1992) stress the historical development of urban form. However, after 2000's there is a burst in urban form studies with different approaches.

By the 2000's the different topics related to urban form can be summarised as; urban growth (Jat et al., 2007), urban morphology (Pinho and Oliveria, 2009; Ryan, 2005), sustainable urban forms (Jabareen, 2006; Jones and MacDonald, 2004) and good city form (Kashef, 2008; Talen and Ellis, 2002; Talen, 2005).

With the increasing threats of enlarging urban borders, the term urban sprawl started to gain importance. Detecting the growth by several different methods, to be able to state sustainable urban planning issues and stable urban form policies, was one of the approaches to this problem. Jat et al. (2007) is an example of these studies. Using remote sensing and GIS (Geographic Information Systems) technologies, urban growth is examined in this study. The other example using GIS that focuses on the evolution of urban form through the urban morphology characteristics is Pinho and Oliveria's (2009) work. The main result of this study was the demonstration that new technological developments are highly beneficial for urban form studies. After giving information about the three European urban morphology schools that use cartographic analysis since the first half of the 20th century, the paper focuses on the use of GIS to develop a cartographic-redrawing approach. The outputs of this method that are discussed in this paper are:

1. A dynamic framework to represent the evolution of the urban form, continuously open to the addition of, and articulation with, other morphological and planning data and information;
2. The overall and simultaneous vision of the urban-form evolution of a particular city in a long time period;
3. The rigorous identification and characterization of urban-expansion areas;
4. The opportunity to systematically analyse unexplored urban-development processes;
5. The possibility of typify the urban fabric, taking advantage of a rigorous and versatile cartographic tool.

The other study where morphological change was also the main focus of the research was Ryan's (2005). The main outcome of this study was that the inner-city redevelopments of residential function mostly brought the suburbanisation in the central areas of the city.

Jabareen (2006) defines sustainable urban forms and design concepts for them. Based on the literature analysis that is done in the study, there are seven different design concepts mentioned. These concepts are compactness, sustainable transport, density, mixed land uses, diversity, passive solar design and greening. Different combination of these concepts can form various sustainable urban form models. The study also identifies four types of sustainable urban forms such as neo-traditional development, urban containment, compact city and eco-city. Although this study does not give the information about the most sustainable urban form, it proposes a matrix that can help practitioners, policy makers and others in analyzing the sustainability of the urban forms. In this sustainable urban form matrix; the previously stated sustainable urban forms and related design concepts are compared through scores. According to this matrix different urban forms contribute in a different way to sustainability. The article concludes that the ideal sustainable urban form according to the design concepts are; high density and adequate diversity, compactness with mixed land uses, sustainable transportation design, greening and passive solar energy. Jones and MacDonald (2004) introduced another study focusing on the sustainable urban forms with an economic perspective. The paper first discusses principal elements of urban form: land use, transport infrastructure, density and the built environment. After the urban form elements descriptions the study considers the urban economic issues that can be effective on these elements and how these elements can shape the urban economy. According to the study, a good understanding of a sustainable urban system is important in order to have a satisfactory urban form planning system in organization with the real estate markets.

There are also some examples of the combination of urban form issues and design concepts. Some of these studies focused on good city form descriptions and some understanding the different perspectives of different practitioners on the urban form and design issues. Talen and Ellis (2002) introduced a study related to good city form that argues that in planning theory urban form theory should have a more important role. In this study the other argument is that planners should use the advantages of the new theoretical and social background to state the elements of good city form. The other study that evaluates the good urban form is Talen's paper (2005), exploring physical urban form of an inner city neighborhood using GIS. The variables used in this study are:

1. Spatial enclosure and definition
    a. Whether the public realm is enclosed, by either buildings or street trees
    b. Whether space is defined and structured vs. undefined and residual
2. The public realm
    a. The presence of sidewalks
    b. The presence of public space structured as buildings, parks, plazas, or squares
3. Spatial suitability
    a. Whether building use is suitably matched to street type
    b. Whether lot dimensions are suitably match to neighborhood type
4. Spatial diversity or mix versus homogeneity
    a. Whether retail and public space are proximal to residential uses
    b. Whether there is a sufficient mix of land uses

The method used in the study is the layering approach, so, GIS is used to measure and record all these qualities to be mapped on each layer. All layers are put together to produce a composite of urban form.

Kashef's (2008) study examines architects and planners' approaches to urban form and design with a purpose of understanding the theoretical and pragmatic concerns within these two different professions. As an outcome, it is mentioned that there is a need for integrated theories for urban form and built environment between different disciplines. From a qualitative perspective, it can easily be stated that all these different perspectives/ideas make urban form an important theory to work on.

2.1.2 Urban form studies with a quantitative perspective

There are preliminary attempts at urban form studies with a quantitative perspective by the late 80's and 90's (Asabere et al., 1989; Vandell and Lane, 1989; Anas et al., 1998). By the 2000's, after urban form became a popular research field, the number of the studies interested in the quantitative aspects of the urban form increased (Asami et al., 2001; Chen et al., 2008; Cuthbert and Anderson, 2002; Horner, 2007;

Maoh and Kanaroglou, 2007; Song, 2005; Song and Knaap, 2007). Some of these studies focused on to quantify urban form (Clifton et al., 2008; Longley and Mesev, 2000; Song and Knaap, 2004; Talen, 2003; Tsai, 2005).

There are varying focal points of these studies, which are trying to identify the urban form issues based on some statistical methods. For example, Asami et al. (2001) investigate the urban street network in the traditional urban form. To be able to examine this, they use different quantitative methods of urban morphological analysis. The research of Chen et al. (2008) is based on sustainable urban form for urban compactness.

Quantitative measure studies have varying descriptions of urban form. Cuthbert and Anderson (2002), in their study, refer to different definitions of urban form. According to these explanations, first, urban form can be the physical organisation of the activities and households in the urban space. So, transformation of urban form can be based on three different aspects: decentralization, deconcentration and segregation of land use. Second, the geographical distribution of population or employment can be a description of the urban form. Related to these explanations, change in the urban form is explored by using the kernel estimates on the parcel level data. The spatial pattern of land development is investigated with both quantitative and qualitative perspectives. In another study, Horner (2007), urban form and commuting correlation is examined. In this research, land use is the representative of the urban form so the study is based on the transportation and land use relationships. According to the results of this study, there is a strong relationship between the jobs-housing balance and the commuting. The other study that uses land use for defining the urban form is Maoh and Kanaroglou's (2007). In this study an empirical framework is provided to investigate the relationship between the urban form and the geographical clustering of firms. The objectives of this study are: "to identify the extent and the shape of firm clustering and co-location at the intrametropolitan level and to examine how the change in the geographic clustering of different industries contributes to decentralization and the evolution of urban form".

Song (2005) studied quantitative measures of urban development patterns with the smart growth perspective. One of the questions evaluated in this study is; do smart growth tools have an impact on urban form. To examine the impacts, street network connectivity, density, land use mix, access and pedestrian walkability are the dimensions considered for the compact and traditional development. After computing these urban form measures, to examine the different regions' (Portland, Oregon; Orange County, Florida; and Montgomery County, Maryland) urban development patterns, the findings are: "1- neighborhoods are becoming better internally connected in all five counties ... 2- neighborhoods are becoming less externally connected in most counties .... 3- neighborhoods have been developed at counties since as early as the late 1970s or the 1980s .... 4- a mixture of land uses within the residential neighborhoods appears to be absent in all five counties, distances from single family houses to commercial stores and transit appears to be increasing in all counties, and pedestrian accessibility to commercial land uses and bus stops appear to be falling over the study period". The other study of Song's with Knaap (2007) focuses on the Portland Metropolitan Area to classify the neighborhood types with a quantitative approach. With the help of factor and cluster analysis, the variables of street design measures; plot design and density measures; mixed land-uses measures; accessibility measures; alternative transportation modes and natural environment measures are used in this research. By using these twenty one attributes of urban form, types of the neighborhoods in the study area are determined.

Other than the studies mentioned above, there are some studies mainly focusing on quantifying the urban form. Clifton et al. (2008) argue that the increasing interest on urban form depend on three different facts; 1- urban sprawl 2- GIS 3- accessible high quality spatial data. Within this frame their purpose is to review multidisciplinary perspectives on urban form with the dimensions; the questions being asked, the disciplinary orientation of the research, the scale of analysis, and the general sources of data. The outcomes of the study are "First, over the last two decades substantial progress has been made in the ability to measure and analyze spatial patterns that help characterize urban form. Second, at multiples scales and for a variety of reasons, there are advantages to development that is mixed and compact. Third, normative principles and policies for addressing urban form need to be crafted at multiple scales and carefully designed to address the disparate issues that arise at each scale. Fourth, with so many disparate measures now used to operationalize the same constructs, it would advance urban form research to have some standardization in operational definitions and measurement protocols". In addition to the study of Clifton et al.

(2008), Talen (2003) presents a study including an overview of the issues of urban measurement, with three aspects of urban study: measurement, evaluation and representation of the urban form. Rather than using the classical methods, developing some new approaches to measure the urban phenomena was the main point of this study. In order to apply smart growth, it is mentioned in this research that there has to be some smart measurements. Enclosure, lost space, public space, spatial suitability, proximity, mix, centres and edges, divisions are the elements of the existing urban form that could be measured in smart growth research. According to the author, two issues are important to make the obtained measurements more valuable. "First, it should be possible to analyse urban form at different levels of resolution, from the individual parcel to the region, and, most importantly, allow finite resolution to be represented at any scale …. Secondly, much could be gained by putting a system in place that integrates temporal change in the evaluation. It is fundamentally important that urban form is understood in terms of change over time".

The other study on measuring urban form is done by Song and Knaap (2004). In their study, they use several urban form measures to evaluate the development pattern of the single-family residential neighborhoods and to investigate the trends in this environment. The attributes used to measure the urban form are:

1. Street design and circulation systems: the number of street intersections divided by the sum of the number of intersections and the number of cul-de-sacs; the median perimeter of blocks; the number of blocks divided by the number of housing units; the median length of cul-de-sacs; the median distance between access points in feet

2. Density: median lot size of single-family dwelling units in the neighbourhood; single-family dwelling units divided by the residential area of the neighbourhood; median floor space of single-family dwelling units in the neighbourhood

3. Land-use mix: acres of commercial, industrial and public land uses in the neighbourhood divided by the number of housing units; acres of land zoned for central commercial, general commercial, neighborhood commercial, office commercial, industrial and mixed land uses in the neighbourhood divided by the number of housing units

4. Accessibility: median distance to the nearest commercial use; median distance to the nearest bus stop; median distance to the nearest park
5. Pedestrian access: percentage of single family residential units within one-quarter mile of all existing commercial uses; percentage of single family dwelling units within one-quarter mile of all existing bus stops.

Computing these varying measurements for different neighborhoods resulted in useful information in the case of urban sprawl at the neighborhood scale. The other example for quantifying urban form in the sense of sprawl is Tsai's (2005). As the main focus of the study is the metropolitan form/structure, the quantitative variables that are developed to measure the urban form are; metropolitan size, activity intensity, the degree that activities are evenly distributed, and the extent that high-density sub-areas are clustered. In addition, Longley and Mesev (2000) focus on the detailed measures of the form of the urban areas. According to their point of view, the possibilities of the easy access and better quality digital data encourage these measurements. So, they develop a model of population densities and some fractal measures of urban development. One of the main findings of the study is "the premise that quantitative measurement of urban form can yield generalised insights about the form, and thence the functioning, of urban areas".

One dimension of these quantitative studies is the relationship between urban form and house prices (Song and Knaap, 2003; Tu and Eppli, 2001; Wassmer and Baass, 2006). The number of the studies based on the correlation of urban form and house prices are increasing. For instance, Song and Knaap (2003) used several different urban form measures to understand the relationship between housing values and new urbanism. Street design and circulation systems; density; land use mix; accessibility; transportation mode choice; pedestrian walkability are some of the variable groups that are used for the hedonic price analysis. Other than these variables, there are some control variables that are used in the study. These are;

1. Property physical housing attributes: lot area in square feet; building area in square feet; age of the building in years; square of the age variable
2. Public service levels: dummy variable indicating if the house is located within the cities; average SAT score in the school district in which the house is located; student/teacher ratio in school district in which the house is

located; binary variables representing if the house is located in one of the school districts; limited tax rate for the parcel

3. Location: distance in feet from the property to the different CBDs (Central Business Districts)
4. Amenity and disamenities: actual area of golf course in the neighborhood divided by number of housing units in a neighborhood; dummy variable indicating whether the property is within 150 feet of water bodies; dummy variable indicating whether the property has a mountain view; distance in feet to the nearest minor road; dummy variable indicating whether the property is within 150 feet of a major road; dummy variable indicating whether the property is within 500 feet of the light rail line
5. Socioeconomic characteristics: percent of population that is white in the neighborhood; median household income in the neighborhood; binary variables representing the year of sale.

At the end of the regression analysis, it is found that there are differences in the urban design characteristics of the different neighborhoods. The differences captured by the urban form measures, are also effective on the residential property values. One of the results of this study is that “residents are willing to pay premiums for houses in neighborhoods with more connective street networks; more streets, shorter dead-end streets; more and smaller blocks; better pedestrian accessibility to commercial uses; more evenly distributed mixed land uses in the neighborhood; and proximity to operating light rail stations”. The other result is, “residents are willing to pay less for houses in neighborhoods that are dense, contain more commercial, multifamily, and public uses (relative to single-family uses), and contain major transportation arterials”. The impact of new urbanism on house prices is studied in another research by Tu and Eppli (2001). With the price dependent variable, independent variables of the study are: 1- site characteristics - square footage of site; natural logarithm of lot size; number of covered or enclosed parking spaces 2- interior characteristics - square footage of living area; number of bathrooms; presence of a basement; number of fireplaces 3– exterior characteristics – binary variables for roof style; binary variables for exterior wall; if the house has a hip roof; if the foundation of improvement is slab; binary variables for the story, presence of a pool 4- quality characteristics – property age in years; binary variables for grade 5- market characteristics – binary variable for the year; if the house is in a traditional neighborhood development. These variables are used to examine the differentiation of price in two different types of neighborhood such as traditional neighborhood developments where the new urbanist features are available and the conventional suburban developments. As a result of this hedonic regression analysis is that consumers are ready to pay more for the housing units in the new urbanist neighborhood developments rather than the ones in the conventional developments. In the study of Wassmer and Baass (2006) house price is examined through the centralized urban form. In this sense, quantitative measures of urban centralization are used to find the relationship between the centralized urban areas with the smart growth policies and price for homes. The question of centrality of urban form on housing prices is answered with the independent variables of demand, supply and control categories. The variables in the different categories are; demand category: income level, median age, percentage of the population, percentage of population from foreign countries, household size, climate; supply category: residential construction cost, agricultural land price, number of households overlapping metro area; control category: garage, age, number of rooms, residents employments, population in central place, land in central place and housing in central place. The result of the study shows that more centralized urban form exhibits a lower house price structure. In summary, as discussed above different studies focus on the varying qualitative and quantitative measures to examine the different relationships of urban form. These measures employ altering descriptions of urban form.

2.2 Aspects of Urban Form

Since the first settlement, the form of the settlement, the location of the settlement and the structural properties of it are controlled by several different aspects. These aspects, which are effective on urban form, will be discussed in this section.

2.2.1 Physical aspects

In the early settlements, the physical condition of the site was the most important aspect for choosing the location for the settlement. The structure of the site varies according to topographical, geological and natural components. The organisation of urban form elements in built environment represents the conditions of the physical environment. The impact of the physical conditions on selecting the urban pattern features has decreased over time because of the other aspects. However, it is still possible to state that physical characteristics of the site can act as both potentials and threats.

2.2.2 Social aspects

Another factor that is effective on urban form is social conditions. Social attributes of the users/residents of a site can result in social diversifications. These diversifications and needs of these diverse groups will have impacts on the urban structure. Age distribution, occupation differentiation, various family types, and changing household numbers are the elements of social diversification as well as the urban structure differentiation. People and place are two connected terms that are impossible to separate in any sense. So, the combination of people and place is the key issue in the organisation of any settlement. In other words, the changing needs of socially different background users change the organisation of the built environment. For instance, changing family structure and also changing number of the households can result in different size and type of housing units. The combination of these varying housing units affects the organisation of the urban form elements which result in varying spatial patterns. Changing preferences of the users lead to policies and trends that are shaping the urban fabric. Therefore, different types of housing settlements (squatter settlements, luxury housing complex, and social housing settlements) actually symbolise the differentiation of each social group. It has to be mentioned that it is not easy to focus only on social aspects without discussing cultural, traditional and economic aspects.

2.2.3 Cultural and traditional values

Cultural values, mostly being the indicators of the life style of a settlement and its users, are the other key factors that have an impact on urban structure. The accepted principles that come with customs and general tendencies of societies are generally reflected in the habitat with the help of physical forms and structures. This is how it is possible to talk about the different urban/architecture styles and cultural background through urban pattern.

Religion can also be the part of cultural and traditional values. The rituals that come with a religion can also be effective on the arrangement, scale and the properties of settlement structure.

2.2.4 Economic conditions

Economic conditions are an effective factor on any type of development and are also one of the important components of the structural development of cities. There are several perspectives from which the relationship between economic conditions and urban form can be investigated.

First of all, if the consideration is based on the economic aspects of a construction, then there will be different dimensions. Budgets, materials and construction technologies can cause variation in urban form elements and urban patterns.

Second, is the advantage of using economic power to access to sites that are not available to settle down easily, because of natural, physical and geological disqualifications. As a result of this, it can be stated that it is not possible to define the limits of form alternatives for an urban area.

Third, not only economic factors themselves but also their composition with the social aspects, the type of the settlement and urban characteristics can differ a lot. The location, type of the settlements, quality of built houses, quality of life and densities are the parts of these different urban characteristics. As a result of these various attributes, the built environment and its features vary within a city. It is important to mention that it is not only the social, cultural and the economic conditions that cause these situations in cities. Policies, laws and regulations- which will be discussed in the following section - are all together effective on development actions of cities.

2.2.5 Technological developments

With science and technology developments in the last decades, the cities’ built form and land use policies are undergoing a change. The effects of these technology-based developments on urban form can be summarised as;

1. Effects related to construction technology
2. Effects related to information technology

3. Effects related to transportation technology

Technological developments in construction materials and equipments are important because they can change physical form/plan of structures that are going to be constructed. Not only the horizontal dimension change but also the vertical can affect the city structure. With alternative construction techniques, the physical and social patterns of urban areas are changing rapidly. Related to this, patterns of human mobility and needs, usage and organisation of open spaces are also being influenced. They all together result in differentiable urban sites containing different urban form elements.

Second is the development in information technology. With the recent developments, easy access to information and easy mobility of data can change land use pattern of cities. In addition, distances that have to be covered in order to reach facilities are decreasing which is also effecting the organisation of neighbourhood settlements. Easy access to information is also making it possible to live at a further location from the centre which is also bringing alternative spatial organisation in city's structure.

The third important technological development that has an impact on urban form is related to transportation technologies. The increasing number of alternative modes with the help of new technologies has an influence on urban form structure. Not only increasing number of alternative modes but also increasing quality are the important key issues. These important developments result in increasing accessibility to any spot within city. Then, this easy access encourages urban sprawl. All these different approaches drive varying urban fabric samples in cities.

2.2.6 Political Issues, laws and regulations

Although every aspect of urban form is powerful on the spatial organisation of a city, laws and regulations can be more powerful than all of the others. In other words, it is possible to direct urban development just with right regulations. Even though regulations are upgraded, it is not easy to cope with rapid changes. Policies are important to state rules for the city structure as in heights, densities, land uses and transport axes. It is also important to control, keep updated and maintain continuity in the regulations. Istanbul, in that case, is not a good example for coordination and efficiency in urban planning policies. As a result of this scenario, legal and illegal implementations are both recognisable in the urban pattern of Istanbul.

Policy and illegal are the key issues for laws and regulations. Policies accepted and implemented by authorities differ because of the popular trends/approaches of that period. Circumstances in that period can have a negative affect on illegal attempts. In Istanbul, there were some periods that some illegal actions were accepted by local and central authorities for their political benefits. As a result, policies accelerated the development of illegal settlements. Actually the situation is the same today, it is not shocking anymore to see a new site in the city under construction that should be a green area or kept as a water basement. In conclusion, combinations of these aspects end up in varying urban structural characteristics which can be both good and bad in quality.

2.3 Elements of Urban Form

The definition of urban form can vary and the content of it as elements can differ according to disciplines and scale of the studies. It is still important to mention the basic elements of this study in order to have meaningful discussions in the following chapters. The properties/characteristics of these elements can change over time but basic urban form elements all exist in any type of settlement.

2.3.1 Buildings

Buildings are one of the important urban form components since they can be distinctive in the perception of the urban environment. The possible alternative characteristics and various combinations of buildings can be critical in the differentiation of built areas. There are several dimensions of the buildings that can have an influence on urban structure. The height, type, form, function and age of the buildings will change the outlook of a building group. These components will be the criteria for investigating the built up image. These structural and functional attributes can also give information about different aspects of the city history such as social, economical, technological, and cultural etc.

Considering housing as the main function for buildings, structural elements such as height, age and type of the building are distinguishing marks of the image of a city.

2.3.2 Streets

Streets being the connectors of the urban fabric are important components of an urban system. Like buildings, street pattern can give clues about the historical development related to the environment they belong to. It is also possible to read social, cultural and economic changes of the environment through the street pattern. Changing characteristics such as type, size, degree and capacity can influence urban form in several different dimensions. That is why they are important valuable urban form components. This can be supported by Clifton et al. (2008) as physical structure and capacity of the roads is an important element of urban form. The importance can be related to the finding referred in the study of Clifton et al. (2008) that in urban areas roads cover the 20-30% of the land. The other important point is that the physical configuration of streets will not only be effective on physical structure of urban areas but also on socio-cultural structure.

2.3.3 Urban blocks

Urban blocks shaped by the form of streets are one of the main urban form elements. Form and function of urban blocks are important on the formation of the urban structure. It can be easily stated that urban blocks with streets represent a small sample of urban life.

There are varying components of urban blocks that have to be investigated to understand varying urban structure. These components can be homogeneous or heterogeneous characteristics, size and other qualitative and quantitative properties. Urban blocks are part of urban tissues as mentioned by Panerai et al. (2004). So, it is better to investigate internal and external activities in urban blocks rather than trying to categorise them as the units in between the building and city scale which can be used for any type of function (Panerai et al., 2004).

2.3.4 Accessibility

Accessibility, based on the transportation system, is one of the important issues in an urban system. While connecting the parts of a city to each other, it supports the movement of people, goods and information. The varying transportation infrastructure based on the varying transportation modes, the type of the mobility system, the scale and the size of the network, in general, the characteristics of the transportation schema will cause differentiation in the urban form components. Because of the strong relationship between accessibility and land use, measures that can represent accessibility are one of the main components of urban studies. In this sense, accessibility can express the distances that residents can cover easily but it also gives information about possible functional regions or facilities that residents can reach.

2.3.5 Density

Density as a representative of physical and social conditions of an urban area is one of the important urban form components. It is a comprehensive concept so there is several ways of representing the density. The number of people in an area or the number of any type of urban form elements can be explored under the density concept. The concept itself is also related to the other urban form elements such as buildings and the accessibility. As a result of these correlations, it is important to examine the changing measures of density. Moreover, as it can be the representative for the quality of life -because of its relation to several important components of different urban systems- measures of density such as; urban population density and building density are used in various researches.

The degree of density, being high or low can act both as advantages and disadvantages in a specific area. That is why several studies have been done in order to find right policies for the optimum density values. In summary, because of all the issues that are mentioned above, for a better understanding of urban form, it is important to consider density measures.

2.4 History of Urban Form Development in Istanbul

Istanbul, as the capital of three empires had varying transformations in the city itself. Not only the changing ownership of the city but also the changing trends in the world, were the reasons for these transformations. In the early ages the structural transformation can be followed under the different names as Byzantion, Constantinople and Istanbul. Although the Istanbul period started in the 15th century, the general information related to characterisation of the urban structure will be given starting from the 19th century.

The main theme of the 19th century was the transformations. Under the control of the Ottoman Empire the city Istanbul was the capital and several modernisation acts were going on. Trying to recover the economic conditions and the technological developments, series of reforms (social, institutional, etc.) were applied under the symbol of Westernisation (Celik, 1993). The physical growth of the city was also under the effect of all these different types of reforms. During the first half of the 19th century, the population was mainly settled in the historical peninsula and around Galata. There were a few neighbourhoods that were populated outside this area. The Bosphorus axis was one of these locations. After the mid-nineteenth century, the boundaries enlarged and there were three new development axes including the Besiktas shoreline, Taksim-Sisli and Besiktas-Tesvikiye (Celik, 1993). The boundaries enlarged, so that the built up area expanded and the population densities increased. This expansion also caused a decrease of the green areas in the city's fabric. Parallel to these developments, in the urban administration level there were some attempts for a better control of the city. As Celik (1993) mentioned, it was not easy to implement all new ideas and technologies in the old city structure of Istanbul. As a result, the implementations were mostly partial. Other than the reforms, the other important term for the 19th century was the fires. Because of the fires in this century, the building materials, the type of the buildings and also the principles of urban planning started to change. In other words, the image of the city started to change. One of the main focus points of the urban planning system in that century was the rehabilitation of the streets (Kuban, 1996). The grid pattern was the accepted pattern for the street network during this period. The other changing characteristics were related to the style of the buildings, for example, in this period, barracks and palaces were popular. Compared to the earlier architectural style of the city, the look of the city and also the architectural style were both affected. According to Kuban (1996) these new buildings damage the visual and physical coherence of the city.

To make a quick review of the 20th century, following the previous century, the important element was urban planning after all the problems (physical changes because of fires, demographic and social changes). Industrialisation, decentralisation and modification of the central business districts were the important themes within this period, which resulted in some new constructions in a wider scale. The urban fabric continued to change due to the new bridge construction connecting the Asian and European sides of the city, followed by the new highways. By the 1980s as with the other world cities, Istanbul was also under the effect of globalisation. Therefore, regeneration, gentrification and reconstruction were the popular concepts in the city's agenda. The things that happened in the last 150 years can be summarised as a loop that did cause changes a lot in the past and will do more on the city's development in the following decades.

a. Short term policies
b. Increasing population – Migration
c. New settlement areas – Legal and illegal
d. Improvements for settlement areas especially for illegal ones
e. Encouragement for new settlements
f. Short term policies
g. Partial planning
h. New problems at every level
i. Short term solutions/policies …

Following these steps the development pattern of the city was more based on sprawl, high-density development in the inner part of the city, and extension of the central business district.

After this general information about the city's development during the last fifteen decades, some attention will be now given to the urban form perspective. Therefore, the development pattern of the urban form will be discussed through the history.

The settlement started in the historical peninsula and stayed within the city walls for a long time. The last years of the Ottoman period were the time of expansion and this is the first main period that urban form structure was explored. The changes started from the city centre but other than an integrated redevelopment, all planning activities were partial. Transportation and housing structure were the urban systems that were mostly affected during this process. The first thing noticed in the urban structure was the changing construction material of the buildings. The traditional wooden buildings were replaced by the new brick or stone buildings. As construction cost was one of the big problems these transformations were more recognizable in the rich neighbourhoods (Tekeli, 1994). Besides, around these neighbourhoods the second noticeable change was the new type of houses or apartment blocks. So, the urban form elements in the sense of type, height and density of the built environment began to diversify. According to Tekeli (1994), the third aspect of the transformations was the changing dimension of the city. The city began to grow through the new areas. The early settlements inside the city walls expanded and the new settlement areas occurred outside the city wall. Makrikoy (Bakirkoy) and Yesilkoy settlements were some of the examples along the railway access. Like the railway, the Bosphorus axis was the other path followed by the new settlements. Small Bosphorus villages became part of the urban structure in this period. Tophane-Ortakoy; Taksim-Sisli; Tesvikiye-Nisantasi; Uskudar-Kuzguncuk and Uskudar-Kadikoy were the other important new settlement paths. The other types of the residential movements that were noticeable in the city form were the suburban settlements. As social transformations cannot be easily be separated from the physical ones, all these changing structural attributes cause differentiations in the social environment. In summary, the historical peninsula started to loose its importance and even some parts of it turned into low income settlement areas (e.g. Eyup) and slum areas (e.g. Kasimpasa). Hierarchy, prestige and attractiveness were some of the terms that were effective on the urban pattern. It was possible to talk about some connections but was impossible to talk about a network within the city. The urban structure was missing integration physically, socially and economically.

After 1930s the urban structure was under the control of different concepts. The Prost Plan was one of the new issues on the agenda. According to this plan, the main goals were focusing on the transportation system (especially the establishment of new wide boulevards), reorganisation of several quarters/centres and also new spatial organisations for different urban facilities. As Kuban (1996) discussed in his book, rather than a comprehensive plan for the city Prost prepared partial plans for some of the districts of the city. In that plan, it was also suggested to separate the city into different functional zones. This scenario was also the reason for the future problems on the city's spatial development. Some parts of the plan were implemented, some needed to wait a few decades to be applied and some were impossible to fit into the city's existing structure. So, the plan could not really act as a comprehensive plan in finding solutions for all existing problems.

During 1950s rapid urbanisation was a problematic issue. The authorities did not know how to deal with it and were trying to adapt the city to this new phenomenon with the partial planning applications. The general development in the urban form was basically based on the three different dimensions; changing hierarchy of the centres, industrialisation and changing built environment especially the housing structure. Kuban (1996) described the main two components of this period's actions as the modern apartment blocks and the motorised vehicles. With increasing trade rates and population density, the land prices were rising, encouraging apartment blocks as the new type of housing (Oncel, 2010).

The other issue in this period was the squatter settlements. The historical residential neighbourhoods of the city transformed into squatter settlements. So, "Whilst reconstruction activities related to the establishment of the urban circulatory system and the beautification of the city was going on, the city was living through a severe housing crisis and facing the first wave of widespread *gecekondu* (squatter) building activity" (Tekeli, 1994). Increasing population and insufficient number of housing units compared to the demand caused these illegal housing types to be formed in the city structure. Not only in a particular district, but one by one in different parts of the city squatter settlements mushroomed.

The period between 1965 and 1984 was one of the time periods of important changes in the city's structural elements. The construction of the bridge was one of these important developments, not only for the transportation policies but also for the urban structural policies. There was a new reason for the city to develop along another direction and of course new settlements were all ready to follow this path. Dokmeci et al., (1993) stated "Istanbul was a vigorous, core-dominated metropolis until well into the 1950s, with a very limited suburban development in the periphery. With this expanded use of the automobile and the construction of the bridges over the Bosphorus, however, the suburbs, in typical fashion, were pushed further out". Another important direction in the city was the new extension of the central business district. The new Sisli-Maslak axis was one of the factors that directed the layout of the city. In addition to this, industrial activities were still active and having an affect on the residential choices of most of the people. While individual squats were being converted into apartments, there were some other housing supply systems effective in the urban areas. According to Bolen's (2004) description there were three different formal housing type developed by the private sector; housing co-operatives, housing produced by the Real Estate and Credit Bank mostly for middle and higher-middle income families and the small enterprise, builder-seller type housing. All these different types of houses had different structural attributes and neighbourhood properties. The only common point of these varying types was they were generally serving the middle or higher income families. Whatever the type was, at the end, the boundaries of the city were extended and the population living in the Asian side increased. Again in this period, because of these illegal and rapid changes, the term conservation started to gain importance.

As Eraydin (2011) stated during the first half of the 1980s, after Istanbul became a competitive city in the global arena, there were some changes in the governmental structure that resulted in some attempts against the existing metropolitan institutions and planning departments. The evaluation attempt was mostly giving the priority to the economic issues. The new legislations related to housing were also following this policy. “During the 1980s, not only have economic policies transformed substantially, but also how central and local governments perceive urban areas has changed radically, as they began to see cities as a source of income and engine for the capital accumulation” (Eraydin, 2011). As mentioned by the author, by the 1990s Istanbul was evaluated as a national economic development focal point by the central government. So, the central government was mostly concentrating on promoting the city and benefiting from the high land prices by introducing new projects. When the economic perspective of the policies was more important than the others, housing became the main target of the policies. As a result, the control of the builder-seller type of housing was given to large-scale construction firms, housing cooperatives started large scale constructions and the Real Estate Bank with the partnership of the private companies started to build large scale housing. Rather than the individual apartments high income housing became popular and squatter settlements were legalised as a next step. So, housing went from being a social service in the 1960s to a tool of economic development (Bolen, 2004).

In the large context, as the connections between the urban historical developments and the housing are associated, the general results can be summarised as follows. Before 1980 due to the increasing population and the housing demand the densities were rising and the squatter settlements were establishing around the industrial areas.

After 1980s the scenario was a little bit different as the squatters looked more like the apartment blocks and the mass housing sites were spread all over the city based on the short term policies. After 2000s, it was not easy to manage the housing system because of its problematic background as a result of the improper location decisions, inaccurate short-term policies and partial urban planning.

As can be followed in Figure 2.1 “Today’s city occupies a vast area. The Istanbul side is no longer defined by the Theodosian walls, but extends westward. The new quarters, built up over the last three decades, spread out on both sides of the Golden Horn for kilometres past the borders of the nineteenth-century city. Their development happened quickly and often organically, resulting once again in irregular settlement patterns. The problems of the nineteenth-century city have thus survived to the present day and so have the goals of the early planners. Their twentieth-century counterparts are still struggling to establish a ‘regularity’….”(Celik, 1993). Although the old residential neighbourhoods have mostly disappeared, the richness of the monuments and the variety of the architectural heritage make Istanbul still one of the important cities of the world (Kuban, 1996).

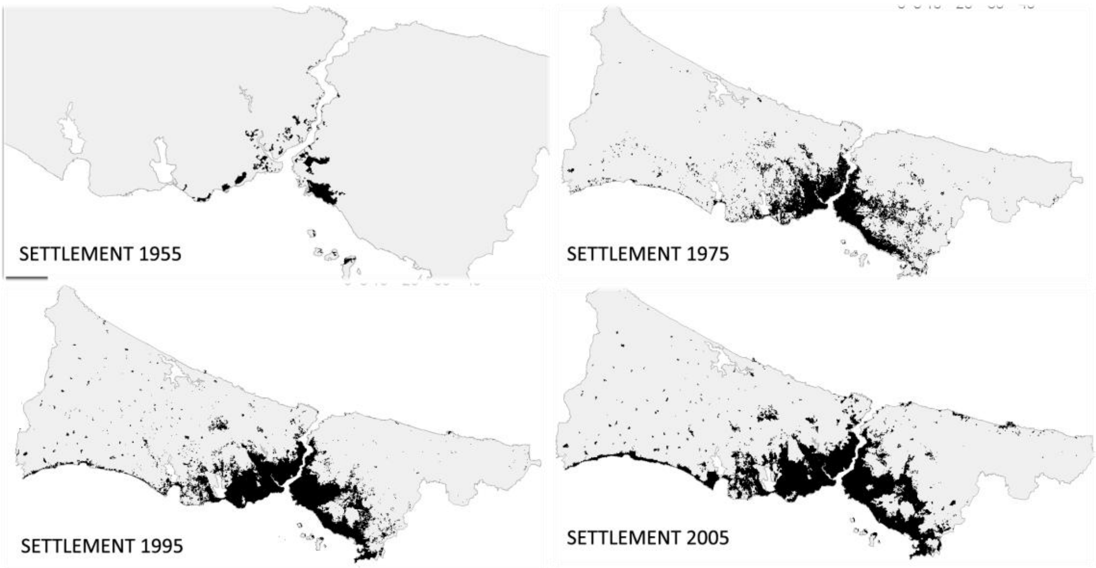


Figure 2.1 : The settlement areas of Istanbul between 1955-2005 (Terzi and Bolen, 2009- by IMP, 2007).

2.5 Evaluation

In urban studies, urban form is an important concept for the reason that it can be related to any type of settlement. Moreover, it is an important concept for the issues related to the urban since it is possible to understand much about the settlement through the examination of urban form components. Through the history the attention to urban form is given by different disciplines. Geography, urban planning, architecture, urban design, transportation planning, economy and sociology are some of the examples of these disciplines. Based on the related discipline, the scale and the content of the urban form concept can show a varying pattern. The studies started to focus on the concept of urban form with the question of what is good city form, and then followed by some other perspectives such as urban growth and urban morphology. After the enlargement of the cities, the other dimension of the urban form studies was related to these issue like urban sprawl. Based on the trends, the level of the interest quality and quantity of urban form studies has changed. This statement can be supported with Clifton et al.'s (2008) argument that some recent trends increase the interest in this multidisciplinary concept. "First, rising concern over the presumed consequences of urban sprawl. Second, geographic information system (GIS) technology has made analysis of spatial patterns a simple exercise on a laptop computer and as engaging as a video game. Finally, the quality of spatially referenced data has reached levels unimaginable a few years ago".

Not only the level of interest but also the methods used for the urban form analysis started to vary as well. The early attempts were mostly focusing on the urban form concept with a qualitative approach and trying to discuss the urban form issues within this perspective. By the late 80's the quantitative approach was also in the list of the urban form analysis. As a result, different relationships of urban form with varying variables were investigated through some statistical methods. In order to use urban form for quantitative purposes the important step was to quantify urban form, leading some researchers to deal with the measures of urban form. After the 2000's with new trends like new urbanism and smart growth, urban form measures gained more importance.

The other important point is that as urban form is a component of a bigger system, the aspects of urban form such as physical, social, cultural and traditional values, economic conditions, technological developments, political issues, laws and regulations have to be considered in the studies. These aspects are the clues for the development of urban form.

In Istanbul, all the elements of urban form like buildings, streets, urban blocks, accessibility and density were under the influence of the transformations based on the aspects mentioned above. The development of the urban form in Istanbul followed a long and a complex path. In every complicated planning situation, in the city history, the solution was a short-term act or policy which led to complexity in the following periods. By the 20^{th} century after the change of ownership of the city three times the forces and trends that the city faced were; modernisation, industrialisation, migration, increasing population, decentralisation, globalisation, privatisation, new settlement areas (both illegal and legal), squatter settlements, luxury housing complexes, new users, needs and preferences. With all these new forces added to the agenda of urban planning, the comprehensive planning approach was getting harder to achieve. Housing was one of the most effected components within this complex structure. Different housing policies and legislations were taking roles in the system of housing supply. Today Istanbul is a city of squatter settlements, mass housing, apartment blocks, villas, skyscrapers and summer houses. Istanbul is now a city of conflicts and composites.

The general review of the urban form concept, studies related to the urban form and urban history of Istanbul is discussed in this chapter. In order to analyse the dynamics at the urban scale, the relationship between urban form and house price will be investigated statistically. Therefore, review of different statistical models and the model of the research will be discussed in the following chapter.

3. HOUSE PRICE MODELING TECHNIQUES

When researchers began to use computers for urban studies, the extent of the analyses increased. Different sorts of software made this process dynamic during the past years and with geographic information systems, the analyses moved up a level. Also, the development of statistical and spatial methods influenced the analysis of data related to urban systems. As mentioned by Paez and Scott (2004) urban studies can now easily adopt and use the advantages of developments in technology and techniques.

The study of house prices one of the topics of urban analysis, has also been affected by this process. House prices as a representative of urban economy are generally examined with quantitative methods. With a statistical perspective, regression models, especially the global regression models, were the most popular ones to examine the relations between house price and several other attributes related to the property. The ability to use different forms of data and also to use different properties of the data takes the house price analysis one step ahead. Therefore, alternative ways of investigating the relationships are possible. Since the study focuses on the relationship between house prices and urban form elements, this chapter discusses the different house price modeling techniques with respect to their advantages and disadvantages.

3.1 Hedonic Price Modeling

Hedonic price modeling applications are generally used for valuation of goods based on their different attributes. In most of the hedonic price modeling papers Court's (1939) study is referred as the pioneering hedonic price analysis. According to Goodman (1998) although the hedonic price analysis was popularised by Griliches in the early 1960s, "Court's work stands up quite well. It deals with the problems of nonlinearity, and with changes in underlying goods bundles. It addresses a substantive methodological problem with circumspect analysis and interpretation". The term hedonic in Court's spreadsheets was used to describe "the weighting of the relative importance of various components, such as horsepower, braking capacity, and window area, among others in constructing an index of usefulness and desirability" for vehicles (Goodman, 1998).

After Court's approach, in 1956, Tiebout in his paper, 'a pure theory of local expenditures', mentioned the differentiating neighbourhoods based on their characteristics in the case of local public goods. After this, Lancaster's (1966) study on a new approach to consumer theory, was dealing with common-sense characteristics of the actual behaviour, which was not taking into account the traditional consumer theory. The study of Muth (1966), another example of the consumer behaviour theory, can said to be one of the pioneering studies for the hedonic models with the econometric perspective. These preliminary hedonic model approaches started to be used in house price models as well as the other models. Rosen (1974) as the leading figure in hedonic house price studies defined the hedonic prices as the implicit prices of properties based on the observed prices of the characteristics of differentiated products. After Rosen's approach to the hedonic house price models there were other studies following this trend. Witte et al. (1979) was one of the early examples of the applications of Rosen's Theory. Freeman III (1979) was also studying the effect of the environmental attributes on house price by using the hedonic price models. Following these pioneering studies, there have been lots of studies done in the last three to four decades.

Based on the theoretical information in Rosen's (1974) study, the hedonic house price model is based on the idea that the house as a unit is composed of different attributes. This can be symbolised as $z = (z1, z2, \ldots\ldots, zn)$.

According to representation above, the price of a house will be the function of z. Following this the next step is the formulation of hedonic price model which can be represented as $H = f(P, L, N, \ldots)$.

In order to buy a house the price that has to be paid is the function of the P (physical attributes of the house), L (location attributes of the housing unit) and N (neighbourhood properties of the house). Different attribute groups can possibly be added to the formula, as there is no definition for the correct model components and the best model. In some of the hedonic price modeling studies location properties and socio-economic variables can be included under the neighbourhood characteristics group. However, in some studies neighbourhood attributes can be totally ignored.

Early studies were trying to develop variations for the hedonic theory by either suggesting an alternative test (Ellickson, 1981), adding a new variable (Goodman and Kawai, 1982; Li and Brown, 1980) or trying to support the best choice of the functional form for the hedonic price functions (Cassel and Mendelsohn, 1985; Cropper et al., 1988). These approaches were followed by other studies in the following decades. Every new study added a new perspective to the hedonic house price theory. By the 1990s, there were more studies trying to understand the relationship between several different attributes and house prices through the hedonic model (Anglin and Gencay, 1996; Benson et al., 1998; Can, 1990-1992; Cheshire and Sheppard, 1995-1998; Gencay and Yang, 1996; Giannias, 1998; Goodman, 1998; Henneberry, 1998; Kask and Maani, 1992; Knight et al., 1993; Mills and Simenauer, 1996; Powe et al., 1997; So et al., 1997; Tu and Eppli, 1999; Tyrvainen, 1997; Wolverton, 1997; Zabel, 1999). During this period the main important development was the awareness of the spatial issues. So, there were some studies trying to implement new theories related to the hedonic models to cover the missing ability to deal with the spatial effect in these models. The well-known approaches during this decade were housing submarkets and the spatial lag term.

In the hedonic model structure, there is nothing particularly based on the spatial attribute and the strength of the relationship between any of the attributes and the house price. The model needs some extra parameters in its structure to be able to analyse the effect of the spatial structure. Since house prices and all attributes related to housing are not easily separable from the location properties, this is something to investigate in the hedonic house price studies. Adair et al. (1996), Can (1990), Case and Mayer (1995), Watkins (1999) and Watkins (2001) are some of the examples of the studies that were trying to work on the spatial variation either with housing submarkets or neighbourhood externalities. The common purpose of these studies was to decrease the negative effect of the spatial issues in house price models and avoid model misspecification. As Can (1990) mentioned, it is important to understand neighbourhood dynamics for the prediction of house values. In other words, acknowledging the existence of the housing market segmentation should be the main focus of these types of studies.

The interest in the housing submarkets in the hedonic price model frame was still popular after 2000s (Bourassa et al., 2002; Bourassa et al., 2005; Fletcher et al., 2000; Goodman and Thibodeau, 2003; Jones et al., 2003; Kauko, 2004; Kim and Park, 2005; Watkins, 2001). While some research was going on based on the housing submarkets, there were some other alternative studies trying to figure out the different dimensions of the components of house price and hedonic models (Arguea and Hsiao, 2000; Bin, 2004; Bowen et al., 2001; Clauretie and Neill, 2000; Colwell et al., 2000; Coulson and Leichenko, 2001; Egert and Mihaljek, 2007; Galster et al., 2004; Gelfand et al., 2004; Jim and Chen, 2006; Keskin, 2008; Ottensmann et al., 2008; Sieg et al., 2002; Song and Knaap, 2003; Tse, 2002; Tu and Eppli, 2001; Wen et al., 2005; Wolverton and Senteza, 2000). During this decade (2000-2010) the other important topic for the hedonic price model studies was the comparison of this model to some other house price evaluation techniques. After the spatial regression modeling techniques became popular, the studies were trying to explore the advantages and the disadvantages of these fairly new techniques compared to the hedonic models. The studies of Farber and Yeates (2006), Fik et al. (2003), Limsombunchai et al. (2004) and Xiaolu and Yasushi (2005) are some examples of this kind of study.

Hedonic price models are the basic modeling technique for house price determination and in some ways they are simple and easy to use. However, there are some disadvantages and missing points in the structure of the model. As Bowen et al. (2001) state, "hedonic housing price model applications typically utilize classical regression analyses in which housing units' sales prices are regressed on measures of their attributes". So, it is important to have the right regression formula including the appropriate attributes for the best explanatory model. To get the best explanatory model is the common purpose of all hedonic price model studies. While trying to achieve the purpose, hedonic house price models can be problematic in some cases. The decision of the independent variables and samples selection are very important for this technique like the other techniques. The usage of right variables, right samples and the right functional form is important to achieve the best explanatory model. Using different types of data also can be problematic for the explanatory level of the model.

Other than these common disadvantages of any type of explanatory model, the main disadvantage is referred to in Can's (1992) statement that there are some developments in spatial statistics that have proved that using traditional methods can not be enough to analyse geographically based data in some cases. Especially issues like spatial effects should be detected before the model misspecification but “hedonic urban housing price models have not yet incorporated these advances into model specification and estimation, and statistical inference is confined to the limitations of the standard parametric framework” (Can, 1992). To sum up, as Fotheringham et al., (2000) stated, linear regression models being aspatial methods, cannot be adequate for modeling the spatial processes.

3.2 Spatial Regression Modeling

Although linear regression modeling was one of the important techniques as a quantitative method, it was not sufficient for modeling the spatial inputs. So, after being used for a certain period, the disadvantage of being an aspatial method accelerated some of the attempts at developing spatial regression models. The early attempts (Cliff and Ord, 1970; Hordijk, 1974; Ord, 1975; Openshaw, 1977) were followed by different researchers from other disciplines. Other than geography and urban planning, spatial regression analysis is used in biology, ecology, sociology, demography, economics, transportation and etc. (Lichstein et al., 2002; Calvo and Escolar, 2003; Clark, 2007; Giaccaria and Frontuto, 2007).

Spatial regression modeling is a set of different methods that has the spatial data input in common, which they examine and evaluate the data under varying processes. The other common focus point of these models is that they address spatial heterogeneity and spatial autocorrelation. The number of studies based on spatial effects - referred to as spatial autocorrelation and spatial heterogeneity by Anselin (1999) - was not impressive during 1980s and 1990s.

According to Anselin’s (1988) definition, spatial autocorrelation is “the lack of independence which is often present among observations in cross-sectional data sets”. The other type of spatial effect spatial heterogeneity “implies that functional forms and parameters vary with location and are not homogeneous throughout the data set”. Both spatial heterogeneity and spatial autocorrelation can be issues in any type of spatial processes. There are a serious number of studies dealing with spatial autocorrelation (spatial dependency) and spatial heterogeneity (spatial non-stationarity) (Anselin, 1988; Anselin and Griffith, 1988; Lesage and Pace et al., 2004; Lesage et al., 2009; Griffith, 1987; Paez et al., 2001; Paez and Scott, 2004).

The number of papers in the literature was limited because of the general trends in regional science and also the lack of software that could handle the spatial methods (Anselin and Hudak, 1992). The increase in the availability of software caused the increase in the number of the studies done. After these supports, a more detailed way of examining the spatial data was the main purpose of the models that were developed during this period.

Following this approach, both global and local regression modeling techniques are trying to cover the spatial effects. There are some differences between these two techniques which will be discussed in the following sections. Briefly the situation can be explained with a good example of Fotheringham et al. (2000). Giving the average Celsius degree on a certain day in the USA does not give any clue about the variation of temperature across the country on this date. Moreover, it hides any potential relationship varying over space. So, what local models try to figure out different than the global ones are the differences rather than the similarities within the space. In summary, according to Fotheringham et al. (2000), “In a global analysis, we typically have no information on whether there is any substantial spatial variation in the relationships being examined - any such information is lost in the analysis”.

The characteristics of the global model and the new local models can be followed in Table 3.1. Detailed discussion about the global and local modeling techniques will be provided in the following sections of this chapter.

As the number of the papers, researches and studies focusing on the spatial input is increasing day by day, the reflections are also recognisable in urban planning applications. Since, every system in an urban area is dynamic and space related, spatial analysis become more important for developing any ideas for urban areas. Paez and Scott’s (2004) study supports this idea as “a characteristic of most urban processes is the fact that they are intrinsically spatial and, moreover, space-dependent”. A mass of information in real estate market, increasing interest and intense data supply in the market produce the potential link between real estate and spatial statistics (Pace et al., 1998). As a result, there are remarkable numbers of studies that are trying to add spatial characteristics of the house for valuing the property, which is parallel to the purpose of this study as well.

Table 3.1 : Characteristics of global and local statistics (Fotheringham, 2010).

Global	Local
Usual single valued	Multi-valued
Assumed invariant over space	Varies over space
Emphasize similarities over space	Emphasize differences across space
Non-mappable ('GIS-unfriendly')	Mappable ('GIS-friendly')
Used to search for regularities	Used to search for exceptions or local 'hotspots'
Aspatial or spatially limited	Spatial

After the general review of spatial regression modeling techniques, it can be stated as a conclusion that location matters (Case et al., 2004; Cheshire and Sheppard, 1995; Clifton et al., 2008; Dubin, 1992; Fik et al., 2003; Gallimore et al., 1996; Gelfand et al., 2004; Hui et al., 2007; Orford, 2002).

3.2.1 Global regression modeling

Global models have being used for last four decades to address spatial effects in regression analysis. There is a remarkable number of studies giving attention to this modeling technique (Cliff and Ord, 1981; Anselin, 1988; Griffith, 1988; Haining, 1990; Cressie, 1993; Anselin and Hudak, 1992; Can, 1990; Cliff and Ord, 1970; Dubin, 1992; LeSage and Pace et al., 2004; Martin, 1974; Militino et al., 2004; Openshaw, 1977; Ord, 1975; Pace and Gilley, 1997; Paez et al., 2001).

The first term that needs to be addressed in spatial regression modeling is spatial heterogeneity or in other terms spatial non-stationarity. It refers to the varying relationships across the space/study area. There are different approaches to deal with spatial heterogeneity but maybe before talking about these approaches the question to be asked is; why we need to deal with the spatial heterogeneity. According to Anselin (1999), there are three main reasons. "First, the 'structure' behind the instability is spatial (or geographic) in the sense that the location of the observations is crucial in determining the form of the instability. Secondly, because the structure is spatial, heterogeneity often occurs jointly with spatial autocorrelation, and standard econometric techniques are no longer appropriate. Thirdly, in a single cross-section, spatial autocorrelation and spatial heterogeneity may be observationally equivalent". In other words, heterogeneity can cause a biased estimation of the parameters and also mislead significance levels (Paez and Scott, 2004).

The second term that has to be stressed is the spatial dependency/spatial autocorrelation. As was mentioned generally in the previous section, spatial autocorrelation means the correlation/association of the values of the analysis points that are located nearby. This idea also refers to Tobler's (1970) statement "the first law of geography: everything is related to everything else, but near things are more related than distant things". So, when there are 'n' number of observations of the same variable in a particular region, the degree of the spatial dependency within the n values refers to the spatial autocorrelation. This measure of the degree of relationship is important for many aspects in spatial data analysis. To understand the real correlation between the values and the variables and to avoid misleading results is very important in spatial analysis. The ways to deal with the tendency for nearby points to be more related than the distant things - as in the first law of geography – is one of the main subjects of global regression modeling.

In global spatial regression models there are two different ways that spatial dependence can be addressed. One of them is the added spatially dependent variable and the other one is the error term. Related to this, one of the approaches to modeling the spatial dependency is the spatial autoregressive model. Different than a standard linear regression model, the model contains a spatial lag term of the dependent variable. So, the formulation of this model will be as;

$$y = \rho Wy + x\beta + \varepsilon \tag{3.1}$$

W as being the spatial weighting matrix applied to the dependent variable *y* and *p*, the spatial autoregression parameters, are the important elements of this model. The additional component of the model *W* (the spatial lag term) consists of the weighting matrix, which is based on the spatial correlation of the observations. Physical contiguity, connectivity and proximity can be the different ways of defining the matrix W (Paez and Scott, 2004). The weight matrix can contain 0 or 1 if the observations are sharing a border or not, or they are in the same neighbourhood or not. This matrix can also include values other than 0 and 1, based on the inverse distance between the observations.

The other approach for SAR (Spatial Autoregressive Model) modeling is the Spatial Error Model (SEM). SEM appears in 3.2;

$$y = x\beta + v$$
$$v = \rho W v + \varepsilon \qquad \textbf{(3.2)}$$

In this formulation *p* is used as the coefficient of the spatially lagged autoregressive errors of *Wv*. Since, the spatial effects (spatial dependency and the heterogeneity) cannot be separated from each other easily, both of the models explained above deal the spatial effects in the models.

Although these models are trying to fill the gap of the spatial issues in the regression functions, there are still some missing points like limited level of spatiality. So, in order to deal with these issues in a detailed perspective, different local forms of modeling techniques have been developed. As stated by Fotheringham (1997), by exploring the spatial differences of the outcome, interesting insights can be discovered. In addition, Farber and Yeates (2006) mentioned a similar statement that moving from global to local estimation can support achieving more interesting outcomes. The possibility of interesting insights and outcomes of relationships is the reason for the local regression models to take place in the literature. After noticing what else can be done with the same data, local models appeared on the stage.

3.2.2 Local regression modeling

The focus of the spatial analysis was more based on the global processes until the recent developments, which changed the direction of focus to the spatial variations in the localized scale of relationships (Brunsdon et al., 1998). There were several reasons for these different attempts for local versus global. Mainly, spatial limitations that come with the structure of the global spatial statistics were the reason for this switch. As mentioned by Paez et al. (2002a), the other reason was that global based regression methods used to understand the spatial pattern are not giving satisfactory results/answers if the pattern gets complicated. So, recently spatial regression analysis started to focus more on the local form. The important point is to understand or realise why relationships differ across the space. While finding the answer for that question, local modeling techniques were discovered/developed to point out these spatial variations in the local scale.

While the local spatial models are trying to focus on the spatial variations in the relationships, the other important point is the elimination of the misspecification bias

(Fotheringham and Brunsdon, 1999). Relationships can vary spatially because of three reasons. First of all, sampling variation, that is expected to occur since the samples that form the data are different from each other. Secondly, there is a difference between relationships across space because of the changing physical, economic, personal and social issues. Third and the lastly, spatial non-stationarity can be observed due to the model misspecification (Fotheringham, 1997).

There are different local forms of spatial analysis for measuring the relationships in multivariate data. Bitter et al. (2007), Case et al. (2004), Clapp and Gioccotto (1998), Cleveland and Devlin (1988), Cleveland (1979), Jones (1991), Jones and Bullen (1994), Long et al. (2007), Lou and Wei (2009), McMillen (1996), Mei et al., (2004), Orford (2002), Paez (2005), Pecci and Sassi (2008) and Ruppert and Wand (1994) are some of the examples for these varying techniques. More detailed information about these varying local modeling techniques (Spatial Expansion Method, Multilevel Modeling, Switching Regression, Locally Weighted Regression, Moving Window Regression) will be discussed in this section of the study. The Geographically Weighted Regression, one of the local spatial models, the main modeling technique of this research, will be described in the following section.

3.2.2.1 Spatial expansion method

The expansion method - one of the local modeling techniques - was introduced by Casetti (1972), in which a ‘terminal’ model is created from an ‘initial’ model. Based on the idea that relationships can vary across the space, the spatial expansion method measures the ‘drift’ of parameter estimates according to their spatial attributes (Jones and Casetti, 1992).

Basically, the method is a combination of four different processes:

1- Specification of an ‘initial’ model

2- Redefinition of the some or all of the parameters of the initial model by ‘expansion equations’

3- Creation of a ‘terminal’ model by replacing the expanded parameters into the initial model

4- Production/estimation of the terminal model (Jones and Casetti, 1992).

Following these processes, the general form in 3.3 is extended based on the location *i* to be able to measure the effect of the spatial context like in 3.4;

$$y_i = \sum_{k=1}^{K} \beta_k X_{ki} + \varepsilon_i \quad \textbf{(3.3)}$$

$$\beta_{1i} = \beta_{11} + \beta_{12} u_i + \beta_{13} v_i$$

$$\beta_{ki} = \beta_{k1} + \beta_{k2} u_i + \beta_{k3} v_i \quad \textbf{(3.4)}$$

where β represents the parameter, v and υ the spatial coordinates of location *i*. As the method works by expanding the parameters of stationary coefficient models (Bitter et al., 2007), the terms in the equation 3.3 are the expanded forms of the parameters which will be later replaced in the general form of the function 3.4. After this step, the terminal model will become like in 3.5.

$$y_i = \beta_{11} + \beta_{12} u_i + \beta_{13} v_i + (\beta_{k1} + \beta_{k2} u_i + \beta_{k3} v_i) x_i + \varepsilon_i \quad \textbf{(3.5)}$$

There are some studies done including the spatial expansion method as an alternative approach and some for a comparison to the other methods (Can, 1990; Can and Megbolugbe, 1997; Paez, 2005; Bitter et al., 2007). Paez (2005) states that the spatial expansion method is an easy way of solving the non-stationarity issue. Moreover, as Can (1990) mentions, the method presents an alternative approach - rather than the classic ones - which emphasises the spatial or temporal variations. Although the spatial expansion method is very important in finding a way for incorporating the spatial attributes in the analysis, there are some disadvantages of this method.

These disadvantages can be summarized in three categories as Fotheringham and Brunsdon (1999) mentioned in their study. First of all, complex versions of the expansion equations will result in a limited representation of the relationships across space. Second, the existing expansion equation form that needs a priori can be replaced with more flexible functional forms. Third and the most important, to be able to solve the problems of estimation in the terminal model, the expansion equations must be assumed to be deterministic.

3.2.2.2 Multilevel modeling

Multilevel modeling is a multi-level approach that was introduced by Jones (1991) as a technique to help reorganise the varying technical and potential problematic areas in a sensible structure (Jones, 1991).

There were different problems (simultaneous estimation of fixed and random parameters, estimating these in a feasible way by computation) that blocked the use of multilevel modeling until three different algorithm methods were introduced; 1- EM (Expectation-Maximisation) algorithm 2- the Fisher-scoring algorithm and 3- the Iterative generalised least-squares algorithm (Jones, 1991) (for detailed information see Jones, 1991 p. 152). Generally there is not a big difference between all these three algorithms working processes. “Initial estimates are made of the fixed terms, and these are then used to provide initial estimates of the random parameters, which in turn are used to permit revised estimation of the fixed terms, and so on. The iterations continue, maximizing a specific function, until convergence is achieved” (Jones, 1991). The model is based on the expanded version (3.6) of the bi-level model (3.6).

$$y_{ij} = \alpha_j + x_{ij}\beta_j + e_{ij} \qquad \textbf{(3.6)}$$

j represents the place and βj , αj are the parameters which are specific to place (3.7).

$$\alpha_j = \alpha + \mu_j^{\alpha}$$

$$\beta_j = \beta + \mu_j^{\beta} \qquad \textbf{(3.7)}$$

After the expansion the model becomes:

$$y_{ij} = \alpha + x_{ij}\beta + (e_{ij} + \mu_j^{\alpha} + \mu_j^{\beta} x_{ij}) \qquad \textbf{(3.8)}$$

The multilevel modeling technique for modeling the spatial processes is applied in several studies (Duncan et al., 2000; Orford, 2000; Jones and Bullen, 1994; Orford 2002). It is a step forward compared to the single level models. Although it takes into consideration that data can have a hierarchical structure, there are still some limitations in the model. According to Paez and Scott (2004), in multilevel modeling like the switching regression structure (which will be explained in the next section), although the parameters can vary between the classes and zones, they are not acting locally within the class or zone. The other problem with this method in spatial processes is the discontinuity caused by a priori definition of a discrete set of spatial units at each hierarchy level. As the effects of space are continuous, most of the spatial processes will not work with this approach (Fotheringham and Brunsdon, 1999).

3.2.2.3 Switching regression

The method of switching regression pioneered by Quandt (1958), divides the dataset into a different number of regimes (Paez et al., 2001; Paez and Scott, 2004). Therefore, this method is suitable and can be applied for solving the heterogeneity problem where the dataset can be divided into a small number of regimes (Paez et al., 2001; Paez and Scott, 2004).

If dataset is classified in two groups, the model will represent itself as in (3.9),

$$\begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} = \begin{bmatrix} X_1 & 0 \\ 0 & X_2 \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} \quad \textbf{(3.9)}$$

where Y_1 and Y_2 symbolise the two different spatial classes.

According to different users of the switching regression method, there are some points where the technique produces suitable solutions for the problems. Especially while dealing with spatial processes for heterogeneity, because there is no need for an extra variable, it makes the method simple to handle (Paez et al., 2001). Paez and Scott (2004) also declare that this method fills the gap between the global and the local analysis. On the other hand, although it is considered as a local modeling technique, there are still some global issues in the model that have to be covered, as in the multilevel modeling method.

3.2.2.4 Locally weighted regression

The Locally Weighted Regression method, which is a nonparametric approach was proposed by Cleveland (1979) and developed by Cleveland and Devlin (1988). As McMillen (1996) stated the idea behind the method is to "give more weight to nearby observations when estimating a regression, so the estimates approximate the curvature with a set of local linear approximations".

Cleveland and Devlin (1988) illustrated the three major uses of this local-fitting methodology. "The first is simply to provide an exploratory graphical tool; graphing smooth surfaces that are fitted to the data can give us insight into the behaviour of the data and help us choose parametric models. The second is to provide additional regression diagnostics to check the adequacy of parametric models fitted to the data. The third is to use the Loess (locally weighted regression) estimate as the estimated regression surface, without resorting to a parametric class of functions".

For spatial modeling and also for dealing with nonlinearity, locally weighted regression is a useful and a simple technique (Ruppert and Wand, 1994). Besides, it is flexible while generalizing the functional form (McMillen, 1996). Also, locally weighted regression gives the opportunity to estimate a wider group of regression surfaces compared to usual classes of parameter functions (Cleveland and Devlin, 1988). Regarding to these advantages, the method is used by different disciplines like chemistry, computer science, biology, climatology and etc. (Naes et al., 1990; Wang et al., 1994; Atkeson, 1991; Atkeson et al., 1997).

On the other hand, as a nonparametric method, solutions need to be found for some specific problems especially in the structure of the model. These can be summarised by McMillen's (1996) such as; 1- sample size 2- the hypothesis test that has to be developed for specific models 3- extension for the discretion of data estimators is needed 4- for selection bias models nonparametric estimators is needed.

3.2.2.5 Moving window regression

Moving Window Regression is one of the local modeling techniques mostly focusing on the problem of the boundaries of the study region. Rather than using the existing provinces, districts or neighbourhoods as in most of the regression studies a grid of regression points are settled over the study area later to form the new set of regions around each regression point. After defining the new borders for the regions, the spatial processes can be done within these new borders.

Because of this structural property, moving window regression is used by several different disciplines. For instance, in urban planning for house price studies (Long et al., 2007; Farber and Yeates, 2006), in chemistry (Jiang et al., 2002; Du et al., 2004), biology (Kasemsumran et al., 2003), hydrology (Lloyd, 2005) and in environmental studies (Haas, 1990) the moving window technique is applied.

Although the model is helpful and commonly used by different disciplines, the results are dependent on the size of the region or the ‘window’ so, larger regions will result in the smoother surfaces (Fotheringham et al., 2002). The other problem, mentioned by the same authors, is the edge effects which mean that regions at the edges will have less regression points than the central ones and this can cause parameter estimates of those regions to have higher standard errors.

3.3 Geographically Weighted Regression

The Geographically Weighted Regression technique that was developed in the last two decades brought a new perspective to the spatial regression models. There are several studies belonging to varying disciplines in the literature that uses this local regression technique as a spatial analysis tool. The GWR technique, which has not applied in any of the urban planning studies in Turkey yet, is separated from the global methods in several ways and represents the local forms of spatial analysis.

Geographically Weighted Regression was introduced by Brunsdon et al. (1996) and Fotheringam et al. (1997) for the estimation of the local parameters rather than the global ones. As mentioned earlier even though there are lots of studies applying this technique, there is limited number of studies using this method in Turkey and none of them is in the urban planning field. Erener and Duzgun (2007) used this method for the assessment of the landslides, Yildirim et al. (2009) for the investigation of income inequalities, Olgun and Erdogan (2009) for the exploration of the crop yield potentials, Bahadir (2011) for the distribution of surfaces for precipitation and Isik and Pinarcioglu (2006) for the differentiation of regional fertility.

In the international literature, other than the urban and regional planning subjects, GWR is applied in different social and environmental issues in different fields. Starting with the environmental subjects, this technique is applied by varying subgroups (Atkinson et al., 2003; Brunsdon et al., 2001; Foody, 2003; Giaccaria and Frontuto, 2007; Mennis and Jordan, 2005; Osborne et al., 2007; Tu and Xia, 2008; Zhang and Shi, 2004; Wang et al., 2005). To give an idea about the variation of the topics of these studies some examples can be given. For instance, Brunsdon et al. (2001) investigated the relationship between rainfall and altitude. In another study by Foody (2003) the relationship between rainfall and normalised difference vegetation index is studied. Mennis and Jordan (2005) were interested in the distribution of the environmental equity by exploring the air toxic releases. For determining the causes of water pollution Tu and Xia (2008) studied the relationship between land use and water quality. Osborne et al. (2007), for example, examined the distributions of wildlife using GWR. While Wang et al. (2005) used the GWR technique for investigating the net primary production of the Chinese forest ecosystems, Atkinson et al. (2003) used it to state the relationships between riverbank erosion and geomorphologic controls. The work of Giaccaria and Frontuto (2007) was the one of the first examples where the GWR methodology has been applied to the environmental economics. For the social aspects, the situation is not different and it is possible to talk about the varying subjects and fields using geographically weighted regression (Cahill and Mulligan, 2007; Nakaya et al., 2005; Waller et al., 2007). To explore the local crime patterns, for example, Cahill and Mulligan (2007) used the geographically weighted regression model. Another study by Walter et al. (2007) was investigating the relationship between the alcohol distribution and the violence. The GWR technique is also used in health studies. For example, Nakaya et al. (2005) used the technique for disease association mapping.

Transportation is another field that this local spatial modeling technique is applied (Clark, 2007; Du and Mulley, 2006; Zhao and Park, 2004). Clark (2007) in his study tried to explain that income is effective on the level of car ownership by using geographically weighted regression. There are some other explanatory variables used to support the model such as population density, fuel price and taxation. With the implication of GWR, Du and Mulley (2006) wanted to show the existing locally varying relationship between land value and transportation accessibility. Furthermore, Zhao and Park (2004) presented the annual average daily traffic estimation by using the GWR model.

Since the method was introduced the number of the studies and the number of different disciplines using the GWR as a local spatial modelling technique is increasing. Not only by its developers, but also by other researchers, there have been some studies that develop or extend the use of this technique. In 1999, Brunsdon et al. extended the ideas of GWR in three different ways: first, by introducing a set of significance tests, second, by discussing the mixed ‘GWR’ models in which some of the independent variables can be fitted globally and the others varying spatially and thirdly, by considering the degree of parameter smoothing in GWR. Following this study, Leung et al. (2000a) focused on the development of the statistical testing methods related to GWR. In their study, importance was mostly given to the statistics for testing the goodness of fit and variation of parameters. In addition to these, a stepwise process for selecting the important independent variables for the model structure was introduced. In another study of Leung et al. (2000b), some other statistical tests for spatial autocorrelation among the residuals of the GWR model were proposed. All these suggested tests can help to understand the structure of the data, the model and the technique. An extension for GWR - Bayesian Geographically Weighted Regression (BGWR) - was introduced by LeSage (2001). The purpose of this Bayesian method was to deal with the some of the possible difficulties in GWR when the sample dataset contain some outliers or non-constant variance. Paez et al. (2002a) in their first paper presented a method that can estimate the location-specific kernel bandwidths and a test for the locational heterogeneity. In their second paper (Paez et al., 2002b) they focused on detecting spatial association by using GWR and formulating some model specification tests. After all these extensions and tests, the research for developments went on in different dimensions. There were some studies prepared for the review of the different techniques including global and the local ones (Paez and Scott, 2004) and some studies tried to develop new extensions of GWR (Mei et al. 2004). The paper of Paez and Scott (2004) was one of the examples for the type of study that makes a review of techniques of spatial statistics for urban analysis. GWR technique was an example of one of these developments. They also presented some examples for urban analysis from recent applications. They concluded mentioning that all the different examples they examined in their study illustrated that more efficient analysis for urban data can be done with the local forms of the spatial analysis. Mei et al. (2004) suggested an approach for identifying a mixed GWR model by some statistical tests. They mainly focused on simulations for examining the test performance. Crespo et al. (2007) developed a spatiotemporal version of the GWR technique to be able to forecast and interpolate the local parameters with the time aspect. Another study similar to Crespo et al.'s (2007) was the study of Huang et al. (2010). Geographically and temporally weighted regression (GTWR) was developed in this study in order to deal with spatial and temporal heterogeneity. There was another research perspective for the GWR technique which was introduced by Mennis (2006). It was focusing on improving the mapping of the results of any GWR study. Mennis's (2006) purpose was to suggest some methods that can improve the earlier implementations on visualisation of the results. He discussed the challenges of mapping the results in different aspects and also supplied a case study to examine the important issues for visualising the outcomes of the GWR analysis.

In urban and regional studies GWR is also becoming one of the popular methods that the researchers prefer to use because of the spatial heterogeneity issues. It is possible to talk about the variation in topics like policy making, regional development, population segregation, industrialisation, house price studies and etc.. Ali et al. (2007) with a dependent variable of percentage change in rural population wanted to improve the regional analysis and policy making using a model like GWR rather than the ordinary least squares and spatial econometric approaches. The explanatory variables that they used in their study were; employment, agglomeration, human and social capital and some distance variables. The important finding of this research stated by the authors was that standard approaches such as OLS (Ordinary Least Squares) and spatial econometric models represent the spatial differences less than actual situation. If the standard approaches are followed it is possible to have poorly suited policies in urban and regional studies. The other example for policy making is the study of Pecci and Sassi (2008) using the mixed GWR to model the agricultural and rural development policies. To investigate the regional development mechanisms in the Greater Beijing Area, Yu (2006) used geographically weighted regression. According to the results of this study, the regional development mechanisms have a significant spatial non-stationarity structure and a strong local characteristic. This study is a good example of the advantage of using a local spatial modeling technique in the regional development research. Lo (2008) applied GWR to estimate population. The GWR model was preferred rather than a global ordinary linear regression because of the spatial non-stationarity issues. In the research, low and high-density urban use, cropland and forest variables were used. It was found that the local regression model GWR performed better than the global OLS model. The other research based on the population segregation and GWR, was done by Yu and Wu (2004). OLS and GWR were applied to understand the relationship between the population segregation and remote sensing variables. To get some local parameter estimates, Huang and Leung (2002) used GWR in their study to identify the spatial interaction between industrialisation and some other factors. Including GDP, labour and various other independent variables, spatial non-stationarity was one of the main results of this study.

A final topic to mention in the field of urban and regional planning studies is the GWR model used to analyse the relationships of house prices. There are different types of studies done for modeling house prices using GWR. In some studies house prices are used as a dataset for introducing new techniques and improving the method (Brunsdon et al., 1999; Fotheringham et al., 2000; Mennis, 2006). In some other studies GWR is the main subject of the research; to compare the results of the global and local regression models for house prices. Also, there are some examples where the differences of several local spatial models are compared within the house price perspective.

Cho et al. (2009a) can be given as an example for the studies that used GWR as the implementation method. In this study, they analysed the effect of the spatial configuration of the forest landscape on the amenity value. As a result of the value estimations, spatial and temporal dynamics were evaluated in order to state some strategies for the forest conservation programs. In the other study of Cho et al. (2009b) the attention was given to the rezoning issues and their effect on house prices. The method was used to cover the spatially varying effects of rezoning. In this study a combination of the GWR and the spatial autoregression method was applied.

Xiaolu and Yasushi (2005) focused on two different approaches to understand the effect of spatial features on house and land prices. One of these approaches was based on the global regression model residual and the other on GWR. Several different independent variables, which can be grouped under the names of lot-associated and area-associated variables, were used. As a result, first, local spatial analysis techniques helped to discover the left out spatial features, second, they helped to distinguish the effects of variables which had conflicts with each other. Yu et al. (2007) is another example with the content of the comparison of the global and the local techniques in order to explore the relationships of house price. With the 'presence of air conditioning, floor size, number of bathrooms, number of fireplace and age' as independent variables, vegetation, impervious surface and soil were used as neighbourhood characteristics in this study. The outcome of this study, suggested that in order to have accurate predictions GWR is the model that should be used. The other important result of the study was that by using GWR it was proven that the significance level of an attribute could vary based on the location. So, the same attribute can add value to the house price in one location and decrease the value of the property at another location. The other example in this category is the study of Diaz-Garayua (2009). While using two different forms of regression analysis (OLS and GWR), the research tried to examine the influence of the neighbourhood characteristics on house prices.

Kestens et al. (2006) looked at the buyers' household profiles to be able to measure the heterogeneity of the implicit prices. In order to achieve this goal they used a variety of variables including some physical characteristics of the property on sale such as; living area, age, existence of pool, fireplace, built-in oven and detached garage and some accessibility, income, vegetation, education and unemployment variables. The main finding of the study was that some characteristics of the buyer's household like income have an impact on house prices. The study was held mainly using the two different local techniques, the spatial expansion method and GWR. Another study related to GWR and house prices that made the comparison between the spatial expansion method and GWR was Bitter et al.'s (2007). In this research various physical properties of the house were the independent variables of the study. Among these independent variables seven of them (bathroom fixtures divided by the total number of rooms, presence of refrigerated air conditioning, presence of a swimming pool, total number of rooms divided by dwelling size, high interior quality of the dwelling, age of the dwelling, number of patios and presence of a garage) were used with the two different local modeling techniques. As a result of this study, both methods proved the presence of spatial heterogeneity in the housing market. Also, for some housing properties the prices showed a varying structure based on the locality. The other important outcome of the study was that GWR performed better than the spatial expansion method in terms of the ability to explain the relationships. On the other hand, the spatial expansion method can be more flexible in the case of the larger number of variables. A comparison of GWR is made with moving windows regression (MWR) and moving windows Kriging in another study (Long et al., 2007). The variables were a combination of three different categories: 1- structural properties of the samples 2- natural and social environment characteristics and 3- locational characteristics of the samples. The two approaches of MWR and GWR models produced the better results.

In summary, all the examples above are the studies that are aware of the importance of the local issues. Because of this awareness, they prefer to use GWR in their studies in several different ways. Fotheringham (1997) mentions the importance of local trend as a “recent and potentially powerful movement within spatial analysis where the focus of attention is on identifying and understanding differences across space rather than similarities. The movement encompasses the dissection of global statistics into their local constituents; the concentration on local exceptions rather than the search for global regularities; and the production of local or mappable statistics rather than `whole-map' values”.

According to Paez and Scott (2004), if the research is based on the spatial structure of a metropolitan area then using local modeling techniques for spatial analysis can be more effective in urban analysis. It is for sure that for the urban form and house price studies in the metropolitan city of Istanbul, using geographically weighted regression will be more efficient, “as a simple way of modeling complex spatial variation” (Paez and Scott, 2004).

3.4 Evaluation

The content of urban analysis shows a different pattern in terms of the type of the data and the level of the model used in the studies in the last four decades. Computers and some software can be stated as the basic reasons of this differentiation. The relationships of varying components of the urban system have been examined through history. Urban form and house prices are both popular topics in urban studies and they are examined with different approaches. Regression models are the most popular to investigate the various relationships in a city.

Hedonic price modeling applications were used for the valuation of the goods since the late 30s. According to this model house were composed of different attributes. These attributes can differ from one study to another. In most of the studies applying this model, the housing physical, neighbourhood and socio-economic attributes were the independent variables of the model. Although the relationships showed a spatially varying structure, this important determinant was not included in any way.

At that stage, being aware of the spatial issues, there were some studies introducing new theories in order to include the spatial issues in the structure of the model. Housing submarkets and the spatial lag term are examples of these attempts. Although the hedonic model was easy and simple to use, the possibility of missing the spatial variation and misleading interpretations were the disadvantages of the model.

Since hedonic price model was an aspatial model the research based on the spatial regression models accelerated. After a short while, spatial regression models were used in urban planning and geography studies as well as the other disciplines such as biology, ecology, sociology, economics and etc. Spatial modeling techniques mostly focus on the idea of examining the spatial data in a detailed way. Furthermore, they were addressing the spatial autocorrelation and the spatial heterogeneity which are important themes for the spatial analysis. First the global spatial modeling techniques and then the local ones started to develop model structures that cover the spatial autocorrelation and spatial heterogeneity issues. The global and the local perspectives of the spatial regression models are separated from each other by several characteristics. Varying over space, being mappable, searching for the special local differentiations are some of the advantages of the local models over the global ones. In the cases when a global scale value and interpretations is not adequate for achieving the purpose, the models that have to be employed in the studies should be local regression models.

In the literature there are several different types of the spatial local modeling techniques (spatial expansion method, multilevel modeling, locally weighted regression, moving window regression, switching regression). Each of them has both the advantages and the disadvantages. Geographically weighted regression, a local modeling technique and the newest of the local models brought a new perspective to the spatial regression methods. Since, it is a good tool for representing the local forms of the spatial analysis, this model is preferred in this study. For the last two decades there are several studies done with this model in various fields such as social and environmental issues, transportation studies, quantitative geography, urban and regional planning studies.

Although GWR or any other local regression modeling techniques are bringing advantages for using the data in urban and regional planning, there are not many studies done in Turkey. In conclusion, any type of study, especially one based on the relationship between urban form and house prices that can have a spatially varying structure, will definitely benefit from the use of the local forms of spatial analysis. In the following chapter the structure of the model will be discussed and the whole analysis process will be presented.

4. APPLICATION OF THE GEOGRAPHICALLY WEIGHTED REGRESSION MODEL

The structure of the model, selection of the variables, distribution of the samples used in the study, evaluation of the data, application of the model, discussion of the outcomes and general evaluation of the process are the topics which will be covered in this chapter.

4.1 Structure of the Model

The general concept behind the Geographically Weighted Regression model is the first law of geography stated by Tobler (1970) as “everything is related to everything else, but near things are more related than distant things”. With this principle the way that the model works is based on the weight matrix. Each data point has its weight related to its distance from the regression point, so that, the closer the data point to the regression point the higher the weight. As a local spatial model the general information about the model will be given below under different titles.

4.1.1 GWR and the spatial kernels

As a basic step for the GWR model, every data point - based on their location- need to be weighted differently. For this purpose, the key issue is to define weighting scheme based on a spatial kernel where the relationship between distance and weight is controlled by a parameter known as the bandwidth. Defining a spatial kernel will affect the weight of each point which is related to the point’s distance from the regression point. As described in Figure 4.1, the weight increases if the distance between the regression point and the data point decreases. Moving the regression point through the study area will generate a set of local regression models across the study area. As a result of this, “for each location, the data will be weighted differently so that the results of any one calibration are unique to a particular location” (Fotheringham et al., 2002). As the bandwidth of the particular spatial kernel will have an effect on the model results, optimal bandwidth value should be determined.

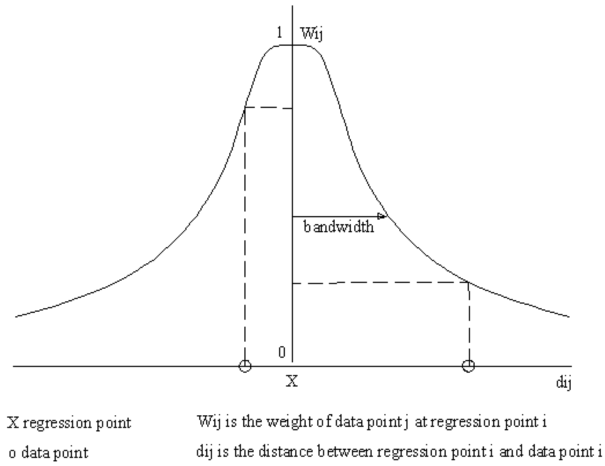


Figure 4.1 : A spatial kernel (Fotheringham, 2010).

In GWR model calibration, there are two general types of weighting function. One is the fixed spatial kernel and the other is the adaptive spatial kernel. If a fixed spatial kernel is used, the distribution of the data points over the space and their density will affect the weights for these points (See Figure 4.2). With this type of spatial kernel there is always the risk of calibration of the model with few data points where they are not dense, producing local parameter estimates with large standard errors (Fotheringham et al., 2002).

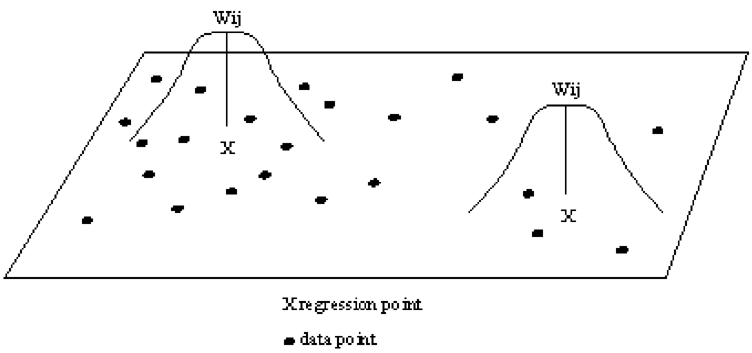


Figure 4.2 : GWR with fixed spatial kernels (Fotheringham, 2010).

On the other hand, if the spatial kernel adapts itself to the data points' scatter scheme (being dispersed in space or not) as in Figure 4.3, it is referred as an adaptive spatial kernel. Where the data points are less dense, the bandwidth gets larger and as the data points become denser the bandwidth gets smaller. As Fotheringham et al. (2002)

stated with adaptive spatial kernel approach, it is possible to reduce the problems of the spatial fixed kernels in GWR model.

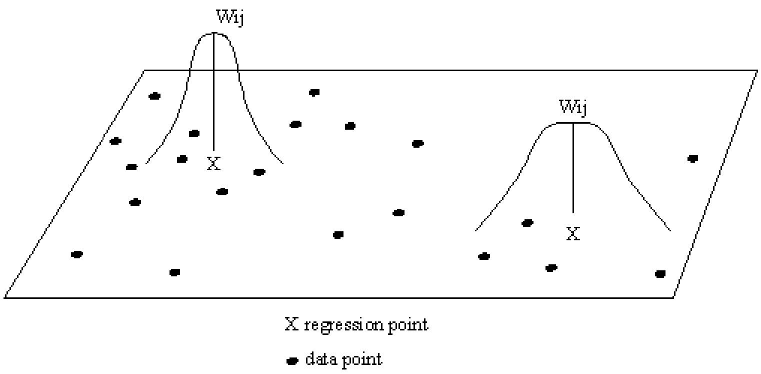


Figure 4.3 : GWR with adaptive spatial kernels (Fotheringham, 2010).

The other difference will be the smoothness of the outcome maps of these two different types of spatial kernels.

4.1.2 Basics for GWR

As mentioned in the earlier sections, GWR, as a local model, differs from global regression models by estimating local parameters rather than global ones. So, the formula of the global regression model (4.1) gets a new form as expressed below (4.2).

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots \beta_n x_{ni} + \varepsilon_i \quad \textbf{(4.1)}$$

$$y_i = \beta_{0(i)} + \beta_{1(i)} x_{1i} + \beta_{2(i)} x_{2i} + \ldots \beta_{n(i)} x_{ni} + \varepsilon_i \quad \textbf{(4.2)}$$

$\beta_{n(i)}$ s in (4.2) is the difference between the two equations which show that location *i* has an effect on the calibration of the formula as this is considered in the calibration of the model. As a result of this, each observation is weighted according to being nearer or farther away from the location *i* and these weights will change as the regression point changes. Moreover, spatial non-stationarity or in other words a relationship varying over space will be handled by calculating a weight matrix in which the weights are computed for each point *i*. So, data points close to *i* are weighted more and they will have more influence compared to the data points that are farther away (Fotheringham et al., 2002).

This is represented by an *n* by *n* matrix (4.3), showing the weights of an observed data point for the regression point *i* in its diagonal elements.

$$W(i) = \begin{bmatrix} W_{i1} & 0 & \ldots\ldots & 0 \\ 0 & W_{i2} & & 0 \\ . & . & & . \\ 0 & 0 & \ldots\ldots & W_{in} \end{bmatrix} \tag{4.3}$$

W(i) is a spatial weight matrix and *Win* is the weight of the data point *n* for the estimates of the local parameters at location *i* (Fotheringham, 2010).

With the weighting matrix the other important issue is the choice of spatial weighting function. The choice between the fixed spatial kernel and spatially varying kernel raises some serious issues in the calibration of the model. As Fotheringham et al. (2002) stated the first issue might be the missed details of the relationships with larger kernels when the data points are dense and the second, with fixed kernels the estimated standard errors of the coefficients will be high if the data points are scarce. To handle these problems, the general solution can be using the spatially varying kernels in the calibration process. One of the methods of producing spatial varying kernels is by selecting only the *N* nearest neighbours to be used in the local regressions. Inclusion of this method in the GWR model means the need for estimation of N. As mentioned in the earlier section, usage of the adaptive bandwidth in GWR is based on the nearest neighbour weighting. *N* is the number of the data points included in the model calibration and the weighting scheme will determine the weight of each observation up to the Nth closest data point which will have a weight of zero.

As well as the type of kernel, bandwidth selection is also important in GWR as the results are sensitive to the choice of bandwidth. To overcome this problem Fotheringham et al. (2002) suggest determining an optimal bandwidth based on one of three goodness-of-fit measures.

1- Cross-Validation (CV)

2- Akaike Information Criterion (AIC)

3- Bayesian Information Criterion (BIC)

There are examples in the literature of the use of each of these criteria. To be able to make the comparison between the global model and the GWR model or any other type of model, AIC (Akaike Information Criterion) will be the used as a key measurement factor in this study. “The AIC is the measure of this closeness, and the closest model is nominated as ‘best’. . . . AIC is not simply a measure of ‘goodness of fit’ such as a sum of squared errors, but also takes model complexity into account” (Fotheringham et al., 2002).

4.1.3 Statistical Details of GWR

For a statistical global model calibration the independent and dependent variables are needed for a certain number of observations. In addition to this with the GWR model the location of the observations is needed. The coordinates of each observation will be included in the data set and GWR will estimate the functions by using the kernel-based methods (Fotheringham et al., 2002). On the other hand, in the global regression model the residual sum of squares (RSS) is the way to measure the ‘goodness of fit’. For instance, if the model has k linear parameters, the expected RSS will be calculated as in (4.4).

$$E(RSS) = (n-k)\sigma^2 \quad \textbf{(4.4)}$$

In this formula n represents the number of the observations and n-k is the degrees of freedom of the residual. Since the GWR has a non-parametric framework mentioning ‘effective number of parameters’ and ‘effective degrees of freedom’ rather than ‘number of parameters’ and ‘degrees of freedom’ is more meaningful. To be able to compare the global model and GWR, an *F-test* can be used. The other issue in the GWR model is the test for the spatial stationarity of each of the parameters included in the model. To compute the variability distribution of the local parameters, a Monte Carlo approach is adopted. With this approach it is also possible to test the significance of the spatial variability of each coefficient (Fotheringham et al., 2002).

The other statistical subject to mention briefly for model selection is the AIC approach. The smallest AIC values can refer to the best model because this value symbolises being closest to the real model. AIC can be used for several different purposes:

1- To compare different GWR models with different variables

2- To compare GWR with an OLS model with same variables

3- To select an appropriate bandwidth

Some brief information about the statistical background of the GWR model is mentioned in this section. More information and also the application of different statistical tests within the GWR model will be discussed in the following sections.

4.1.4 Extensions of GWR

In the previous sections the basic idea of GWR was described and in this section the main aim is to give some brief information about some extensions of these models. The first one is the mixed GWR which is for the case where some relationships that are not varying over space in the data set. If it is possible both geographically varying and non-geographically varying variables the mixed GWR model should be considered. At this point, it is important to mention that for the variables not varying geographically it does not mean that they do not have any effect; it means their effect is same for every location in the study area. The mixed GWR model is written in the form that the formula consists of two different parts (4.5). Each part is including a different group of variables.

$$y_i = \sum_{j=1,ka} a_j x_{ij}(a) + \sum_{l=1,kb} b_l x_{il}(b) + \varepsilon i \qquad \textbf{(4.5)}$$

If the first part of the equation the a-group variables have no spatially varying relationship, the b-group variables exhibit spatial variability in their relationships, it means that the model is a full GWR model. If there are no b-group variables, the model will be a standard linear regression model. A model having both a and b type variables will be the mixed GWR model.

There are some other extensions that are focusing on the error term. One of them is Robust GWR, dealing with the problem of outliers, and the other one is the Spatially Heteroskedastic Models, dealing with the spatial non-stationarity error terms. Furthermore, to deal with the spatial and temporal non-stationarity, an extended model, geographically and temporally weighted regression (GWTR) was introduced (Huang et al., 2010). Another alternative extension is the Bayesian GWR (BGWR) developed by LeSage (2001).

4.2 Variable Selection

The main purpose of this study is to analyse the effect of urban form elements on housing price. Parallel to this purpose, there are three groups of independent variables with a main group of urban form characteristics.

The idea was to have the opportunity for using urban form elements in quantitative research, so making them measurable and comparable. The next idea was adding these measurable and comparable attributes to different types of models to have comprehensive evaluation ability.

The international rather than the national literature (due to the lack of number of studies done on quantitative analysis of urban form in Turkey) was helpful to guide the variable selection in this study. However, these studies being applied on some regions which are physically and socio-economically different than Istanbul city and focused on different purposes made it difficult for the full interaction (Song and Knaap, 2004; Song, 2005; Clifton et al., 2008).

On the other hand, these quantitative analyses of urban form studies were not linked to any house price information and also there was no study in the literature on house price including the urban form elements as the main variable group. As a result, this study includes different types of urban attributes that are joined together under the urban form attributes/elements. *Urban structural attributes* such as type, age and height of the building, *Urban density attributes* like building coverage, floor area ratio, net building density, gross building density, *Urban morphological attributes* like street pattern, urban block size and topography, *Urban accessibility/location attributes* such as distance to central business district, highway, coast and sub-centres (primary and secondary).

Not only the urban form attributes but also housing physical properties and socio-economic properties of the neighbourhood are also included as different characteristics groups in this research.

Housing physical properties and neighbourhood socio-economic properties' components can differ between studies. The other issue encountered in the literature is the varying title for the same group of attributes in different studies (The detailed information on this issue can be found in the literature review chapter). In this study,

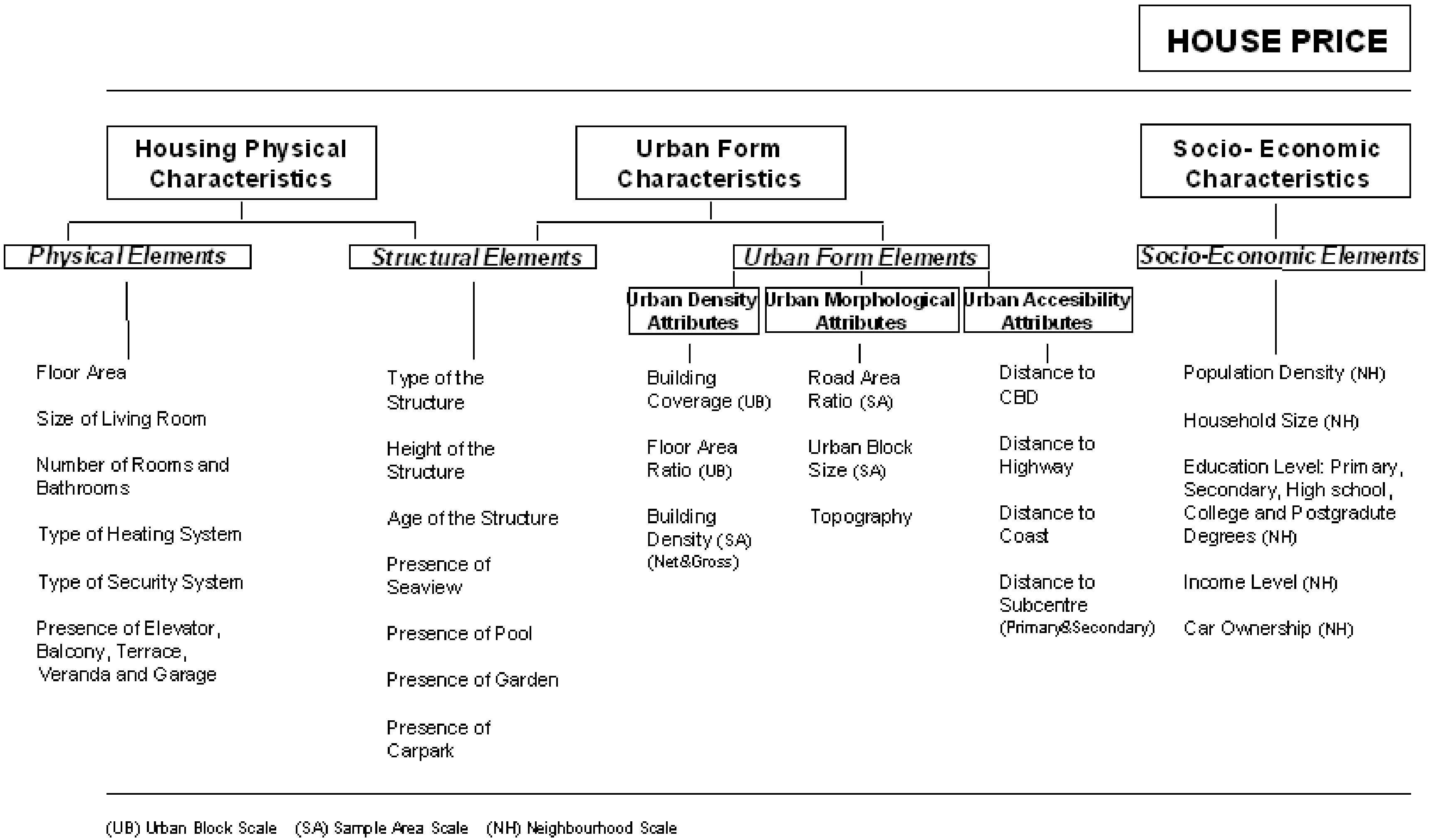


Figure 4.4 : Organisation of the variables included in the study.

floor area, size of living room, number of bathroom, number of rooms, type of heating system, type of security system, presence of elevator, balcony, terrace, veranda, garage, swimming pool, garden and car park represent the housing physical attributes; whereas population density, number of household, different education levels including literacy, primary, secondary, high school, college and postgraduate percentages, percentages of different income levels and car ownership are the representatives of the socio-economic neighbourhood properties.

As mentioned earlier the organization of each variable group can change related to the content of the research and the studies done by Adair et al. (1996), Anglin and Gencay, (1996), Arguea and Hsiao (2000), Basu and Thibobedau (1998), Benson et al. (1998), Bin (2004), Bitter et al. (2007), Bourassa et al. (2007), Bowen et al. (2001), Can (1990; 1992), Cheshire and Sheppard (1998), Clapp and Gioccotto (1998), Clauretie and Neill (2000), Colwell et al. (2000), Coulson and Leichenko (2001), Dubin (1992; 1998), Ellickson (1981), Farber and Yeates (2006), Fik et al (2003), Fletcher et al. (2000), Gallimore et al. (1996), Galster et al. (2004), Gencay and Yang (1996), Goodman and Thibodeau (2003), Hui et al. (2007), Jim and Chen (2006), Kask and Maani (1992), Kauko (2004), Kestens et al. (2006), Kim (1992), Knight et al. (1993), Li and Brown (1980), Long et al.(2007), Orford (2000), Ottensmann et al. (2008), Palmquist (1992), Sirmans et al. (2006), Tse and Love (2000), Tse (2002), Vandell and Lane (1989), Watkins (2001), Xiaolu and Yasushi (2005), Zietz et al. (2007) can be examples of studies that have at least one of the groups -physical components of the house, socio-economic components of the neighbourhood or location components - as variables. At the national level research done related to house price generally include the same type of group organization that is mentioned above (Alkay, 2008; Keskin, 2008; Ozus and Dokmeci, 2005; Selim, 2008; Yavas and Dokmeci, 2000; Yazgi and Dokmeci, 2006).

With the guidance of all these studies and taking the purpose of this study as a focal point, the general variable groups that will lead the research are decided as housing physical characteristics, urban form characteristics and socio-economic characteristics as mentioned before. The general groups of characteristics are divided into sub-groups and all of them are described in Figure 4.4.

4.3 Sample Distribution

If the evolution of the urban structure takes place over a long period of time in a city, this situation can be strongly effective on the content/scale of the studies that will be done for that city. In Istanbul, an example of one of these cities, the scale of the study is very important for the interpretations of that research. Including the examples of both past and future urban form properties has a great importance on the sample selection process. This process is especially critical for research that is trying to link to the future rather than only being satisfied with recent relations.

To be able to orientate the facts mentioned above the city boundary of Istanbul- which is same as the Istanbul Metropolitan Area border – is selected as the study area for this research.

The city of Istanbul, with all different kinds of transformations (historical, physical, social, cultural, economical and technological) in its background, exposes a multi-component structure. In order to investigate the meaningful relations with the research, the main focus will be the multi-level structure of the urban form developments and housing markets in Istanbul.

As stated in the latest 1/25000 scale Istanbul City Plan report, there are four main different types of housing pattern examples in the city.

1. Historical housing pattern : low-rise
2. Planned housing pattern: low-rise and high-rise
3. Mass housing : low-rise villas and high-rise apartment blocks
4. Unplanned housing pattern: squatter settlements and slum areas with reclamation plans

The different housing patterns except than the unplanned housing patterns are represented by various sample areas in the study. Related to the hypothesis and the research method of this study unplanned housing pattern examples of Istanbul Metropolitan Area are excluded from the sample groups for the following reasons:

1. The housing market in these types of settlements has different tendencies compared to the formal house market trends/activities/movements.

2. The houses belonging to this pattern are either examples of the illegal housing or reclamation of the slum areas.
3. Because of these stated reasons, inclusion of these sample areas/houses in the study would lead to bias in the results.

Because of the multilevel structure of Istanbul Metropolitan Area, based on both urban form and housing pattern, it was desirable to keep the study area as extensive as possible. However, because of the reasons stated above some districts were excluded from the research area. Therefore, data points are in the borders of Buyukcekmece, Beylikduzu, Avcilar, Bakirkoy, Kucukcekemece, Basaksehir, Esenyurt, Bahcelievler, Eyup, Zeytinburnu, Beyoglu, Fatih, Sisli, Sariyer, Besiktas, Beykoz, Cekmekoy, Uskudar, Umraniye, Kadikoy, Atasehir, Maltepe, Kartal, Pendik and Tuzla districts.

With the reflection of the all given information above, the selection process of the housing sample areas was done with a coordinated perspective. So, during the selection process, while connections between different historical urban developments, housing market and urban form elements were kept in mind, an attempt was made to represent all potential different groups of samples. According to all these diverse criteria, 376 different sample areas were selected to be analysed. The distribution of the sample areas is shown in the Figure 4.5.

There were several issues that decreased the number of the samples included in the study. The lack of a housing unit for sale in the previously selected sample area, the tendency of real estate agencies to hide the exact location of the house for sale and also missing socio-economic variables for some neighbourhoods were some these issues. As a result of all these conditions, the number of the samples included in this study is 631, from 267 different sample areas within the study region. The other point to emphasize is the strategy employed in the case of having more than one sample from the same sample area. In these special cases, different representative examples of houses are preferred to be included in the dataset. The distribution of the samples can be followed in the Figure 4.6.

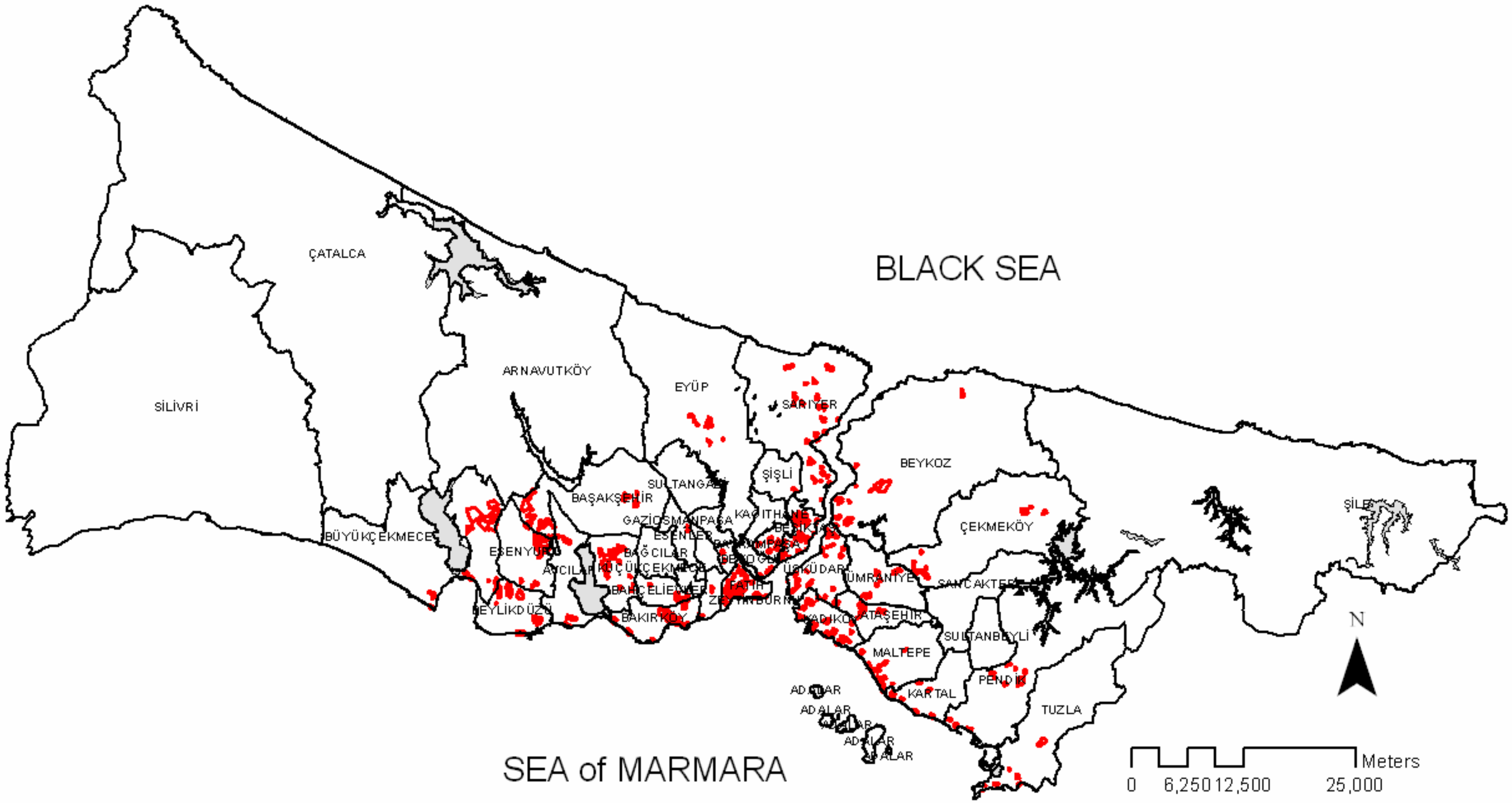


Figure 4.5 : Distribution of the sample areas included in the study.

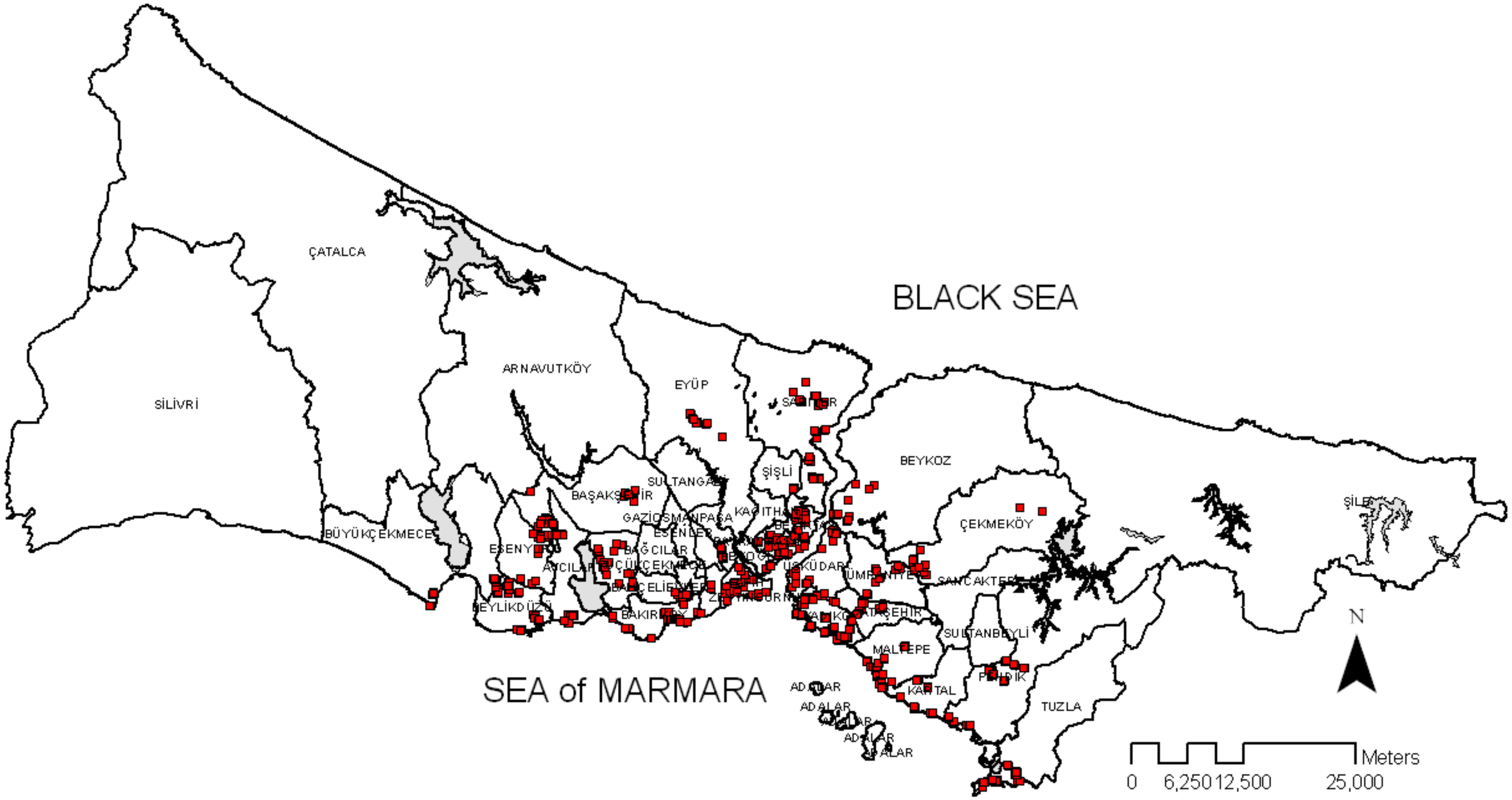


Figure 4.6 : Distribution of the samples included in the study.

4.4 Data Evaluation

After the variable decision and sample selection process the database needed for this analysis was derived by several different methods. The first dataset, housing physical characteristics, were gathered by field work and questionnaires done with the owner, real estate agency or the developer company responsible for the selected on sale housing unit. The second dataset was obtained from the Istanbul Transportation Master Plan Household Survey (2006) and this is the source for the all socio-economic characteristics at neighbourhood scale. The third and last dataset, which is urban form characteristics, were calculated from city maps using computer aided design programmes and geographic information system software.

A description of the variables based on the general group they belong to can be found in Tables 4.1, 4.2, 4.3, 4.4 and 4.5 below.

Table 4.1 : Description of the variables - physical elements.

Variable Name	*Definition*	*Unit/Type*	*Name in the analysis*
Price	Price of the on sale house	Turkish Lira (TL)	PRICE
Physical Elements			
Floor Area	Floor are of the on sale property	Square meter (m²)	FLOORAREA
Size of Living Room	Living room size of the on sale property	Square meter (m²)	SIZELIV
Number of Rooms	Total number of the rooms in the property	Continuous	NOOFROOM
Number of Bathrooms	Total number of the bathrooms in the property	Continuous	NOOFBATH
Heating System	Property has a gas heating system*	0-1	HEATGAS
	Property has a central heating system*	0-1	HEATCENT
	Property has a floor heating system*	0-1	HEATFLOOR
Security System	Property has a security system: 7/24 security, alarm or camera*	0-1	SECURITY
Presence of Elevator	Property has an elevator*	0-1	ELEVATOR
Presence of Balcony	Property has a balcony*	0-1	BALCONY
Presence of Terrace	Property has a terrace*	0-1	TERRACE
Presence of Veranda	Property has a veranda*	0-1	VERANDA
Presence of Garage	Property has a garage*	0-1	GARAGE

* 1 if the property's situation is like in the definition, 0 otherwise

Table 4.2 : Description of the variables - structural elements.

Variable Name	*Definition*	*Unit/Type*	*Name in the analysis*
Structural Elements			
Type of the Structure	Property is an apartment*	0-1	T_APARTMENT
	Property is detached*	0-1	T_DETACHED
	Property is semi-detached*	0-1	T_SDETACHED
Height of the Structure	Property has less than 5 stories	0-1	STOREY
Age of the Structure	Property was built after 2010*	0-1	A_2010
	Property was built between 2000-2010*	0-1	A_2000
	Property was built between 1990-2000*	0-1	A_1990
	Property was built between 1980-1990*	0-1	A_1980
	Property was built between 1970-1980*	0-1	A_1970
	Property was built between 1960-1970*	0-1	A_1960
	Property was built before 1960*	0-1	A_1960B
Presence of a Sea view	Property has a sea view*	0-1	SEAVIEW
Presence of a Pool	Property has a swimming pool: private or public*	0-1	POOL
Presence of a Garden	Property has a garden: private or public*	0-1	GARDEN
Presence of a Car park	Property has a car park: private or public*	0-1	CPARK

* 1 if the property's situation is like in the definition, 0 otherwise

The structural elements group is a composition of common group elements between the housing physical characteristics and urban form characteristics. In addition to these variables some interaction variables referred to in the study of Fotheringham et al. (1997) are also added to the model. These are given in the Table 4.3.

Table 4.3 : Description of the variables - interaction elements.

Variable Name	*Definition*	*Unit/Type*	*Name in the analysis*
Interaction Variables			
Floor Area and Type	Floor area multiplied by the type of property (apartment flat)	Continuous	FLRFLAT
	Floor area multiplied by the type of property (detach)	Continuous	FLRDET
	Floor area multiplied by the type of property (semi detached)	Continuous	FLRSDET

Table 4.4 : Description of the variables - urban form elements.

Variable Name	*Definition*	*Unit/Type*	*Name in the analysis*
Urban Form Elements			
Building Coverage	Total building coverage in the urban block that the property is located in divided by the area of the same urban block	Continuous	BC
Floor Area Ratio	Total covered area on all floors in the urban block that the property is located in divided by the area of the same urban block	Continuous	FAR
Building Density	Gross Density: Total building coverage in the sample area that the property is in divided by the total sample area	Continuous	GBDENSE
	Net Density: Total building coverage in the sample area that the property is in divided by the total residential area	Continuous	NBDENSE
Road Area Ratio	Total road area in the sample area that the property is in divided by the total sample area	Continuous	ROADR
Urban Block Size	Average urban block size in the sample area that the property is located	Continuous	BLOCKS
Topography	Slope value of the property's location	Continuous	TOPOG
Distance to CBD	Distance between CBD and the property*	meter (m)	DISCBD
Distance to Old City Centre	Distance between old centre and the property* **	meter (m)	DISOC
Distance to Highway***	Distance between highway and the property*	meter (m)	DISHIGHW
Distance to Coast	Distance between coast line and the property*	meter (m)	DISCOAST
Distance to Subcentre	Distance between sub-centre (primary and secondary) and the property* **	meter (m)	DISSC

* All distance variables are calculated as the Euclidean Distances

** Location coordinates of the old centre and sub-centre (primary and secondary) points are taken from the study of Urban Sprawl Measurement of Istanbul (Terzi and Bolen, 2009)

*** While calculating the distance between the property and the highway, closest distance to either TEM or E5 highways are considered.

Table 4.5 : Description of the variables - socio-economic elements.

Variable Name	*Definition*	*Unit/Type*	*Name in the analysis*
Socio-Economic Elements			
Population Density	Population of the neighbourhood that the property is in divided by the area of the same neighbourhood	p/km²	PDENSE
Household Size	Average number of members of the household of the neighbourhood that the property belongs to	Continuous	HHOLD
Education Level	Percentage of the no literacy in the property's neighbourhood	Continuous	E_LIT
	Percentage of primary school degree holder in the property's neighbourhood	Continuous	E_PRI
	Percentage of secondary school degree holder in the property's neighbourhood	Continuous	E_SEC
	Percentage of high school degree holder in the property's neighbourhood	Continuous	E_HIGH
	Percentage of college degree holder in the property's neighbourhood	Continuous	E_COLLEGE
	Percentage of postgraduate degree holder in the property's neighbourhood	Continuous	E_POSTG
Income Level	Percentage of different income level intervals between 0 and 15000 TL in the property's neighbourhood	Continuous	I_LEVEL
Car Ownership	Percentage of the car ownership in the property's neighbourhood	Continuous	CAROWN

After giving these summary variable description tables, general characteristics of the dataset with different supporting statistical techniques will be discussed in the following sections.

4.4.1 Descriptive statistics

After gathering various datasets from different sources, some steps of statistical analysis have been done to be able to understand the data. This investigation will be done in two different ways; first by exploring the variables individually, more for examining the consistency by histograms and the descriptive statistics such as minimum, maximum, mean and standard deviation values; second by testing the correlations and interaction between the variables by using the correlation matrix and other statistical methods such as variance inflation factor and tolerance tests. The first set of results can be found under the topic descriptive statistics and the second the multicollinearity test results are in the following section of this chapter.

Based on the histograms, charts and descriptive statistics some brief information about the findings will be discussed. Summarisation will be based on the highest frequencies and average values. Detailed information can be obtained either from the following tables (Table 4.6; 4.7; 4.8 and 4.9) and figures (Figure 4.7 and 4.8). To start with the size of the property, according to frequency distributions, most of the houses have 100-200 m^2 area with an average size of 174 m^2. Besides, having four rooms and one bathroom are the most common physical components of the sample houses. In most of the houses the heating system is gas heating with a percentage of 69%, central heating is following this with a rate of 26%. Floor heating and gas stove are the other type of heating systems that are not used commonly in the sample group. More than half of the houses - 59% of them -have 7/24 security guards while 3% of them have a camera or alarm system for security purposes. It can be stated that elevator is one of the basic components of the houses. So, only 4% of the houses that are more than five stories high do not have an elevator (According to the planning regulations – Act 45 all houses with more than five stories should have an elevator). Aside from this, 84% of the houses have a balcony, 13% a terrace, 8% a veranda and 12% a garage.

According to the descriptive statistics of structural elements, most of the samples are apartments (84%) and the second biggest group is the detached houses (10%). More than half of these houses have between 1 and 5 storeys and the average height is around 7 storeys. The construction of the houses is mostly in the last five years but actually most of these houses are 1 year old and the oldest building is 70 years old. Sea view is one of the other structural components which only 16% of the properties have. Nature and lake view are the other view options but they are not even sharing a big quantity in this pie. There is a varying distribution of amenities (public or private) such as presence of swimming pool, car park or garden within the houses.

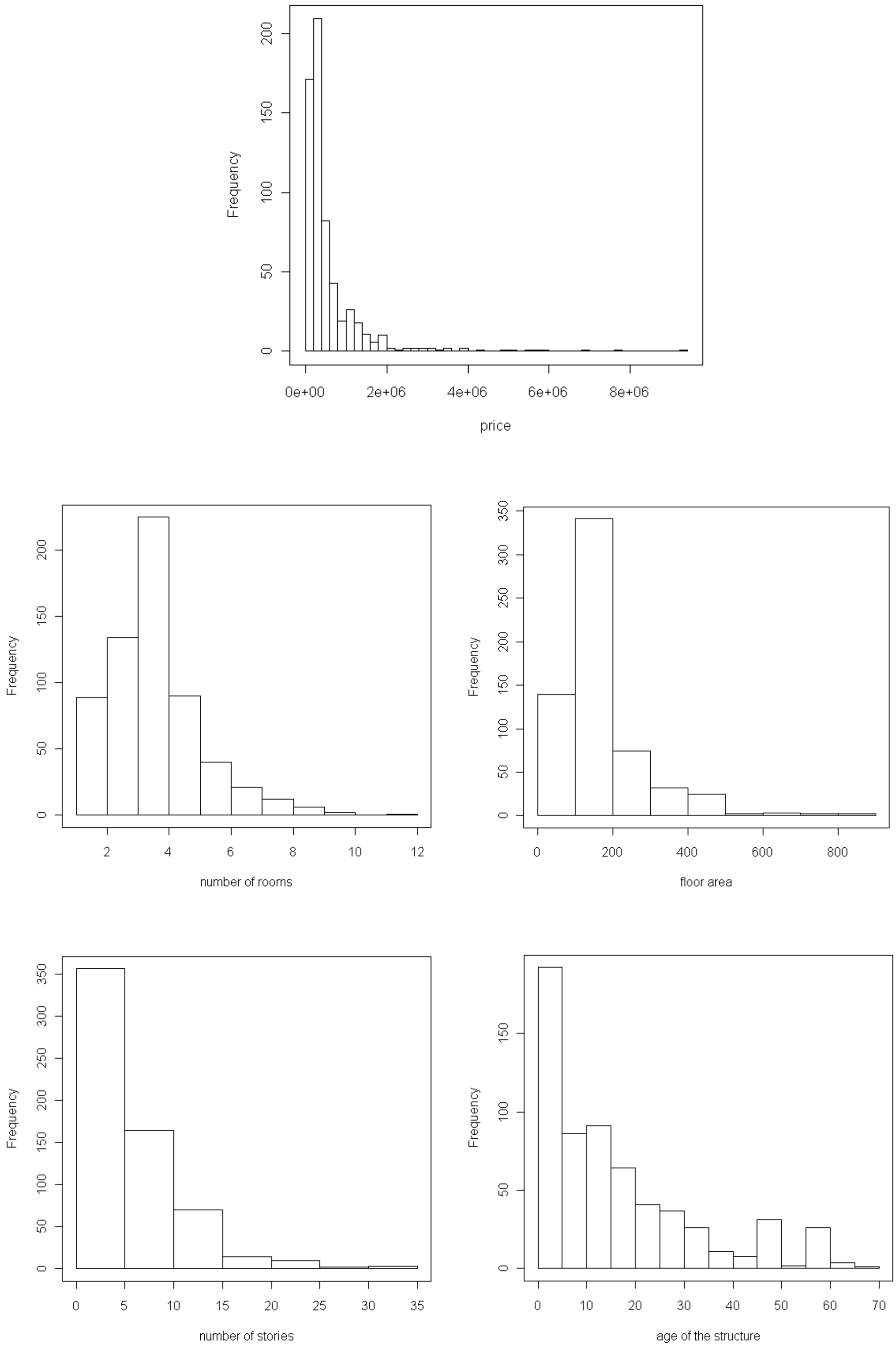


Figure 4.7 : Histograms of price and some physical elements.

Table 4.6 : Descriptive statistics for price and physical elements.

	Minimum	*Maximum*	*Mean*	*Std. Deviation*
price	35000	10000000	634000	1034724.088
Physical Elements				
floorarea	35	870	174.09	115.263
noofroom	1	12	4.02	1.526
noofbath	1	8	1.83	1.065
heatgas	0	1	.69	.461
heatcent	0	1	.26	.436
security	0	1	.61	.487
balcony	0	1	.84	.364
terrace	0	1	.14	.344
veranda	0	1	.08	.272
garage	0	1	.12	.320

Table 4.7 : Descriptive statistics for structural elements.

	Minimum	*Maximum*	*Mean*	*Std. Deviation*
t_apartment	0	1	.84	.370
t_detached	0	1	.10	.302
storey	1	32	6.74	4.624
a_2010	0	1	.14	.344
a_2000	0	1	.33	.472
a_1990	0	1	.23	.421
a_1980	0	1	.12	.328
a_1970	0	1	.06	.240
a_1960	0	1	.04	.200
pool	0	1	.41	.492
cpark	0	1	.74	.442
garden	0	1	.77	.421
seaview	0	1	.17	.372

During the data collection process, the differentiation between the private and public amenities was noted. So, while 41% of the houses have a swimming pool only 2% of these are private ones. Compared to the pool amenity, the presence of a garden has higher percentages. 77% of the houses in the samples have a garden and 16% of this group have it as a private amenity. In the case of car park the percentage is quite high at 74% where only 10% of them are private.

For the urban form elements, the frequency distributions can be followed in Figure 4.8 and the descriptive values in Table 4.8. In summary, building coverage for the urban block that the sample unit is located has a highest frequency of the value between 0.20 and 0.30. The building coverage ratio between the 0.30 and 0.40 is the second highest frequent value. The average value of building coverage within the sample areas is approximately 0.40. However, there are some urban blocks that have a building coverage rate of 0.80 to 0.93. Related to the building coverage, floor area ratios differ from 0.25 to 8.50 with an average value of 2.35. The most common ratio for this variable is in the range of 2-3. In addition to these, the road area ratio was

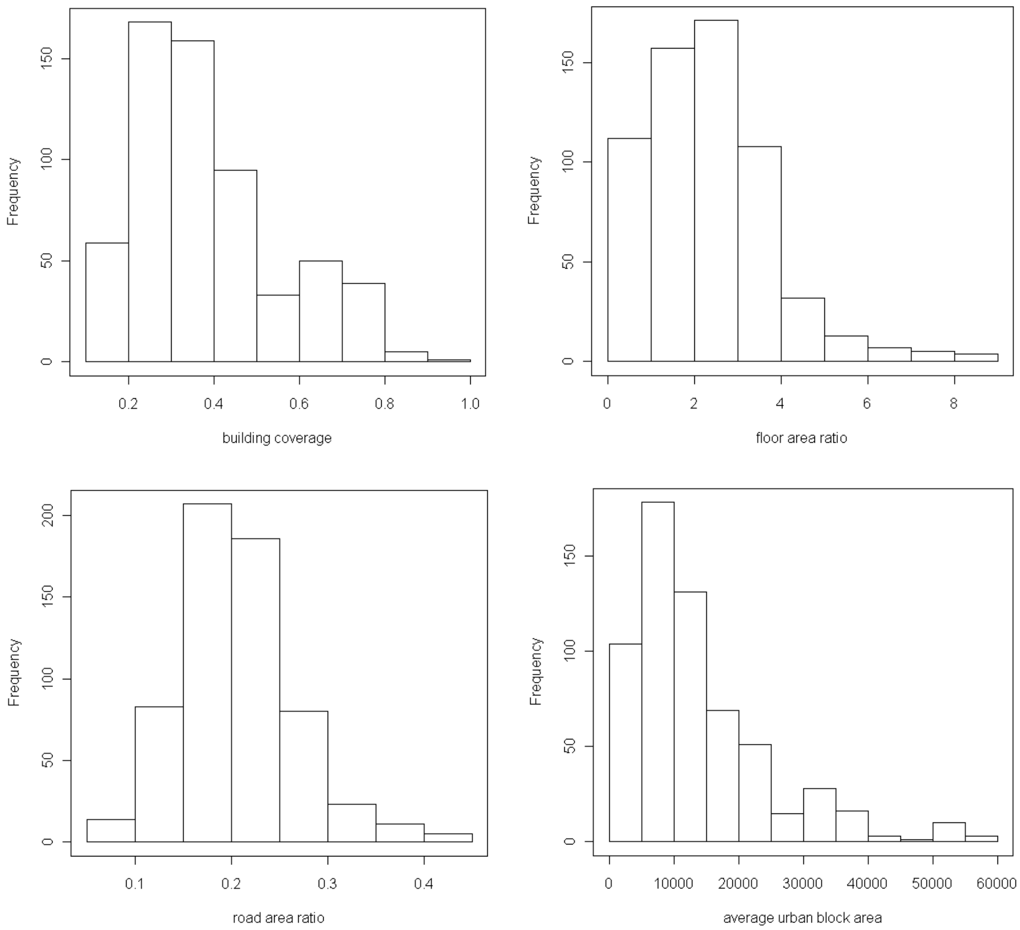


Figure 4.8 : Histograms of some urban form elements.

calculated for each sample area including a sample house unit in it. The average coverage of road area is one fifth of the sample area. The most common ratio is the range of 0.15-0.20. The other variable representing the urban form elements is the urban block size. The average urban block size across the sample areas in the study area is around 13000 m². The size of 5000 to 10000 m² is the most common size of urban blocks in the sample group. According to the set of attributes for urban accessibility the Euclidean distance to the coast line from each property ranges from 29 m. to 13294 m. The average distance to coastline is 2864 m. The distance to the nearest highway shows almost the same pattern as the coastline, ranging from 86 to 15042 m. with an average distance of 2469 m. On the other hand, the distances to the CBD and the old centre display larger range. While minimum distance to the CBD is 476 m. and the old centre is 876 m., the maximum distance 38322 m. to the CBD and 37175 m. to the old centre.

Table 4.8 : Descriptive statistics for urban form elements.

	Minimum	***Maximum***	***Mean***	***Std. Deviation***
BC	.118	.929	.386	.170
FAR	.235	8.548	2.355	1.416
roadr	.063	.425	.206	.059
blocks	1160	58497	13834.86	10534.926
discoast	29	13294	2935.08	3397.593
dishighw	86	15042	2469.90	2563.180
disCBD	476	38322	15240.32	9456.895
disoc	876	37175	15160.89	9160.265
disprisc	905	24325	8606.77	4702.585
dissecsc	746	27265	11138.70	6965.500

There are differences between the neighbourhoods that are included in the study based on the socio-economic characteristics. There are different sets of data at the neighbourhood scale that represent the varying income and education levels, as well as the density variables (density and household size). According to the descriptive statistics for socio-economic elements, the average population density (person per km^2) is 1466 across the neighbourhoods included in the studies. The size of the household for the same neighbourhoods ranges from 1.7 to 6.8 with an average household size of 3.5. The highest primary school education degree holder ratio in the neighbourhoods is 66% and the ratio for the college degree holder is 73%. The interesting detail is the average percentage falls from 34% to 23% when the parameter changes from primary level graduates to college graduates. Income levels are also showing a heterogenic structure. There is a huge difference between the minimum and the maximum income rates (250-15000 TL - Turkish Lira). The last variable of this category can be also considered as a representative for the income level which is the car ownership ratio. The maximum percentage of car ownership percentage is 86% and the average is around 48%.

Table 4.9 : Descriptive statistics for socio-economic elements.

	Minimum	*Maximum*	*Mean*	*Std. Deviation*
pdense	8	9590	1461.71	1455.707
hhold	1.7	6.8	3.596	.6587
e_pri	9	66	34.02	12.176
e_sec	0	43	23.49	7.867
e_college	0	73	19.23	13.711
e_postg	0	18	2.21	3.382
carown	0	86	47.83	17.722

The descriptive statistic values for the house price as a dependent variable show an interesting distribution. The most common price for house within the samples is between 200000 TL and 400000 TL. The range for the price of the property is from 35000 TL to 10000000 TL. In this large range, the average value for the house on sale is around 610000 TL. The descriptive statistic results for variables across the metropolitan area can lead to the assumption that a model including these different kinds of variables (structural, urban environment and neighbourhood characteristics) can be powerful and interesting. Moreover, this wider perspective will make the local modelling technique more interesting to work with.

Before moving one more step ahead, after looking through the data in detail, a qualitative data assessment is needed for the logical reduction in the number of the variables that will be used in the model.

There are several different situations that are taken into consideration during the elimination process, such as different variables representing the same type of relation such as floor area, number of rooms and number of bathrooms. Besides, potential correlation is another issue in these types of variables. Related to these, floor area will be kept as an independent variable in the model. The other issue is related to the different education degree levels and income levels. Not to represent all groups for the correlation reasons, only the highest level of these two socio-economic characteristics will be part of the model as independent variables. In order to get the 'higher education' degree percentage, the sum of the percentages of the college graduates and post-graduates will be used. The distance to sub-centre variable is another example of this elimination process.

The other step for organizing data is the decision of using some continuous variables as categorical variables based on the frequency distributions. Attributes such as age of the building and number of the stories have clear tipping points. It is therefore more appropriate to include them in the analysis as categorical rather than continuous variables.

Furthermore, for the parameters; presence of swimming pool, car park and garden, the available information about the private and public separations is dismissed because of the low percentages of the private ownerships. As these low percentages of privately owned facilities cannot potentially represent that specific type, these variables will be considered in the way as the property has any of these amenities (public or private) or not.

There is only one variable in the dataset that is behaving as a common element for the properties which is the existence of an elevator. As a result of this finding, this variable is dropped from the model. Topography and the size of living room are excluded from the model because of the missing data problem. After all these qualitative data assessment, for the coherence of the dataset some further tests will be applied.

4.4.2 Multicollinearity tests

After the descriptive studies, some other statistical tests are done to be able to do a detailed statistical examination. These will be described and discussed in this section as the last step of the preliminary tests just before the application of the model.

Being aware of the multiple correlations between the variables is important for several different aspects, especially for getting right estimates of the regression coefficients. There are different ways of testing for multicollinearity in regression analysis. In this study, two different methods; the correlation matrix and the variance inflation factor (VIF) with the tolerance level will be applied.

4.4.2.1 Correlation matrix

A correlation matrix can be used to learn the significance of the relationship between explanatory variables. Not only the significance level but also the type of the relation can be examined as a result of this process. As there are no dependent and independent concepts in these matrices, the final values will change between -1 to +1 for all variables included in the process. The value getting closer to ±1 is the indicator of high degree collinearity between the related variables.

As can be seen from the Table 4.10, the significance of the correlations differs from 0.01 and 0.05 level and there are also some correlations that are not significant at all. The other interpretation from this matrix is the high correlation levels. While searching through the results, the values of more than 0.80 will be kept under investigation. In this case, distance to the CBD correlated with another continuous variable distance to the old centre, and also the gas heating system correlated with another dummy variable central heating system, are the examples of the variables that can have highly correlated relationships.

Before eliminating these variables from the model another test for multicollinearity will be held in the following section.

4.4.2.2 Variance inflation factor

The other method that will be used for detecting multicollinearity will be the testing for variance inflation factor and the tolerance level of the variables. This step is actually based on the assumption of an OLS regression model of the stated dependent variable price and the independent variables that are included in the study. What this factor calculates is the contribution of each variable to the standard error in the regression analysis.

Mostly a value of greater than 10 stated as the indicator of a multicollinearity problem, although 4 can also be the critical value for VIF for different studies. As mentioned by O'Brien (2007), even though 4 and 10 are associated with VIF as the critical values, it should be considered some other factors can affect VIF values such as the number of the observations and the variance of them.

Table 4.11 shows the tolerance level and the VIF values and as it can be noticed from the table, distance to CBD, distance to old centre, gas heating system and central heating system have the highest VIF and the lowest tolerance levels. With the fact that, these variables are the same variables that were mentioned from the correlation matrix, this finding will be taken into consideration for the multicollinearity purposes.

Table 4.10 : Correlation matrix of all samples.

	t_apartment	t_detached	floorarea	balcony	terrace	veranda	garage	garden	pool	cpark	seaview	security	discoast	dishighw	disCBD
t_apartment	1	-.758**	-.686**	-.096*	-.380**	-.508**	-.220**	-.221**	-.205**	-.089*	-.153**	-.218**	-.194**	-.376**	-.264**
t_detached	-.758**	1	.602**	0.043	.223**	.508**	.228**	.158**	.121**	0.008	.094*	.124**	0.078	.407**	.121**
floorarea	-.686**	.602**	1	.168**	.402**	.338**	.330**	.242**	.326**	.212**	.195**	.295**	.194**	.342**	.150**
balcony	-.096*	0.043	.168**	1	-0.008	-0.018	-0.051	.267**	.091*	.290**	0.074	.191**	-0.007	-.096*	.219**
terrace	-.380**	.223**	.402**	-0.008	1	.227**	.134**	0.039	.164**	0.048	.138**	.114**	0.067	.177**	0.044
veranda	-.508**	.508**	.338**	-0.018	.227**	1	.189**	0.077	.103*	0.043	-0.02	.138**	.118**	.396**	.091*
garage	-.220**	.228**	.330**	-0.051	.134**	.189**	1	.161**	.312**	.092*	-0.026	.163**	.235**	0.05	-0.023
garden	-.221**	.158**	.242**	.267**	0.039	0.077	.161**	1	.423**	.676**	0.037	.624**	.330**	0.054	.403**
pool	-.205**	.121**	.326**	.091*	.164**	.103*	.312**	.423**	1	.418**	.130**	.601**	.466**	.121**	.320**
cpark	-.089*	0.008	.212**	.290**	0.048	0.043	.092*	.676**	.418**	1	0.022	.651**	.300**	0.005	.409**
seaview	-.153**	.094*	.195**	0.074	.138**	-0.02	-0.026	0.037	.130**	0.022	1	.087*	-.209**	-0.071	.153**
security	-.218**	.124**	.295**	.191**	.114**	.138**	.163**	.624**	.601**	.651**	.087*	1	.392**	0.053	.376**
discoast	-.194**	0.078	.194**	-0.007	0.067	.118**	.235**	.330**	.466**	.300**	-.209**	.392**	1	.288**	.296**
dishighw	-.376**	.407**	.342**	-.096*	.177**	.396**	0.05	0.054	.121**	0.005	-0.071	0.053	.288**	1	.088*
disCBD	-.264**	.121**	.150**	.219**	0.044	.091*	-0.023	.403**	.320**	.409**	.153**	.376**	.296**	.088*	1
BC	.224**	-.224**	-.260**	-.201**	-0.068	-.118**	-.160**	-.600**	-.350**	-.619**	-.125**	-.550**	-.362**	-0.069	-.459**
FAR	.513**	-.415**	-.395**	-0.055	-.293**	-.301**	-.111**	-.113**	-0.016	-.082*	-0.022	-0.048	-0.076	-.369**	-.156**
roadr	.134**	-.118**	-.146**	-0.021	-.082*	-0.078	-.087*	0.012	.140**	0.023	0.036	.089*	.163**	-0.055	.195**
pdense	.303**	-.229**	-.277**	-.133**	-.151**	-.150**	-.114**	-.483**	-.355**	-.423**	-.085*	-.428**	-.348**	-.244**	-.469**
hhold	-0.021	0.005	-.086*	-0.058	0.053	.088*	0.056	0.03	.185**	0.05	0.062	.104**	.141**	-.185**	.154**
carown	-0.043	0.017	.201**	.170**	-0.034	0.001	0.059	.302**	.098*	.347**	-0.067	.218**	.135**	.202**	.153**
e_college	0.051	-0.02	.142**	0.01	-.097*	-.086*	0.023	.082*	-0.049	0.074	-.118**	0.022	0.065	.312**	-.154**
i_7500	-0.013	0.041	0.043	0.038	-0.03	0.033	0.028	.111**	0.024	.097*	-0.058	0.044	0.03	0.061	-0.02
blocks	.115**	-.091*	-0.015	0.009	-.112**	-.083*	.081*	.406**	.166**	.430**	0.04	.440**	.151**	-.120**	.254**
heatgas	-.219**	.165**	.133**	.086*	.132**	.120**	.088*	0.01	.143**	-0.068	.109**	-0.071	.143**	.172**	.232**
heatcent	.209**	-.147**	-.088*	0.03	-.147**	-.132**	-0.073	.118**	-0.068	.184**	-0.072	.155**	-0.075	-.171**	-.165**
disoc	-.254**	.146**	.183**	.214**	0.069	.095*	-0.014	.385**	.350**	.410**	.124**	.403**	.326**	.134**	.906**
price	-.453**	.536**	.653**	0.059	.326**	.205**	.254**	.148**	.238**	.129**	.203**	.213**	-0.007	.145**	-.149**

Table 4.10 (cont.) : Correlation matrix of all samples.

	BC	FAR	roadr	pdense	hhold	carown	e_college	i_7500	blocks	heatgas	heatcent	disoc	price
t_apartment	.224**	.513**	.134**	.303**	-0.021	-0.043	0.051	-0.013	.115**	-.219**	.209**	-.254**	-.453**
t_detached	-.224**	-.415**	-.118**	-.229**	0.005	0.017	-0.02	0.041	-.091*	.165**	-.147**	.146**	.536**
floorarea	-.260**	-.395**	-.146**	-.277**	-.086*	.201**	.142**	0.043	-0.015	.133**	-.088*	.183**	.653**
balcony	-.201**	-0.055	-0.021	-.133**	-0.058	.170**	0.01	0.038	0.009	.086*	0.03	.214**	0.059
terrace	-0.068	-.293**	-.082*	-.151**	0.053	-0.034	-.097*	-0.03	-.112**	.132**	-.147**	0.069	.326**
veranda	-.118**	-.301**	-0.078	-.150**	.088*	0.001	-.086*	0.033	-.083*	.120**	-.132**	.095*	.205**
garage	-.160**	-.111**	-.087*	-.114**	0.056	0.059	0.023	0.028	.081*	.088*	-0.073	-0.014	.254**
garden	-.600**	-.113**	0.012	-.483**	0.03	.302**	.082*	.111**	.406**	0.01	.118**	.385**	.148**
pool	-.350**	-0.016	.140**	-.355**	.185**	.098*	-0.049	0.024	.166**	.143**	-0.068	.350**	.238**
cpark	-.619**	-.082*	0.023	-.423**	0.05	.347**	0.074	.097*	.430**	-0.068	.184**	.410**	.129**
seaview	-.125**	-0.022	0.036	-.085*	0.062	-0.067	-.118**	-0.058	0.04	.109**	-0.072	.124**	.203**
security	-.550**	-0.048	.089*	-.428**	.104**	.218**	0.022	0.044	.440**	-0.071	.155**	.403**	.213**
discoast	-.362**	-0.076	.163**	-.348**	.141**	.135**	0.065	0.03	.151**	.143**	-0.075	.326**	-0.007
dishighw	-0.069	-.369**	-0.055	-.244**	-.185**	.202**	.312**	0.061	-.120**	.172**	-.171**	.134**	.145**
disCBD	-.459**	-.156**	.195**	-.469**	.154**	.153**	-.154**	-0.02	.254**	.232**	-.165**	.906**	-.149**
BC	1	.353**	-0.004	.500**	-.101*	-.250**	0.019	-.088*	-.487**	-0.021	-.103**	-.440**	-.162**
FAR	.353**	1	.156**	.309**	.121**	-.174**	-.085*	0.009	0.077	-.153**	.148**	-.151**	-.291**
roadr	-0.004	.156**	1	-0.034	.121**	-.118**	-.163**	-0.06	-.094*	.097*	-.100*	.198**	-.204**
pdense	.500**	.309**	-0.034	1	-0.032	-.352**	-.122**	-.167**	-.306**	-0.047	-0.019	-.477**	-.141**
hhold	-.101*	.121**	.121**	-0.032	1	-.523**	-.792**	-.255**	-0.023	.211**	-.276**	.144**	-.119**
carown	-.250**	-.174**	-.118**	-.352**	-.523**	1	.671**	.591**	.252**	-.174**	.294**	.178**	.131**
e_college	0.019	-.085*	-.163**	-.122**	-.792**	.671**	1	.386**	.095*	-.241**	.298**	-.119**	.140**
i_7500	-.088*	0.009	-0.06	-.167**	-.255**	.591**	.386**	1	.098*	-.208**	.274**	0.013	.091*
blocks	-.487**	0.077	-.094*	-.306**	-0.023	.252**	.095*	.098*	1	-.201**	.271**	.230**	-0.017
heatgas	-0.021	-.153**	.097*	-0.047	.211**	-.174**	-.241**	-.208**	-.201**	1	-.880**	.279**	-0.052
heatcent	-.103**	.148**	-.100*	-0.019	-.276**	.294**	.298**	.274**	.271**	-.880**	1	-.211**	0.078
disoc	-.440**	-.151**	.198**	-.477**	.144**	.178**	-.119**	0.013	.230**	.279**	-.211**	1	-.089*
price	-.162**	-.291**	-.204**	-.141**	-.119**	.131**	.140**	.091*	-0.017	-0.052	0.078	-.089*	1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

As a result of all these different applications, not only because of the high VIF values and low tolerance levels but also the high correlation level between the distance to CBD and distance to old centre, the variable of distance to old centre will be excluded from the local model to avoid the multicollinearity problems. The variables for heating system will also be excluded from the housing physical attributes in the final model based on the similar reason.

Table 4.11 : Collinearity statistics.

	Tolerance	***VIF***
t_apartment	0.238	4.21
t_detached	0.321	3.112
floorarea	0.361	2.767
balcony	0.769	1.3
terrace	0.724	1.382
veranda	0.614	1.629
garage	0.74	1.352
garden	0.405	2.471
pool	0.471	2.124
cpark	0.358	2.793
seaview	0.752	1.33
security	0.345	2.903
discoast	0.502	1.993
dishighw	0.515	1.941
disCBD	0.155	6.441
BC	0.327	3.056
FAR	0.485	2.062
roadr	0.797	1.254
pdense	0.521	1.921
hhold	0.289	3.462
carown	0.292	3.425
e_college	0.206	4.856
i_7500	0.563	1.777
blocks	0.538	1.86
heatgas	0.19	5.275
heatcent	0.176	5.691
disoc	0.156	6.398

4.5 Application of the Model

Based on the reality that relationships vary over the space within the metropolitan area of Istanbul, the stationary processes (like hedonic models assuming the relationships are constant) will lead model misspecification. To avoid this not only selecting the right method, but also exploring the dataset is important. Based on this information, different types of data exploration techniques were used and discussed in the previous sections. Not only a quantitative perspective, but also a qualitative approach was applied in the process. In addition to these, there is a last step of a stepwise procedure to select the final best model. So, the process included these steps;

1- Descriptive examination of the 67 possible explanatory variables symbolising the different characteristic groups such as housing physical elements, urban form elements and socio-economic elements

2- Reducing the number of the variables by qualitative data assessment

3- Statistical examining for the multicollinearity by correlation matrix and variance inflation factor test

4- Removing some of the variables as a result of the statistical examination

5- Running the stepwise GWR with the possible 27 independent variables.

A stepwise GWR procedure was used to select the best model, based on the principle of AIC minimisation. This procedure involves both forward and backward variable selection steps. During the forward step, GWR is run with each variable. The variable which causes the minimum AIC will be added to the model. After the forward step if there are more than two variables in the model, a backward step will occur where GWR is run leaving out one of the previously included variables. This forward-backward process repeats until the AIC cannot be lowered less than 3 by the addition or removal of any variables. At the end of this two-step process the potential variables that should be included in the best model will be obtained. After this procedure, the next and final step is to run the GWR software and start to examine the outputs of this local regression modelling technique.

In general, there are two parts of the output; global and local. The global model part includes two parts. One part is including the diagnostic information and second part is matrix of information (name of the variable, the estimate of the parameter, the standard error of the parameter estimate and the t statistics) for each variable. These global regression parameters are presented in Table 4.12.

According to these results, the first thing that can be mentioned is the parallelism between the global model and the preliminary expectations. In other words, the type of the relationships (negative or positive) of any independent variable and the dependent variable in the model formula acting as the way it was expected (signs of the attributes agree with the hypotheses). In the function there are nine variables for the explanation of the varying house prices. Within these nine variables, the coefficient of determination is 0.579 and the adjusted R-square is 0.572. So, only 57% of the variation of house price structure can be explained with this model in the global regression analysis. To be able to compare the global regression results with the local ones, rather than R-square, AIC value will be used and the AIC value for the global regression is 18506.

One physical element, one socio-economic element and some of the urban accessibility/location elements of the urban form elements were involved in the formula. Moreover, some of the structural elements which are the parts of the urban form characteristics as well as the housing physical characteristics appear in the model. On the other hand, none of the urban density or urban morphological attributes representing the urban form structure was in the best explanatory model.

Like most of the house price studies, floor area of the housing unit is significantly positive as one of the variables to explain house prices and it has the strongest effect on house prices. A one unit increase in the floor area will result in a 4513 unit increase in the price according to the global model. In the global model, this value is assumed to have the same influence on house prices at every location of the study area.

Other than some structural elements like type of the building, presence of the car park and pool facility, the urban accessibility/location attributes are part of the global house price model as significant attributes. Distances to the central business district, highway and also coastline have a negative relationship with house prices. Decreasing amount of distance to any of the mentioned destinations will increase the value of the house. According to the global results, although the value that they add to house prices does not differ a lot, between all these location attributes, being close to the central business district is the most important accessibility attribute. In addition, distance to CBD has the second highest impact on house prices in the global regression results.

The type of the building, especially the detached housing dummy variable has the third strongest impact on house prices according to the global model results. Detached housing and the house price are positively related, therefore, living in a detached house will cost more than living in the other types of the housing (apartment, semidetached housing).

According to the model, one of the variables affecting the house price is the presence of a swimming pool. The housing units with a pool have a higher price compared to the housing units which don't have this facility. Related to this fourth highest significant relationship between swimming pool and price, the existence of the pool will cause an increase in the house price.

Table 4.12 : Global regression parameters.

Parameter	***Estimate***	***Std Err***	***T***
Intercept	-124071.665	173657.103	-0.714
t_apartment	129423.512	131230.392	0.986
t_detached	1177741.395	145435.271	8.098
floorarea	4513.314	356.706	12.652
pool	338735.856	68905.156	4.915
cpark	220122.674	76822.604	2.865
discoast	-32.417	9.625	-3.367
dishighw	-49.608	12.349	-4.016
disCBD	-34.073	3.359	-10.143
carown	3786.64	1710.339	2.213
Sigma		675907.785	
Akaike Information Criterion		18506.418	
Coefficient of Determination		0.579	
Adjusted r-square		0.572	
Effective number of parameters		10.00	

Presence of a car park is the other variable in the model that is significant. Like swimming pool, existence of this facility is important and will increase the house price according to the global regression parameters.

The last variable, car ownership, the only socio-economic characteristics representative in the model, has an effect on house prices. The neighbourhoods with a higher car ownership ratio will have the higher house values.

As mentioned earlier, even though the global model is significant and there are some relationships between the dependent and independent variables, the global model is only able to explain the 57% of the variance in house price market in the city of Istanbul. It also means that there are some factors that are not covered by the global model. Another point that should be underlined is the fact that the parameters as an outcome of the global regression model are meant to be the only one general value for all spatial points included in the research. There is no chance to see the locality issues or varying spatial characteristics – in the case of possible spatial variation pattern - with the global model.

Table 4.13 : GWR estimation diagnostics.

Number of nearest neighbours	208
Number of locations to fit model	623
Effective number of parameters	60.776
Sigma	358448.531
Akaike Information Criterion	17777.213
Coefficient of Determination	0.891
Adjusted r-square	0.879

As it can be seen in Table 4.13, the first part of the GWR analysis results presents some diagnostics. These values make it possible to investigate the differences in both models. The coefficient of determination is 0.891 and has increased from 0.579 to 0.891. The adjusted R-square is 0.879. So, with the local modeling 87% of the house price relations can be explained by this formula and the model represents the data very well. As mentioned before, the adjusted R-square is not available to make the comparison between the local and global regression model, so, the AIC value will be the control value. The GWR model has an AIC value of 17777 which is less than the global model value (18506). Given the fact that minimum AIC is the better fit of model, it can be easily stated that GWR as a local modeling technique performs better than the global regression modeling.

Table 4.14 : ANOVA test results.

	SS	***DF***	***MS***	***F***
OLS Residuals	280049868341320.9	10.00		
GWR Improvement	207812361715712.0	50.78		
GWR Residuals	72237512141287.2	562.22	128485349896.6	31.85

The comparison can be supported by the ANOVA (Analysis of Variance) test which is also an output of the GWR analysis. The results of the ANOVA test are shown in Table 4.14 to compare the fit of the global model (OLS) to local model (GWR). Residuals sum of squares (SS), degrees of freedom (DF), mean square (MS) and the pseudo-F statistic is given in this table. Adoption of the GWR model causes a decrease in the residual sum of squares and so, this test suggests that OLS is not performing better than GWR. Degrees of freedom being non-integer and also the degrees of freedom for the improvement in residual sum of squares being not equal to the difference of GWR residuals and the OLS residuals, show that it is clearly possible to talk about the significant improvement in the model fit when GWR approach is used (Brunsdon et al., 1999).

Table 4.15 : GWR parameter summaries.

	Minimum	*Lower quartile*	*Median*	*Upper Quartile*	*Maximum*
t_apartment	-400162.84	-1197	106323.3	765063.67	2426200.89
t_detached	-133372.58	458277.74	817086.92	4102595.04	7099355.41
floorarea	1791.17	3007.23	3765.38	4845.99	8100.7
pool	61385.55	133706.53	328448.42	611643.82	874508.12
cpark	-759601.09	-56492.95	104963.33	203440.96	696484.91
discoast	-491.09	-190.55	-42.21	-17.19	-2.84
dishighw	-348.54	-88.08	-19.84	9.94	106.52
disCBD	-102.37	-30.11	-15.46	-12.23	131.03
carown	-25300.23	-2848.59	2787.28	3797.75	14123.93

A 5-number summary of the local parameter estimates, the other output of the GWR analysis is presented in the Table 4.15. This table summarises the minimum, median, maximum, lower and upper quartile values of the data. It is a simple way of showing the variability of the local parameter estimates over space. The other way of searching for the spatial variability in the local parameter estimates is the Monte Carlo test which is optional in the software. The result of this test tells whether the spatial variation in the local parameter estimates for each variable is significant or not (Table 4.16). This information can be useful in the interpretation of the visualised parameter estimates of the variables. The main importance can be given to the local estimates which show spatial non-stationarity.

According to the test results for spatial non-stationarity, the variables of detached housing, presence of a car park, distance to coast, distance to CBD, distance to highway and car ownership have significant spatial variation at 0.1% level. Moreover, apartment flat housing is significant at 1% level where presence of swimming pool is significant at 5% level. However, there is not significant spatial variation in the local parameter estimates for the floor area variable. Yet, the relationship between the floor size and house price is still worth investigating through the mapped local estimates since floor area is one of the important components of the house price models.

Table 4.16 : Test results for spatial variability of parameters.

Parameter	***p-value***	
intercept	0.02000	*
t_apartment	0.01000	**
t_detached	0.00000	***
floorarea	0.19000	n/s
pool	0.04000	*
cpark	0.00000	***
discoast	0.00000	***
dishighw	0.00000	***
disCBD	0.00000	***
carown	0.00000	***

*** significant at .1% level
** significant at 1% level
* significant at 5% level

The local parameter estimates for each variable is the main output of the GWR. This group of output includes;

- Parameter estimates values at each entry point for every variable
- Standard error estimates values at each entry point for every variable
- Pseudo-t values at each regression point for every variable
- Observed y variable value
- Predicted y variable value
- Unstandardised residual
- Leverage value / Hat matrix
- Standardised residual

- Cook's Distance
- Pseudo-R^2 values

From this point, the interpretation will be based on the mappable local estimates parameters mentioned above.

4.5.1 Findings of the model

After the application of the model, in this section the preliminary findings of the model will be presented. The maps of the t values for the significance level of the each relationship for every variable and parameter estimates for the estimation of the price based on each variable will be the visual sources for the description of the results.

Parameter estimates and pseudo-*t* values at each regression point for every variable are visualised in several different figures. The other values such as standard error estimates, residuals and standardised residuals for every regression point, are also mapped and can be found in the appendix.

As it can be followed in the figures of GWR results, all of the variables are not significantly related to house price at every location in the study area. This is one of the important outcomes of this method compared to the global models, as in global model once the variable is significant; it is assumed that it is not varying spatially.

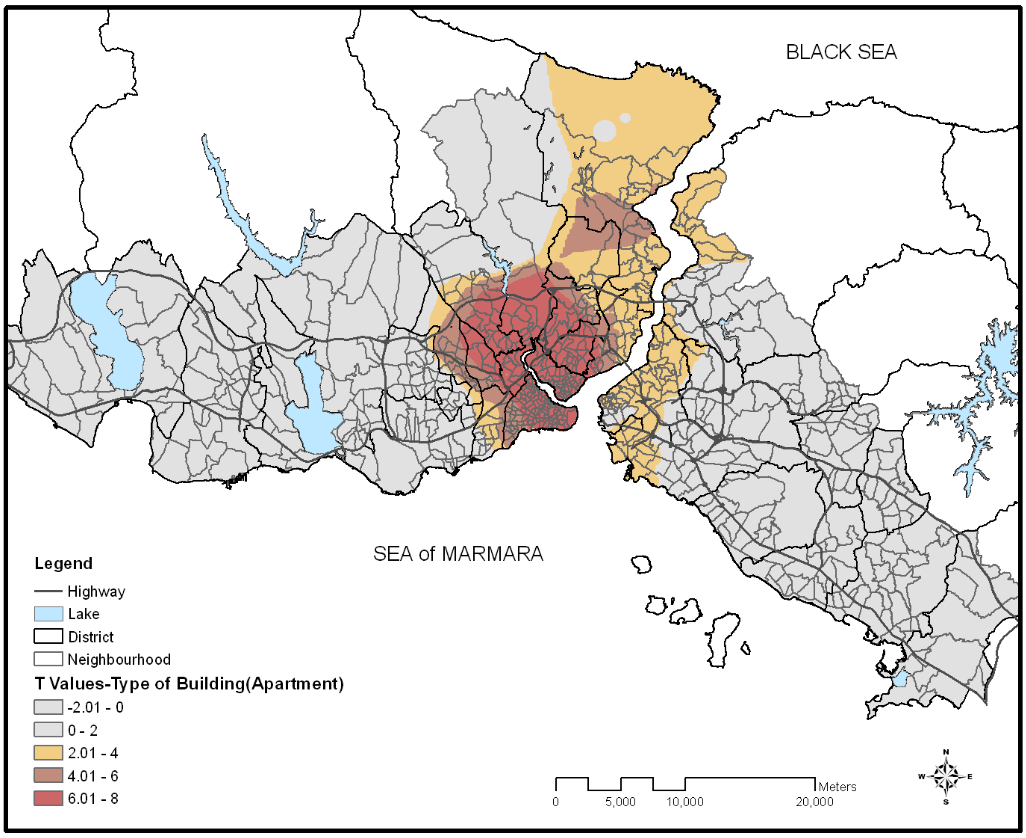
The other important and general outcome of these results is that the effects of any characteristics (housing physical, urban form and socio-economic) on house prices vary over space so the relationships exhibit spatial non-stationarity.

The last one is that the GWR method makes it possible to demonstrate the changing local patterns with mappable values, so that the local spatial variations in the study area can be investigated in a broad perspective.

In the first figure (4.9) of GWR result visualisations, the spatial variation in the value of an apartment flat housing across the study area is shown as well as the t values. According to the global model results, apartment housing was not a significant variable in the relationship on house price. As it can be followed by the *t* values based on the local modelling technique, contrary to the global model results, in some parts of the city this variable is significant which represents an interesting local variation of this variable. As a result of this, along the Bosphorus it is possible to mention the significance of apartment flat compared to other types of housing. This north-south axis shows a variety of parameter estimates. On the European side the price range is big from north to south related to this type of housing, whereas on the Asian side the price difference is not that big. What is common for both sides of the Bosphorus is that apartment type of housing has a positive influence on house prices at all of the regression points where the relationship is significant. Because of the spatial variety the affect will be priced differently but in general it will differ between 300000-2500000 TL. The highest impact of this variable will be at the areas around the historical peninsula. Apartment type of housing is most effective on both sides of Halic, *ceteris paribus.* In summary, as it can be easily seen in Figure 4.9, the apartment flat is an important parameter for the houses around the old city centre and Halic rather than the other parts of the city.

The other type of housing, detached housing, is also one of the parameters of the model. According to the global model outcomes, detached housing has a significant positive effect on house prices. So, being a detached unit increases the price of the property. When the local relationships are investigated, being significant over the study area and positively affecting the house price are the results in common but in addition, the effect of detached housing on house price is not same at every point in the examined region. Therefore, there is a spatially varying relationship between detached housing and the house price. Different than the apartment flat, detached housing is significant generally at most of the regression points (Figure 4.10).

At first sight, the difference along the Bosphorus can be easily recognised. Except than the Asian side southeast-northwest axis along the Sea of Marmara and the north-south axis by the Bosphorus, detached housing has a greater effect on the house price. The same situation is valid for the European side. Having a detached house in the neighbourhoods by the Bosphorus adds more to the price of the property



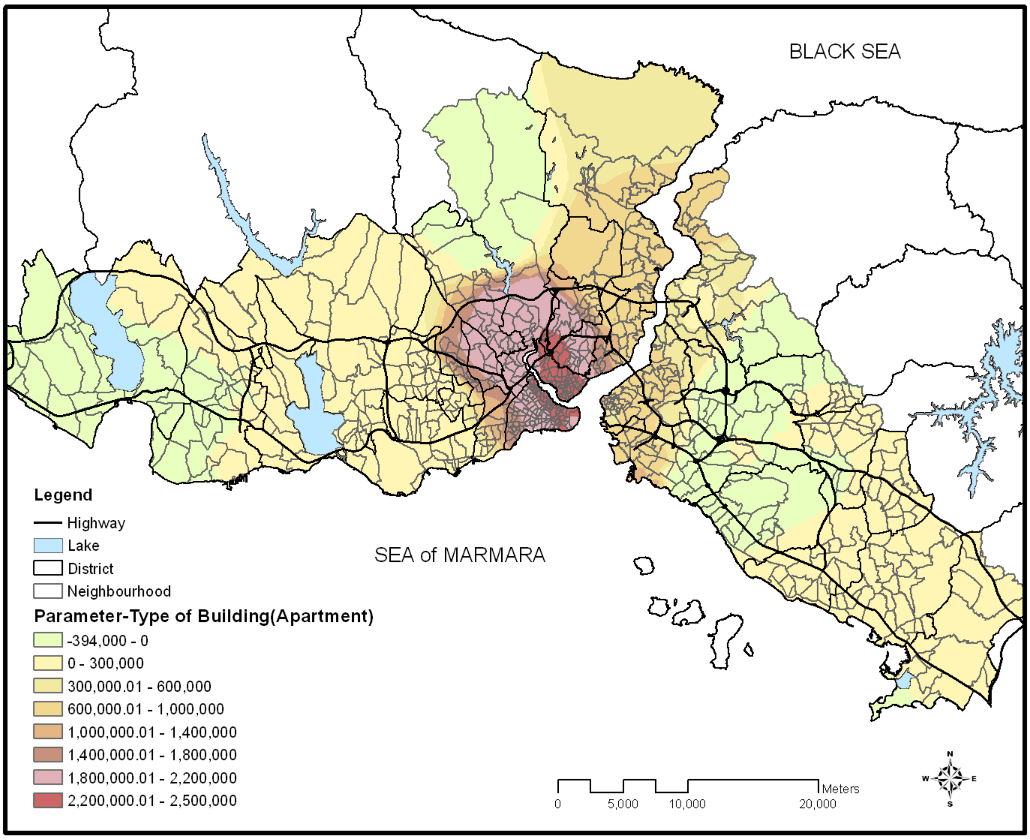
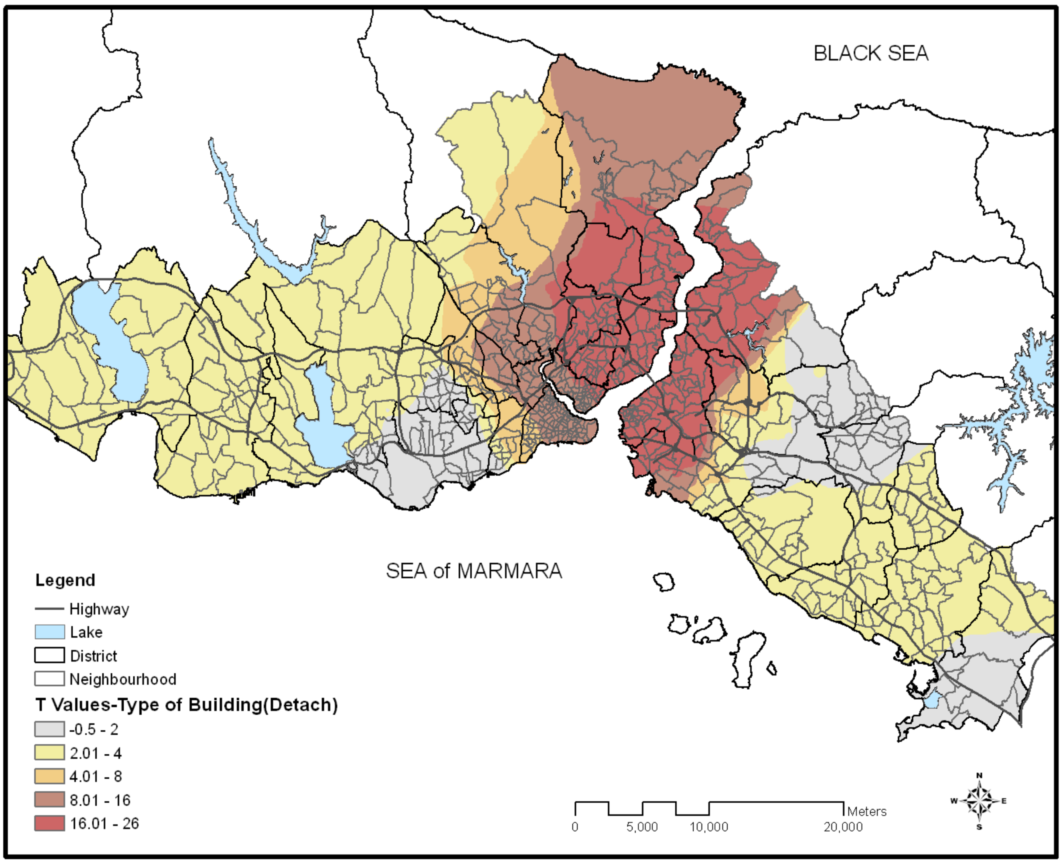


Figure 4.9 : Local *t* values and parameter estimates of ‘apartment’.



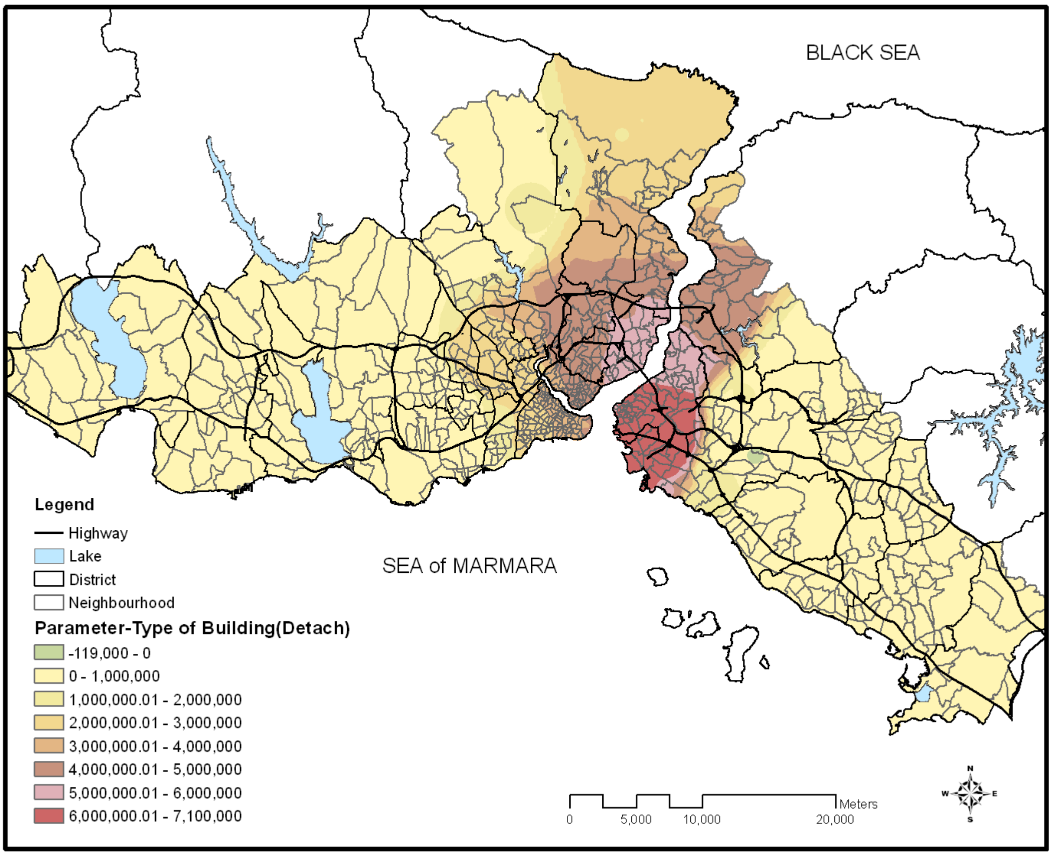


Figure 4.10 : Local *t* values and parameter estimates of ‘detached housing’.

compared to the other neighbourhoods on this side. If the comparison is made in general, then Kadikoy district and around attracts the attention. The amount added to the sale price can be up to 7000000 TL around this spatial location. In most of the locations along the study area, this amount will be between 0-1000000 TL. Along the Bosphorus this will be changing between 2000000-7000000 TL.

In general, the type of the structure, as the representative of the housing physical characteristics as well as the urban form characteristics in this research, demonstrates some correlations with the property's sale price. This positive relationship's strength depends on the type of the building and also the location of the building. Detached housing presents more significant relationships over the study area rather than the apartment flat. Besides, for both of the parameters Bosphorus is the area of most impact. However, for the apartment flats Halic in the European side and for the detached housing Kadikoy on the Asian side are the focus points.

The floor area as a physical element of the property is one of the significant components of the model, like in most of the house price studies. The global model regression parameter results suggest that floor area has an effect on house price. So, increasing square meters of the house on sale will increase the price of that property. From the local regression parameter perspective, even though it is significant at every entry point over the study area, it is not symbolising the huge differences between the varying spatial points (Figure 4.11). The effect is positive and it is not adding too much to the values of the house as the other variables in the model does. However, the area covering the historical peninsula and further north-west direction from the Halic, has a different pattern. If a detailed investigation is done on this particular area, the range of the floor area of the samples would be noticed as it is only changing between 40-180 m². With attention to this information, the floor area criterion being much more effective on this part of the city, when the all other components are held/kept constant, is a good local hotspot to emphasize (See Figure 4.11).

As mentioned in the previous sections, structural elements are the properties of the house that is referred to both group of urban form and housing physical characteristics in this study. The presence of a swimming pool and the presence of a car park are the examples for this category and they are the representative parameters of this group in the model structure. In the global model, these two variables were significant and they both had a positive relationship with the dependent variable, house price. On the contrary, in the local model, these relationships are not significant all over the study area. In addition, as a result of the Monte Carlo test done in the GWR analysis process, these two parameters vary significantly over space (Figure 4.12).

Starting with the swimming pool parameter, as shown by the map for *t*-values in Figure 4.12, this variable is not significant for every location within the study area. For the European side it is a more limited area compared to the Asian side where pool as a parameter in the house price model is significant.

If the parameter estimates are defined, the spatial structure is quite interesting. Different than the global modeling outcomes, there is not only an average value to be added to the house price for each sample. There are different ranges for different spatial locations as a result of the spatial analysis method used. There are seven different price classifications related to the location that the property is in. Starting from 60000 TL and going up by 874000 TL will be the affect of the swimming pool facility on the house price. When the spatial variation is examined, it can easily be noticed that Bosphorus is again the key spatial location. Along the Bosphorus having the swimming pool facility in the property will increase the price of the property more than everywhere else. While moving away from the Bosphorus through the inner sides of the city, to the east and west directions, the effect will decrease. In summary, thinking of two different housing units with the all same properties, the one located by the Bosphorus having a swimming pool will cost more than the other having a pool but settled in the inner parts of the city.

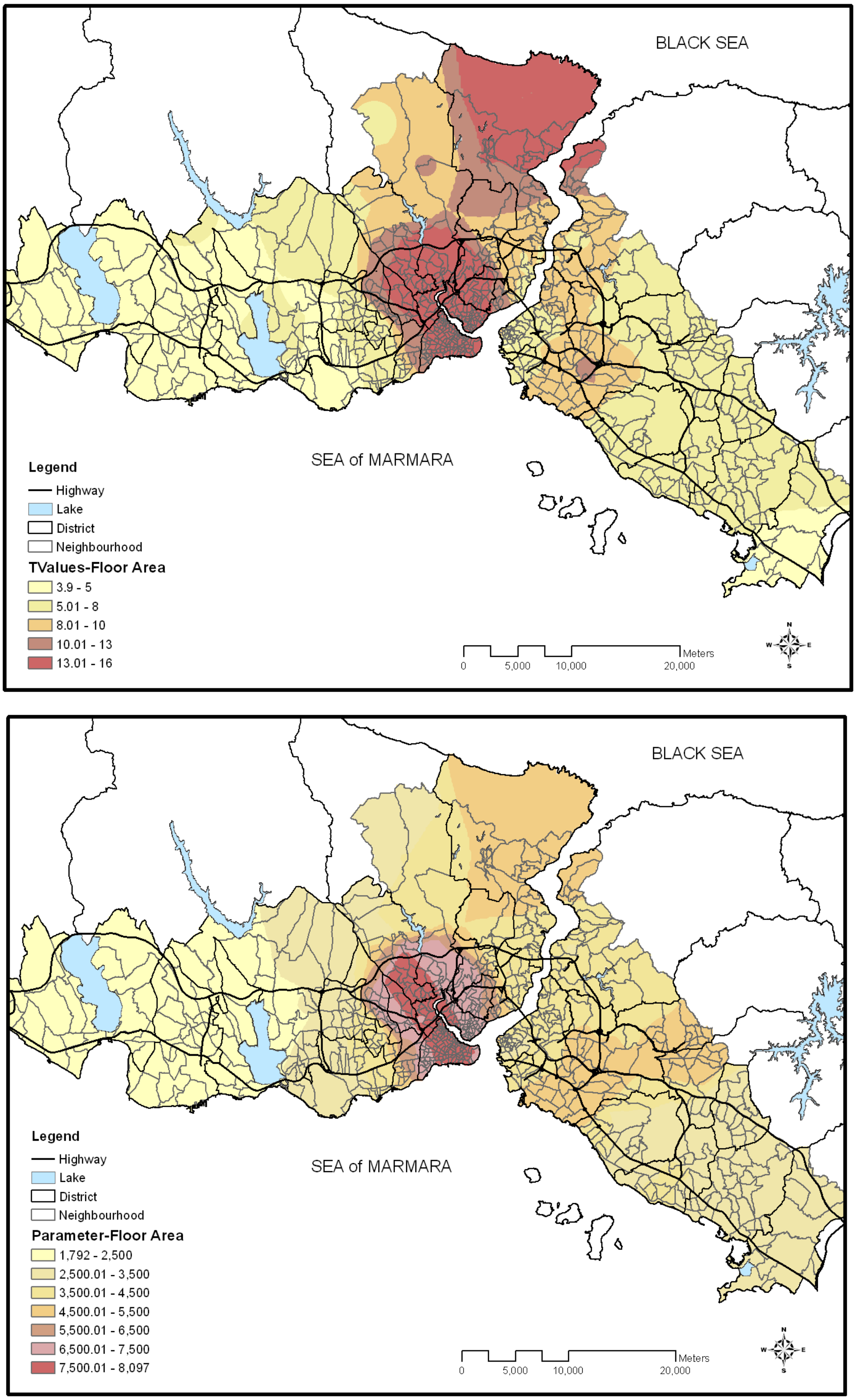


Figure 4.11 : Local *t* values and parameter estimates of 'floor area'.

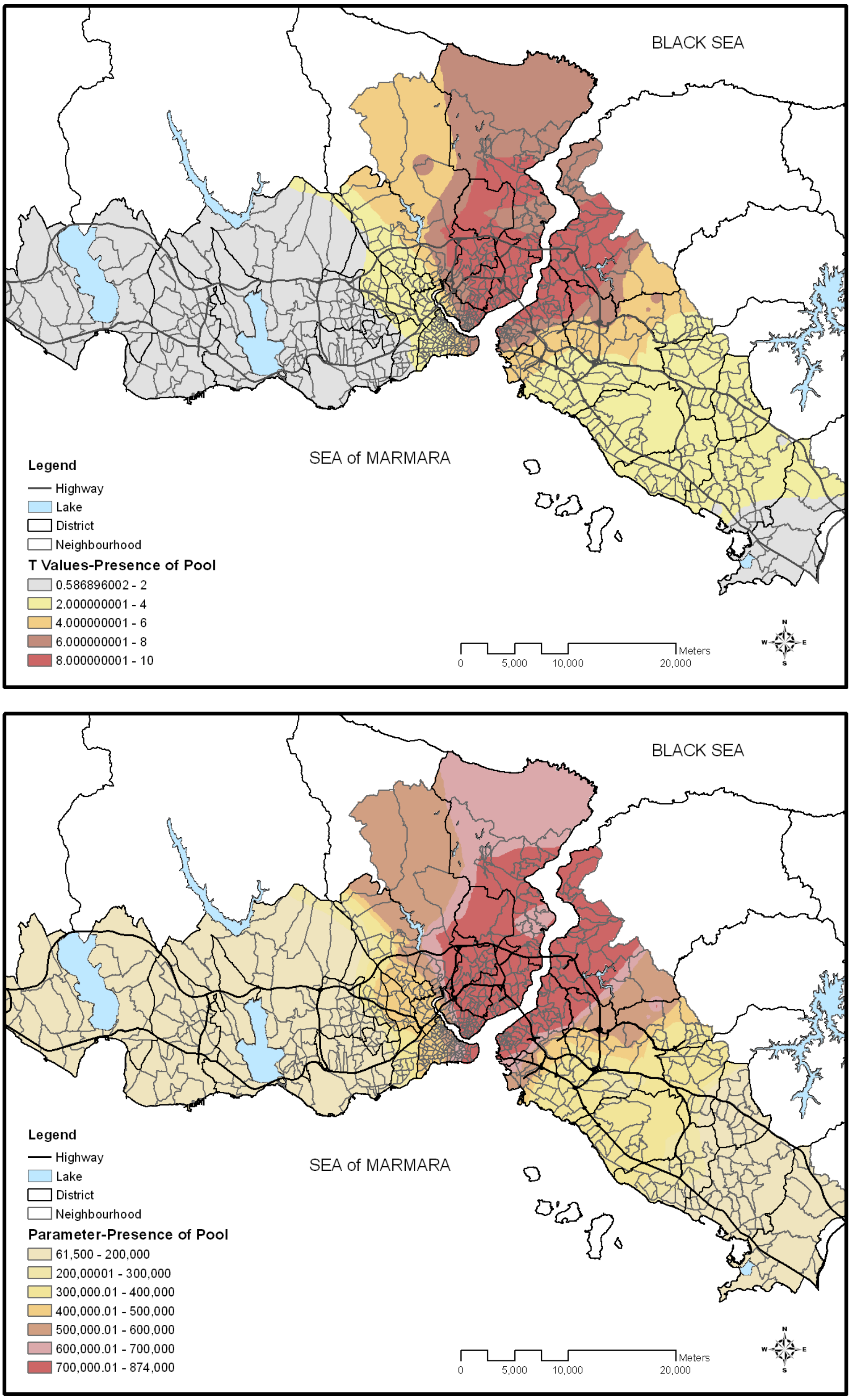


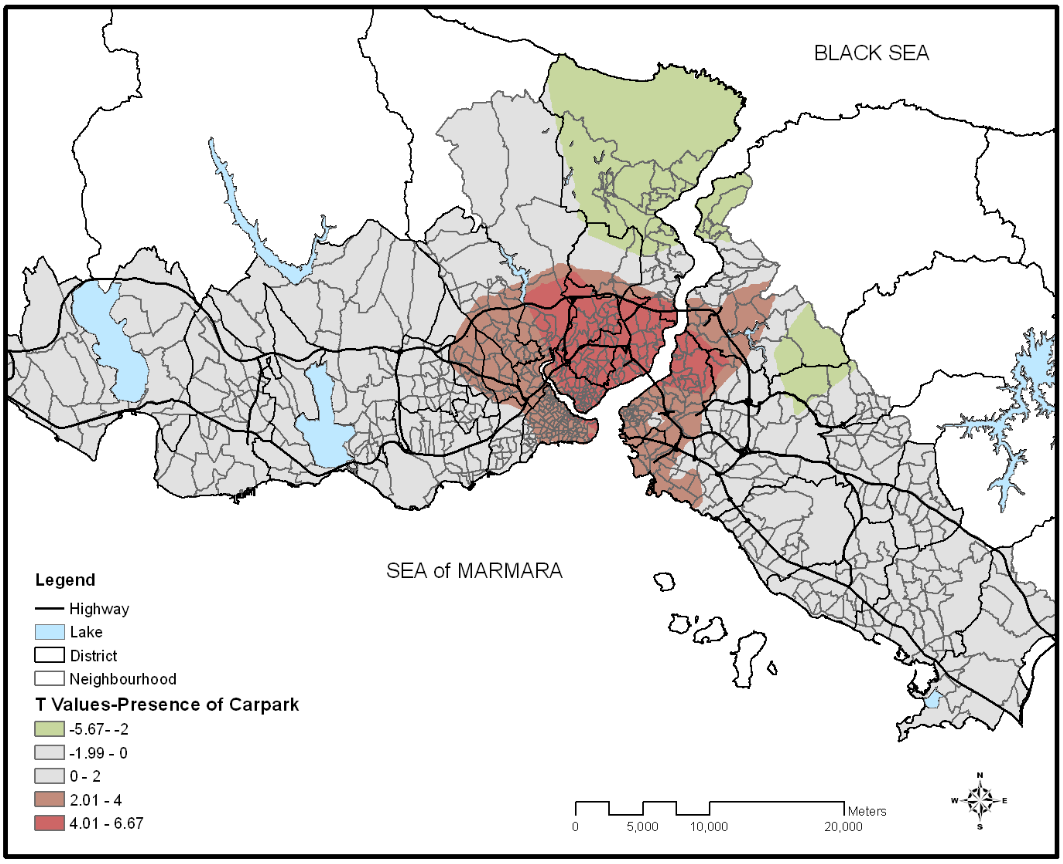
Figure 4.12 : Local t values and parameter estimates of 'presence of a swimming pool'.

As can be followed in Figure 4.13 and 4.14, the general distribution pattern of the parameter estimates for both of the variables exhibit some differences across the space which is interesting to explore. In other words, GWR as a local modelling technique is presenting some interesting spatial information in the local details.

In the case of the presence of a car park facility as a part of the property, the situation is a little bit different. Even though, this parameter is significant in the global model structure, it is not significant at every location across the study area according to the GWR outcomes. The other interesting outcome of the comparison of the two different modelling techniques to point out is the type of the relationship. Especially at one spatial location in the study area the sign of the relationship is negative rather than being positive. This unexpected situation is one of the advantages of the local modeling technique which is giving the researcher the option to zoom in. Figure 4.13 presents the local *t* values and parameter estimates of the 'presence of a car park' variable. For instance, although this independent variable is globally significant on house price, the significance level gets weaker based on the GWR analysis results. The regions that car park property is significant on house price are limited across the study area.

The districts where the regression relationship is significant between house price and car park facility are Besiktas, Sisli, Sariyer, Fatih, Uskudar, Beykoz, and Kadikoy. In these central districts with high densities, there is not enough space for parking. The relationship between the car park and house price is strong and therefore the parameter estimates are high in the order of; Besiktas, Sisli, Beyoglu, Fatih, Uskudar and Kadikoy. On the other hand, some parts of the Sariyer and Beykoz districts have a negative relationship.

The other group of variables under the title of urban accessibility/location attributes in the house price formula in this research are; distance to highway, distance to central business district and distance to coast line. In the global regression results, all these location attributes are significant and have a negative effect on the value of the property. Being close to any of these important points will increase the price of the house. If the local regression results are considered, there is some remarkably detailed variation in all three relationships.



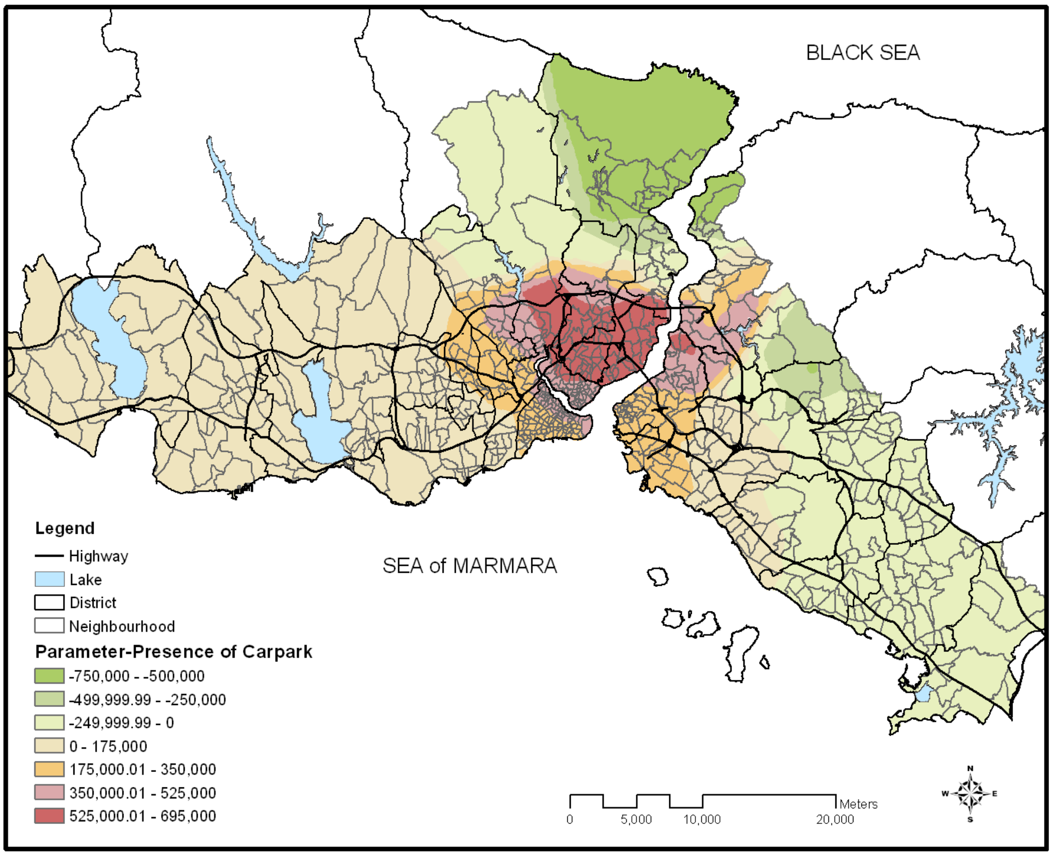


Figure 4.13 : Local *t* values and parameter estimates of 'presence of a car park'.

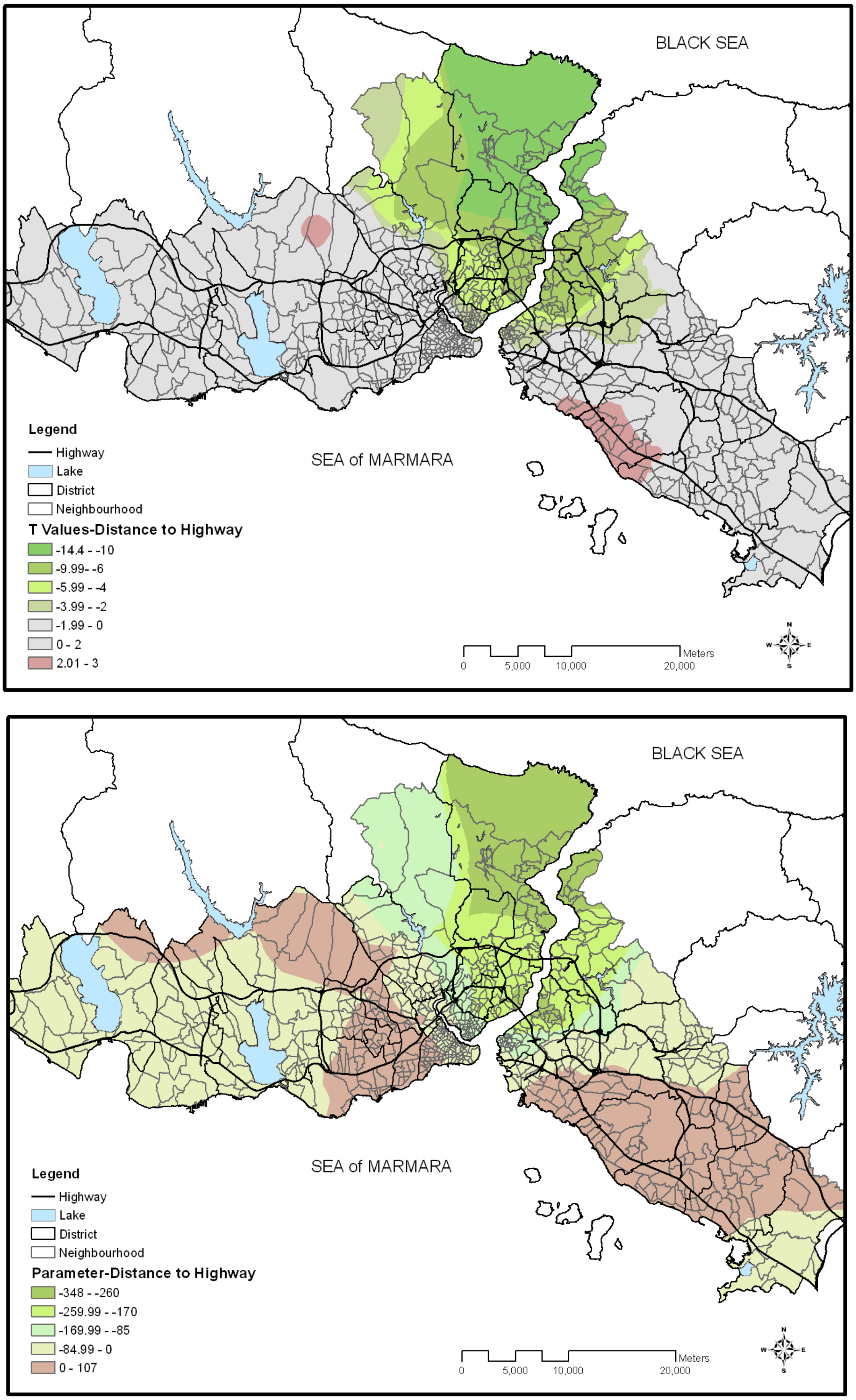
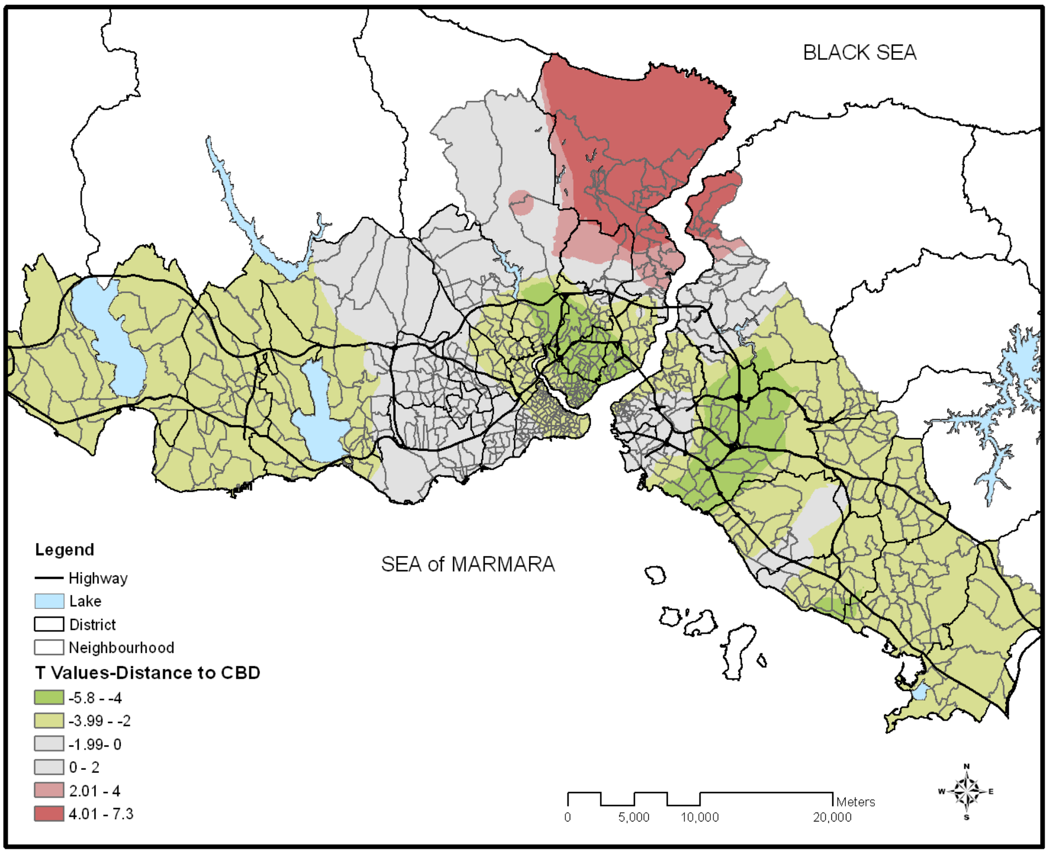


Figure 4.14 : Local *t* values and parameter estimates of 'distance to highway'.

First of all, the independent variable, distance to highway and its affect on house price will be discussed (Figure 4.14). According to the GWR analysis, the first point to stress is the distribution of the t values for this variable. This variable is not significant across all the locations included in the study. Actually, it presents significance at only a limited number of spatial areas. Similar to the other variables, the borders for significance are including the both sides of Bosphorus but differently not including the Halic region. At the points where the relationship can be considered as significant, the estimates are not high compared to the other variables of the study. In general, the further the location of the property from the highway, the lower is its value. There are also some more local variations which will be discussed in the following section after overall descriptions.

The second location parameter to analyse the local regression relation with the house price is distance to the CBD. As it can be seen in Figure 4.15, there are some parts of the study area where this variable does not present a significant relationship, contrary to the global regression outcome. This significance level figure actually shows a more partial structure. Some locations along the Bosphorus and coastline axis by the Sea of Marmara on both continents are part of this discontinuous pattern. Like the previous distance variable, the effect on the value of the house is not high per unit difference in the distance but still, it is possible to talk about the existence of the significant relationships. Different than the global model, based on the GWR analysis results, there are spatially varying outcomes which can be generalised in three different groups. First, locations quite further away from CBD are affected negatively. Second is the location relatively close but still in a distance to the CBD are positively affected. The third and the last locations around the CBD area are influenced in a negative way. All these varying dynamics within the study area emphasise the importance of looking at spatial variations in relationships.

The third urban accessibility attribute placed in the model is the distance to coast variable. As summarising the global parameter estimates, decreasing distance to coastline means increasing amount of the house price. So, there is a significant negative relationship at the global level. When the exploration is done at the local level with a local spatial analysis (Figure 4.16), there is much more to talk about this relationship. For instance, t values are showing a heterogeneous distribution instead of a homogeneous value valid for every point in the study area.



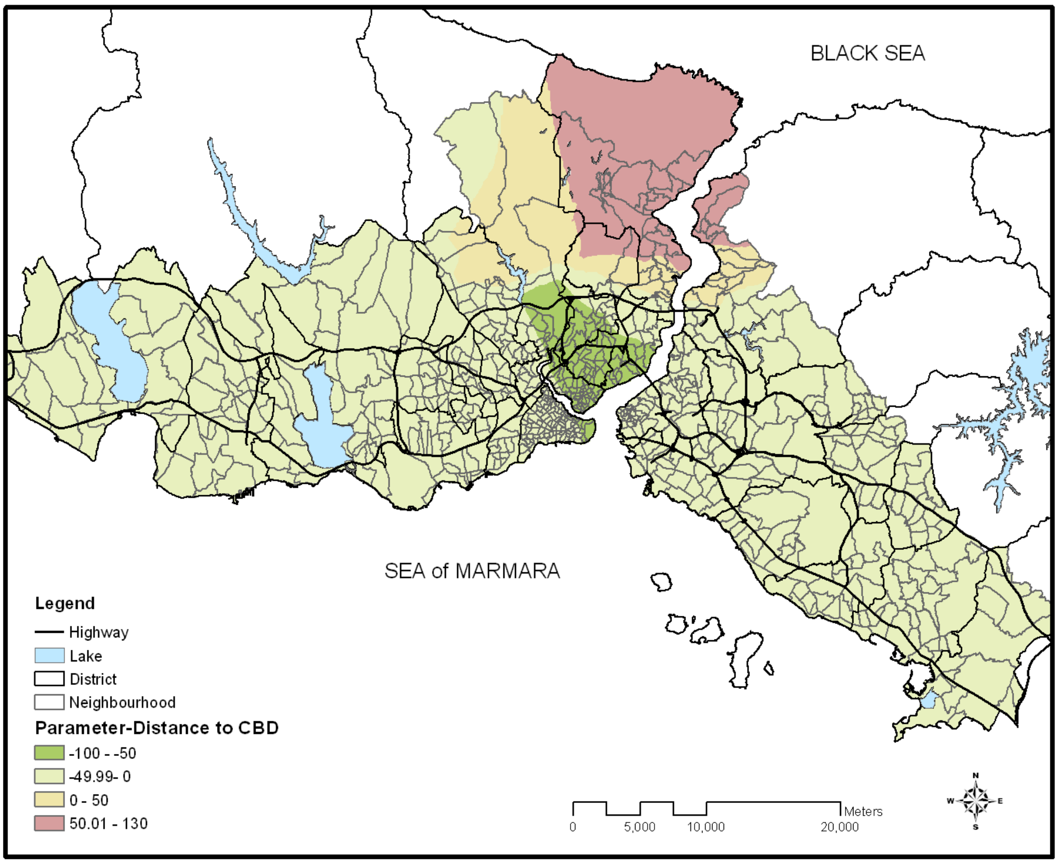


Figure 4.15 : Local *t* values and parameter estimates of 'distance to CBD'.

Within this heterogeneous distribution, there are some points where the *t* value is between -2 and 2 which symbolises non-significance. If the attention is given to the areas where the t values are significant, the heterogeneous structure is still valid. The general tendency is the negative regression relationship; as the distance to the coastline increases the value of the property decreases but of course the degree of this relationship changes from one point to another. According to these spatially varying characteristics even along the Bosphorus there are special locations where the effect on house prices will differ. For example, if the property is located in the region north of Halic - around Beyoglu district, the house price will be less than any other location where this relationship is significant at the local level. This particular outcome will be discussed with a broader perspective in the following section.

The last variable of the house price function and the only representative of the socio-economic characteristics is the car ownership ratio. As explained in the previous sections about the general result of the GWR analysis, the first group of the results was the global regression parameters (Table 4.10). According to these global regression results, car ownership ratio was one of the significant independent variables in the house price function. Aside from this, in the local regression parameters this situation varies based on the different spatial points in the study area. As a result, the significance degree is changing and also it is being non-significant at some points. The visualised pattern of the *t* values can be followed in Figure 4.17. As can be noticed from the related figure, there are basically two main different attitudes at the areas where the significance is valid; one positively and the other negatively on the value of the house. Moreover, the global regression result which suggested that the relationship between car ownership and house prices was positive, exhibits a more complicated pattern based on the GWR analysis. As a result of the local regression, the areas closer to the central business district have the opposite type of relationship to the outcomes suggested by the global regression.

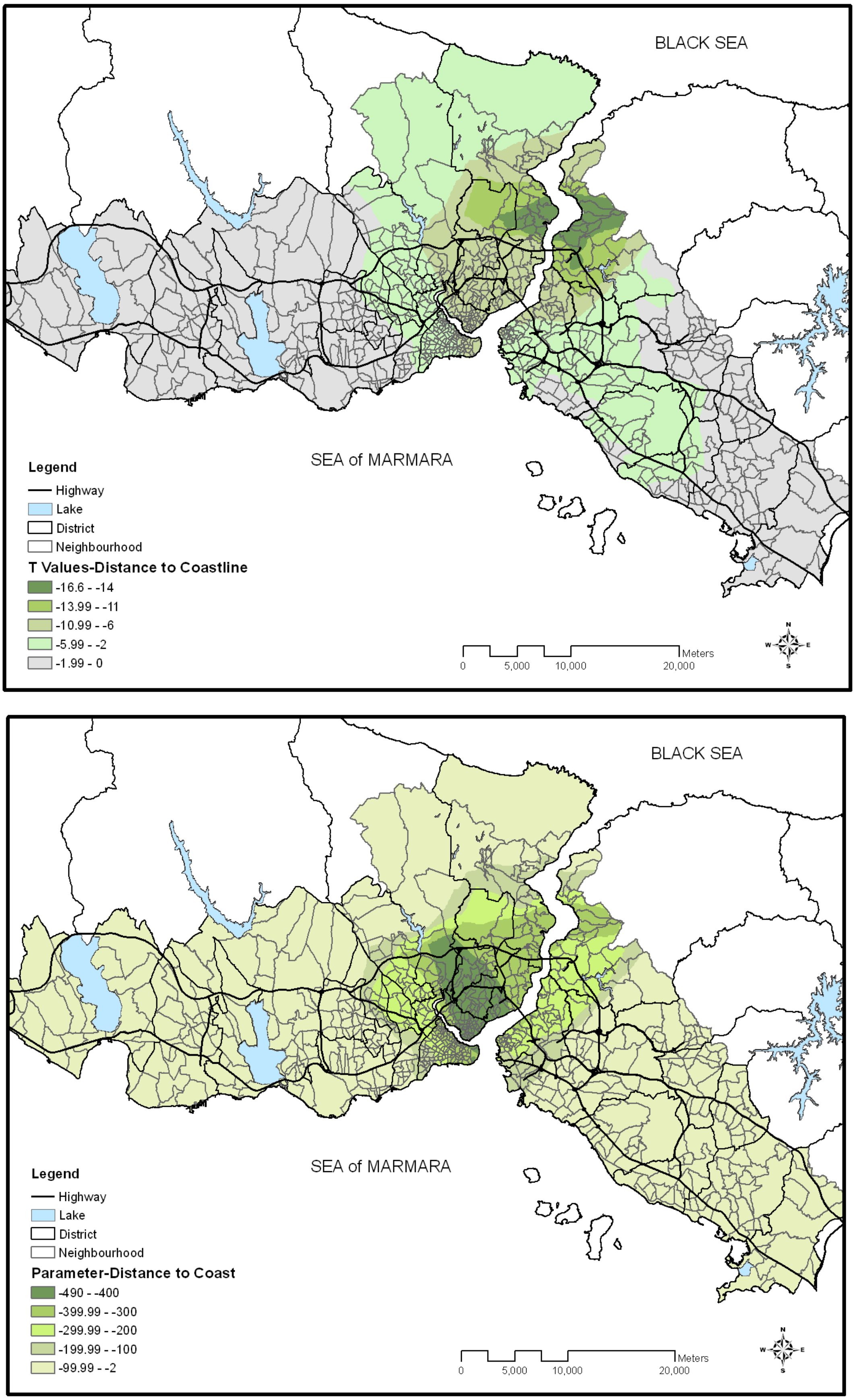
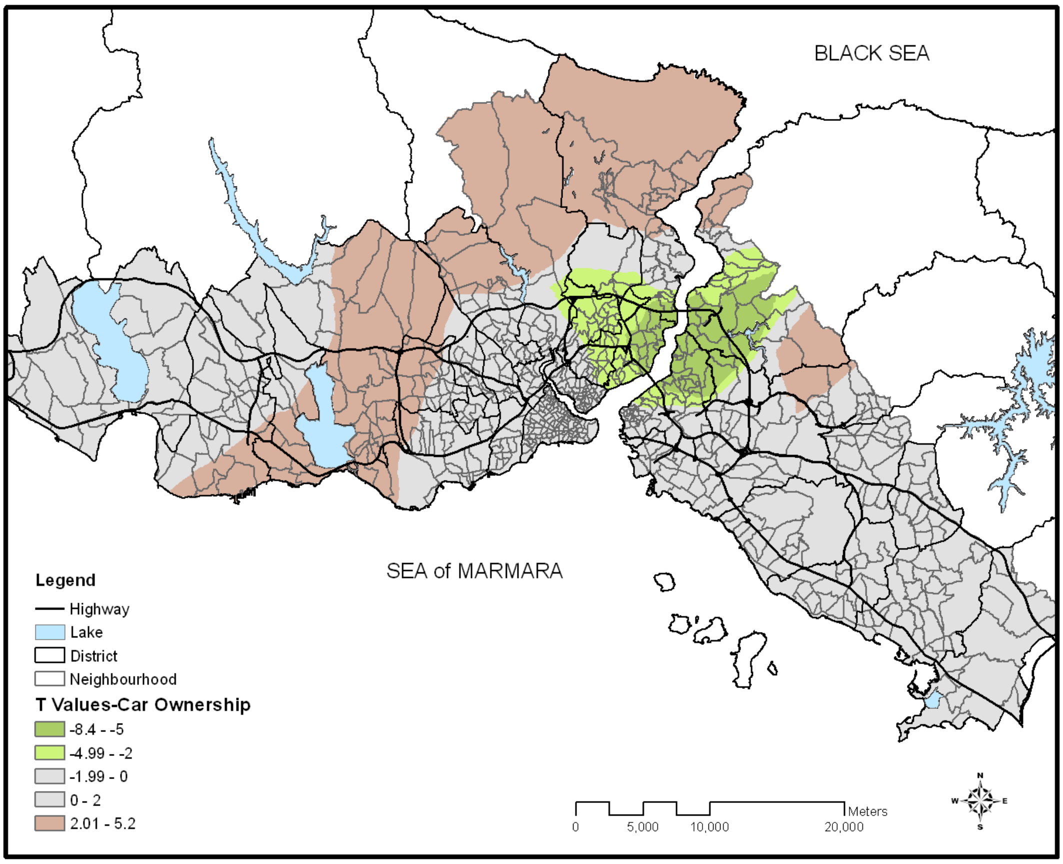


Figure 4.16 : Local *t* values and parameter estimates of ‘distance to coast’.



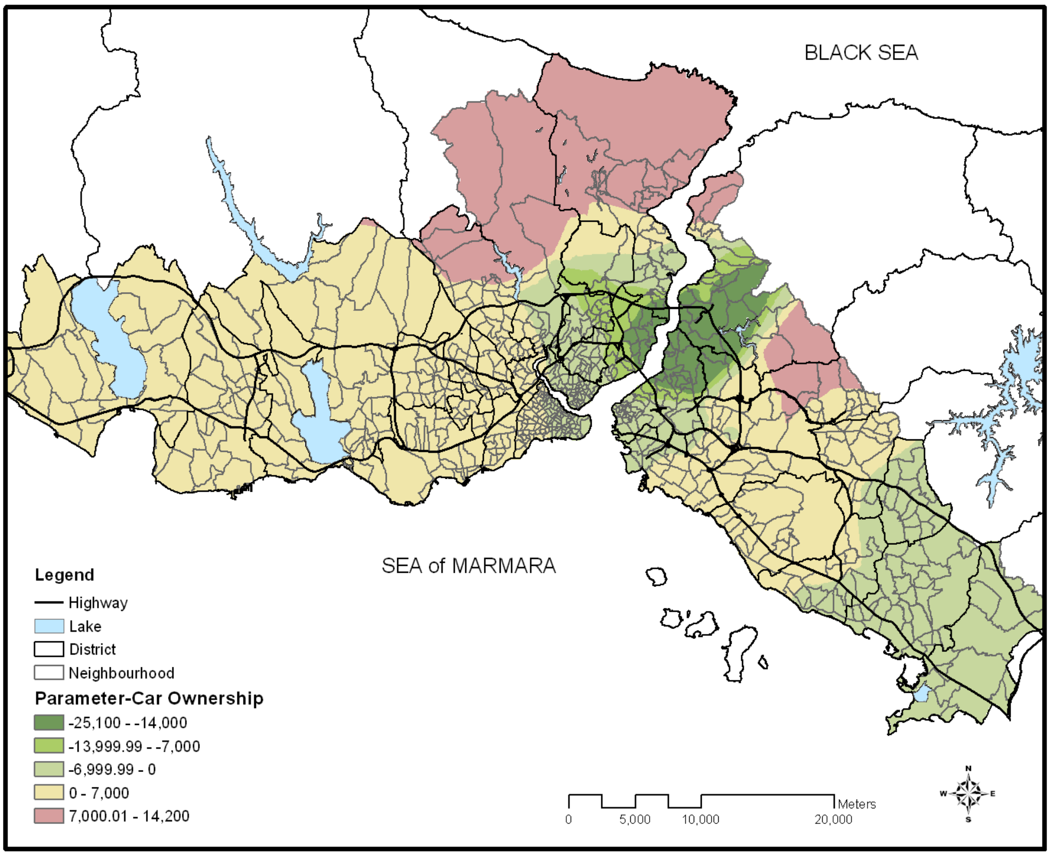


Figure 4.17 : Local *t* values and parameter estimates of 'car ownership'.

4.5.2 Discussion

The first part of the explanatory notes is described in the previous section with different aspects. In this section, the main purpose is to discuss the special issues related to the findings for the city of Istanbul. In general, the main results focus on;

1- Every variable is not significant at every point across the study area

2- Each of the variables has their own effective zone.

3- The power of the relationship can vary locally.

This situation can be supported with the changing R^2 values within the study area (Figure 4.18). As it can be seen in the figure below, the local R^2 values differ from 0.70 up to 0.96. According to this can be stated that with the same house price model the power of explaining the relationships between the variables can vary locally. These variations based on the spatial locations will be detailed for each independent variable in a special framing aspect for the Istanbul metropolitan area.

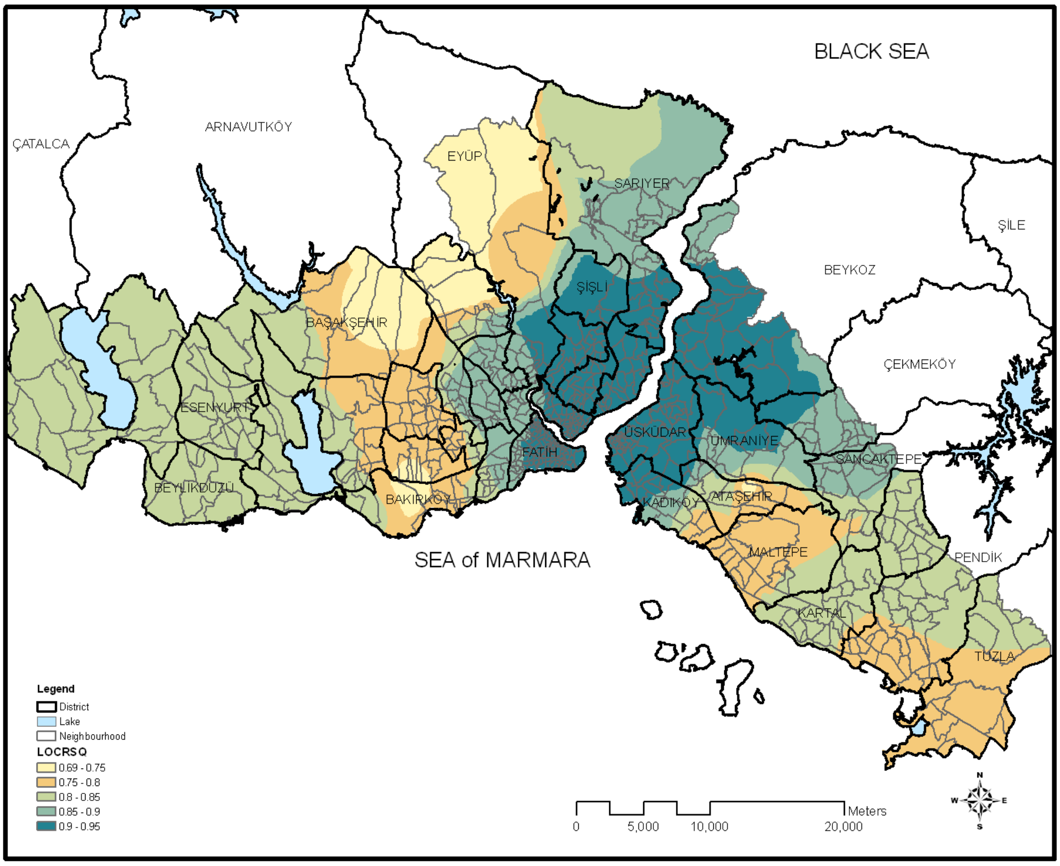


Figure 4.18 : Local R^2 values.

The first of these variables is the apartment flat. Apartment blocks started to appear in the city structure in the early 20th century in Istanbul. Today, they are the most common type of housing in Istanbul. Even though the height of the blocks differs a lot, they are the main components of the urban fabric. The general pattern of each district in Istanbul can consist of all different types of housing such as attached, detached and as well as the semi-detached housing units. In some districts one of these types will be the more dominant element. For instance, in and around the historical peninsula and in the neighbourhoods around Halic, the most common type of housing is the apartment because of the general historical urban fabric. On the contrary, the neighbourhoods established in the later periods or in other words recently settled ones can have the detached houses as villa style more often in their environments. So, moving to the north from the historical peninsula and crossing the Bosphorus can lead to some differences in the urban structure. Besides, for the housing settlement areas that are located around the Halic and historical peninsula, it is possible to talk about the high urban densities (building and population) and small lot sizes. Actually, as a result of this fact, the only possible and reasonable housing

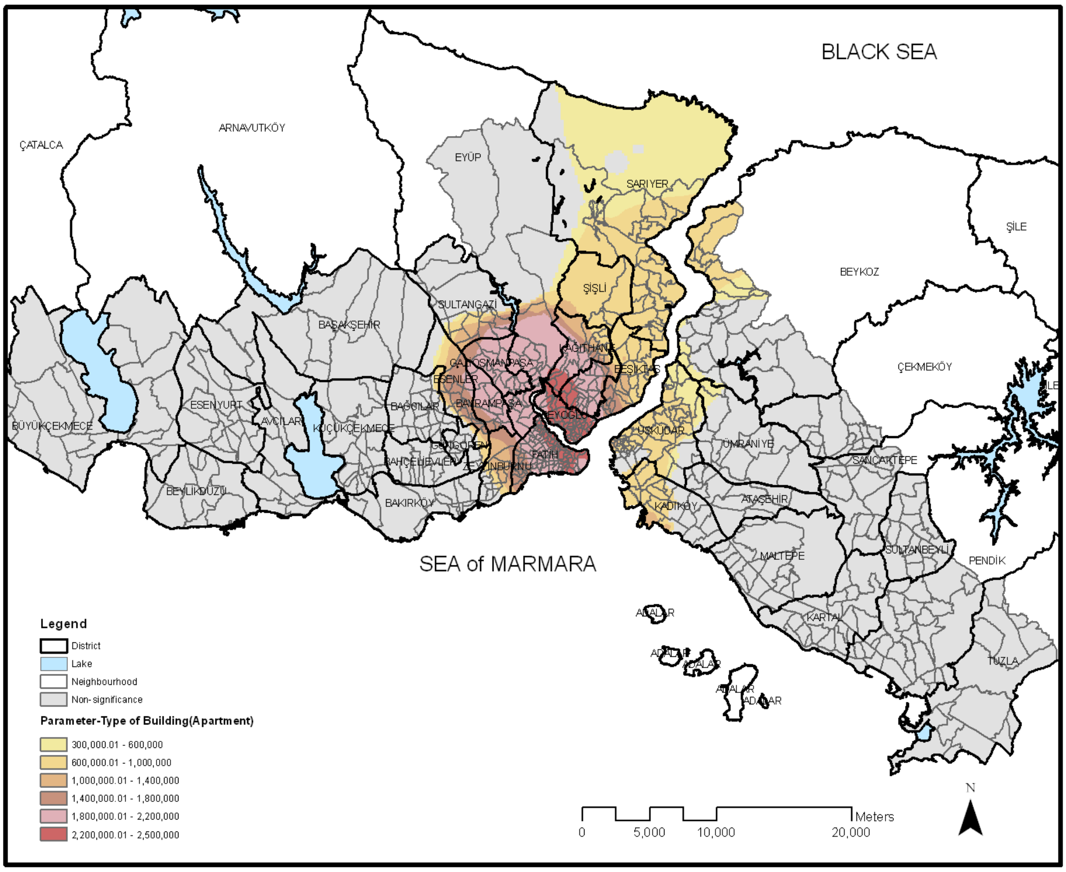


Figure 4.19 : Parameter estimates for the variable ‘apartment’ in significant areas.

type seems to be the apartment blocks.

The local modeling results support this specific situation so that, the areas that the variable has a significant effect on house prices varies spatially and also the local differentiation represents that the change in the house price will be highest if we are talking about an apartment flat around the Halic region. Within the significance borders of this variable, apartment flat as an independent parameter will cause differentiation in the house price as decreasing from south to north direction by the Bosphorus on the European side. On the Asian side, there is not a hotspot like the historical area of the European side. Uskudar, part of Kadikoy and Beykoz are the locations that apartment flat can be positively related to house price although the range of the parameter estimate will be less than Fatih and Beyoglu. Sisli and Sariyer are the sites in the European side that will have the same price range as in Uskudar, Kadikoy and Beykoz.

Moreover, the housing unit being detached in the city of Istanbul has an effect on the value of the property. Symbolising privacy and freedom, detached housing is mostly seen as the villa type houses in Istanbul. The early popular types of the detached houses were the Bosphorus villas and also the summer houses in the historical periods of the city. It was also the type of the housing in the early settlement neighbourhoods until the fires and also the increase in the population. Higher densities and demand for the land were the reasons for the detached houses to transform into apartment blocks. However, in the late 20th century, detached houses started to become popular again in the new housing complexes. It was the new way of advertising the new life style in the metropolitan city of Istanbul especially at the outskirts of the city. After a while, not only in suburban areas but also at some central locations detached houses became the desirable type of housing.

Parallel to the issues mentioned above, results reported in Figure 4.20 represent detached housing has a significant impact on house prices at almost every location across the study area. Although it is positive everywhere, the addition to the house price shows a changing pattern. Unlike to the apartment type, some parts of Kadikoy and Uskudar districts on the Asian side are the hotspots for this parameter. North of Uskudar and Besiktas regions are the other important spots for this variable. The possibility of keeping the privacy in a detached house and using the benefits of the central facilities should be the potential reasons for this observed outcome.

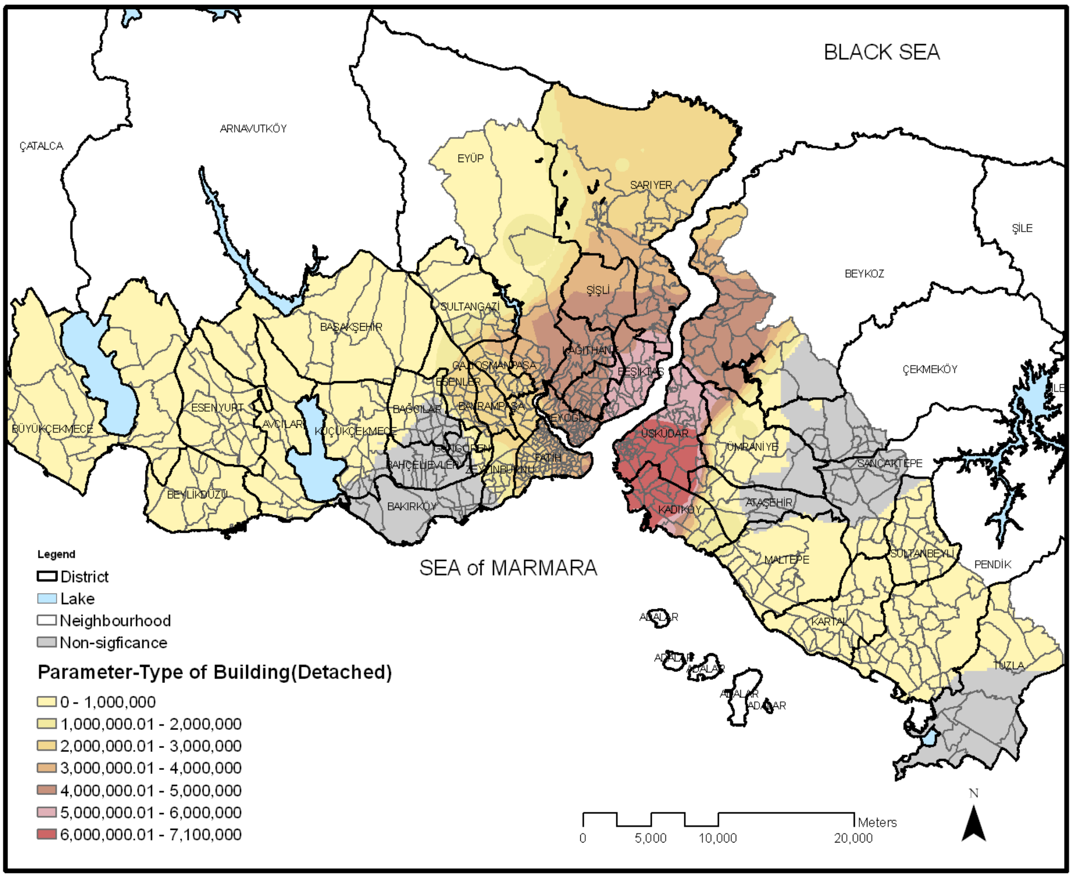


Figure 4.20 : Parameter estimates for the variable 'detached housing' in significant areas.

Generally speaking, the Bosphorus will perceive the highest impact on house prices based on detached housing. At the inner locations or the other districts by the coast both in Asian and European sides, the impact will be the less. In summary, having a detached house by the Bosphorus in high prestigious neighbourhoods will definitely cost more. The view affect, accessible central amenities, prestige and privacy can all be the issues responsible for these consequences.

Floor area is the only variable in the model that is significant at all points along the study area. Size of the property is the main component of the most house price models. Figure 4.21 shows the results and according to the analysis of the maps, the neighbourhoods around the historical peninsula and Halic are the focal points. Following the same principles of urban fabric that are mentioned earlier for this historical/old centre zone, noticing the highest effect of floor area on this part of the city is not unexpected. In other words, increasing size in square meters resulting in the increasing price of the property makes more sense in the old parts of the city with high densities and small lot sizes. High floor areas are easy to access outside the old city part. So, floor area adding more to price is reasonable for the parts in and around the historical centre. Besides, the important point of the analysis is to be able to see the varying structure of the parameter estimates and also this reasonable output can be obtained only as a result of a local level investigation technique. There is a focal point around the historical peninsula where the parameter estimates are high. The outer ring of this focal point is the zone where the second highest parameter estimates can be seen. The area around Sariyer and Kadikoy districts are the locations that the estimates are higher than the rest of the locations except than the focal point. Although there is not a big variation in the relationship of house price and floor area, it is still interesting to investigate the differentiation at the local scale.

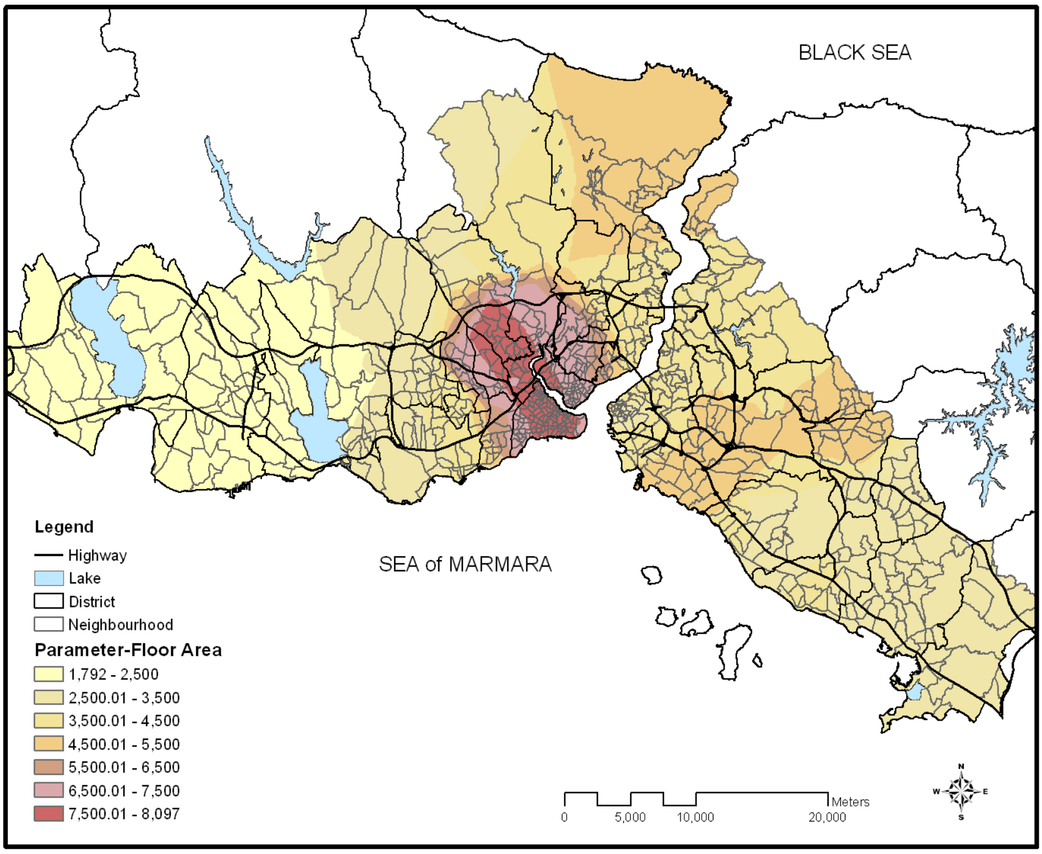


Figure 4.21 : Parameter estimates for the variable ‘floor area’ in significant areas.

One of variables as a structural element in the research is the presence of a swimming pool. Owning this facility as a part of the property has a positive effect on the value of the property. In general, it has a non-stationary pattern in the neighbourhoods of Istanbul that are part of the study (Figure 4.22). As a result of the GWR analysis, if two housing units having all the same properties, with one located in Uskudar-Beykoz or Besiktas-Sariyer axis and the other in Kadikoy-Pendik axis, with a swimming pool, the first one will cost approximately 500000 TL more. There can be several reasons related to this finding. It can be based on the different urban systems that exist in the city structure such as historical, physical and socio-economical. As location represents all of these different potentials, tendencies and correlations based on the different structures, looking from one perspective will not be sufficient to understand the relations especially in a city like Istanbul. From the historical point of view, the potentials come with the differing historical backgrounds of each district. The old districts such as Beyoglu, Besiktas, Sisli and Uskudar are still keeping the tag of being old but also respectful neighbourhoods. In addition, they are the districts by the Bosphorus which is the key element of Istanbul. From the physical point of view, Bosphorus itself is the point of interest for Istanbul. Not only the Bosphorus itself, but also the proximity to the main central facilities makes these areas more attractive. From the social point of view, all these circumstances coming together with a quality social environment can result in a higher price for an extra

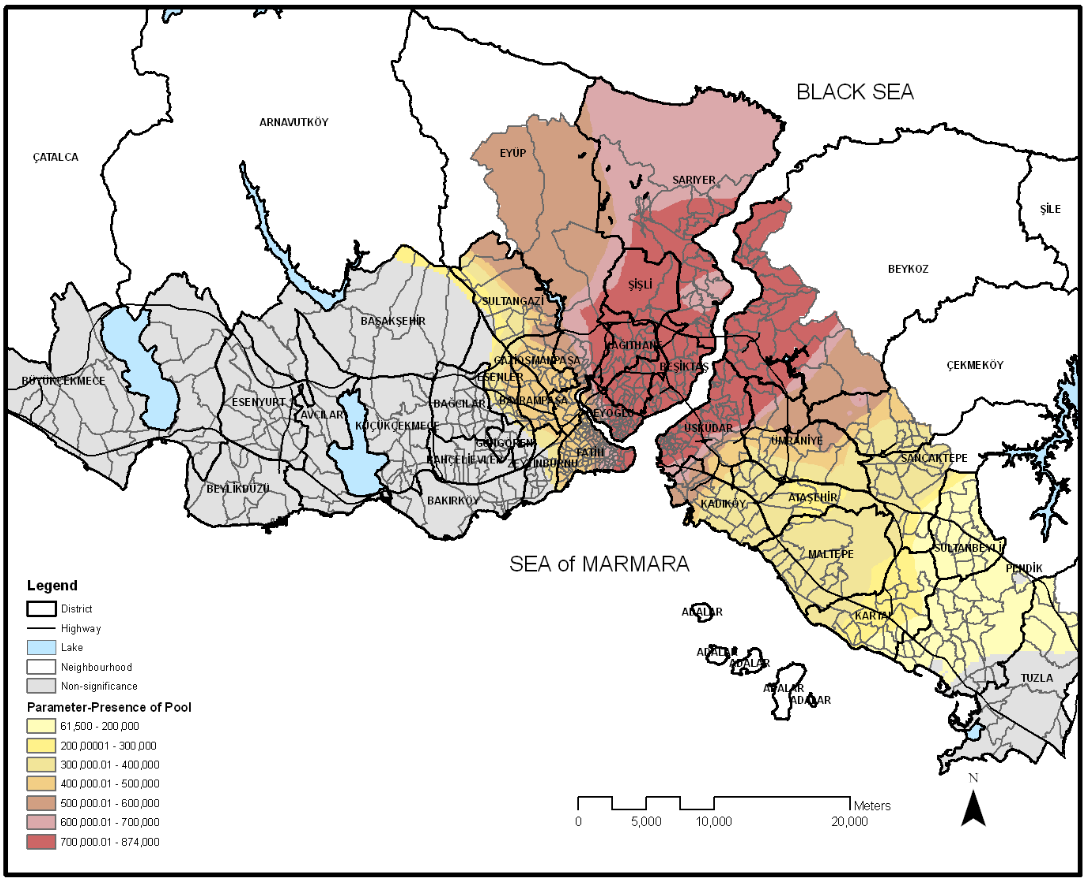


Figure 4.22 : Parameter estimates for the variable 'swimming pool' in significant areas.

amenity like swimming pool.

The situation is similar in some aspects for the other important amenity in the house price model which is the presence of car parking. The variable is significant at the main core of the city which is lying around the historical peninsula and including the districts like Besiktas, Beyoglu, Sisli and Uskudar. The relationship is showing a non-positive structure at the north side of the city.

North of Sariyer and Beykoz are example areas of this non-positive relationship between the presence of car parking and house price. This non-positive relationship can possibly be explained by either the situation that car park spots are mostly a default facility in these areas or a special car park spot is not very important since there are lots of parking opportunities compared to really dense neighbourhoods. The alternative possibility is that the presence of garages in these areas can eliminate the importance of car parks.

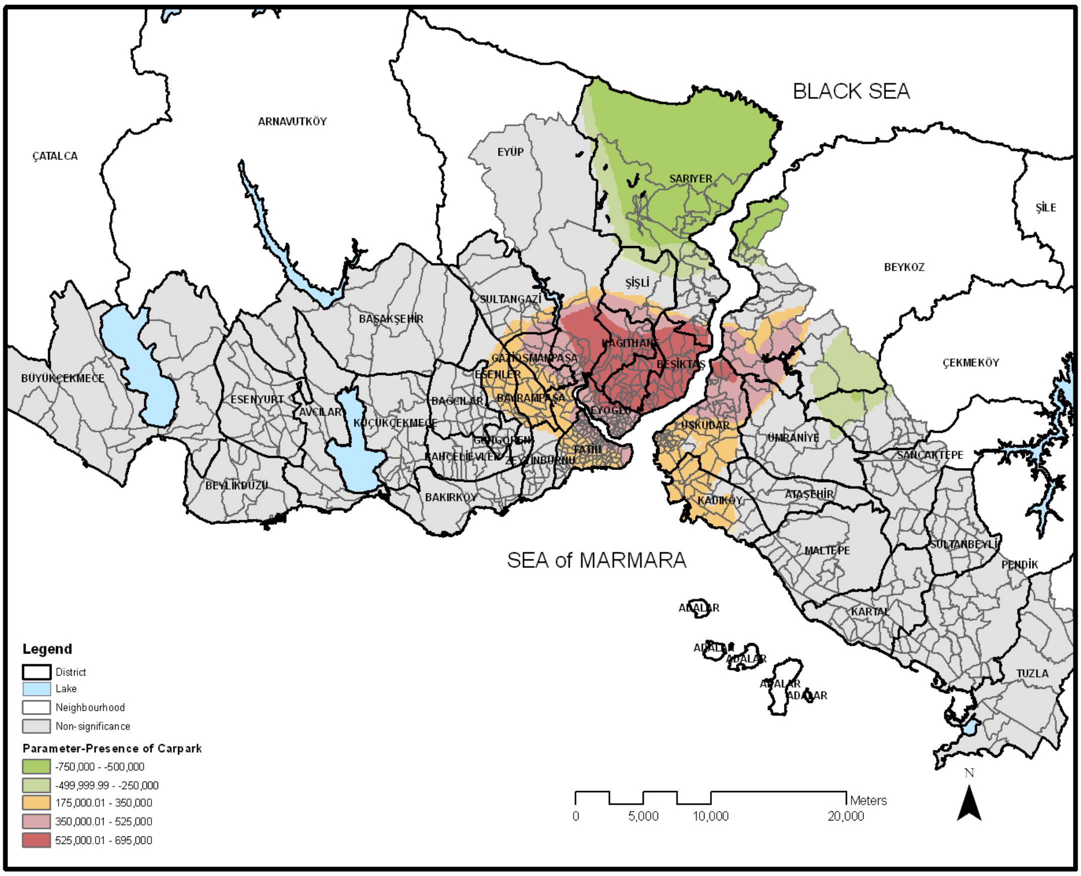


Figure 4.23 : Parameter estimates for the variable ‘car park’ in significant areas.

On the contrary, in the early settlement neighbourhoods/old parts of the city, parking is one of the important problems. As it can be seen in Figure 4.23, the highest parameter estimates for the presence of car park is mostly located around the Besiktas, Sisli, Beyoglu, Fatih, Uskudar and Kadikoy districts which are the examples of early settlement structures. Even though the urban pattern in these areas has been transformed, traditional measures/scales are effective in built environment which makes car parking still a big problem.

Representing the accessibility of the houses on sale, proximities to some specific destinations are used in the house price local regression model. Accessibility to highway, central business district and coast are these variables. Discussions will be following the order of the variable names as mentioned above. The relationship between distance to highway and house price is mostly negative and shows a spatially varying pattern (Figure 4.24). There are different zones in the city that the unit

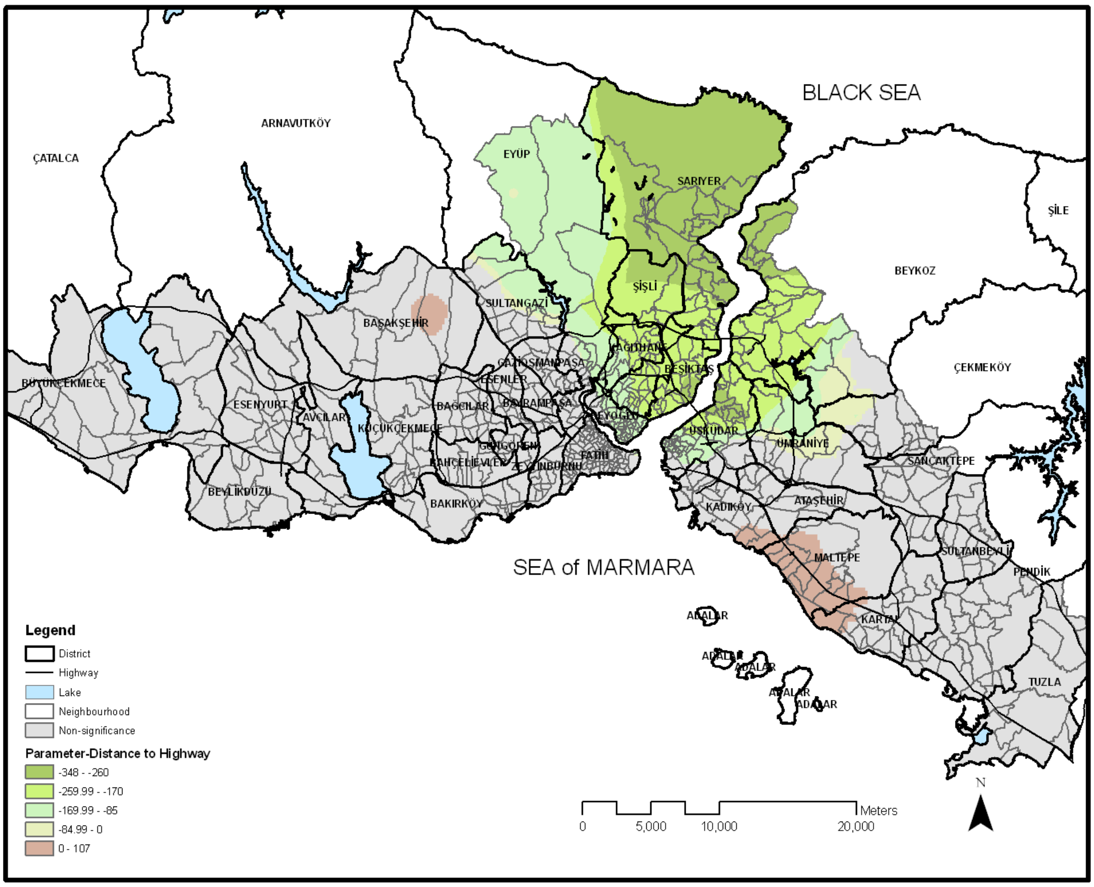


Figure 4.24 : Parameter estimates for the variable ‘distance to highway’ in significant areas.

change in the proximity will have a different value effect on the price of houses. It can be stated that the zone that is located further away from the highways (TEM and E5) has the highest negative effect on the house price among the areas that this relationship is significant. The negative impact value will decrease gradually when the distance gets closer to the highway. However, there is a constant negative relationship generally in the study area even though the negative effect on the house price is really small compared to the some other independent variables included in the study. Closer to the highway generally will mean a higher house price value compared to the locations far away from the highway. Interestingly, there are only two spatial locations where actually being away from the highway will add more value to the house price. This positive relationship can be the result of their inner-region dynamics since Basaksehir is one of these areas.

When it is distance to the CBD, the situation is a little bit complicated. As was mentioned earlier there are three possible different variations based on this variable in the house price function (Figure 4.25). The first of them is the Kucukcekmece-Buyukcekmece axis on the European side and Maltepe-Kartal-Pendik-Tuzla axis in the Asian side. At these locations, the CBD is a long way away, so, the parameter estimates are dropping. So, increasing distance to CBD is causing a decrease in the value house price at these axes. This is the expected CBD effect; as distance increases from the CBD house prices drop. Second, the in locations around the Halic region, even though they are closer to the CBD there is a negative relationship. Being close to the CBD, is not seen as an advantage in some parts of the city. In this result, some other attributes of these central districts can be effective. Third, in the top north of European side around Sariyer district, there is a significantly positive relationship as the distance increases prices go up. This can be mostly explained with the urban movements of Istanbul in the last two decades. First of all, leaving central locations and moving to the peripheries, was one of the popular trends especially for a better environment and luxury houses. Secondly, the earthquake in 1999 had a powerful effect on people’s decisions for their new-secure residential habitats. The north part of the city, because of its geological structure, was the target point for the establishment of new housing complexes. Third, being away from the central facilities was not really a problem for the residents as it was the actual purpose of their movements.

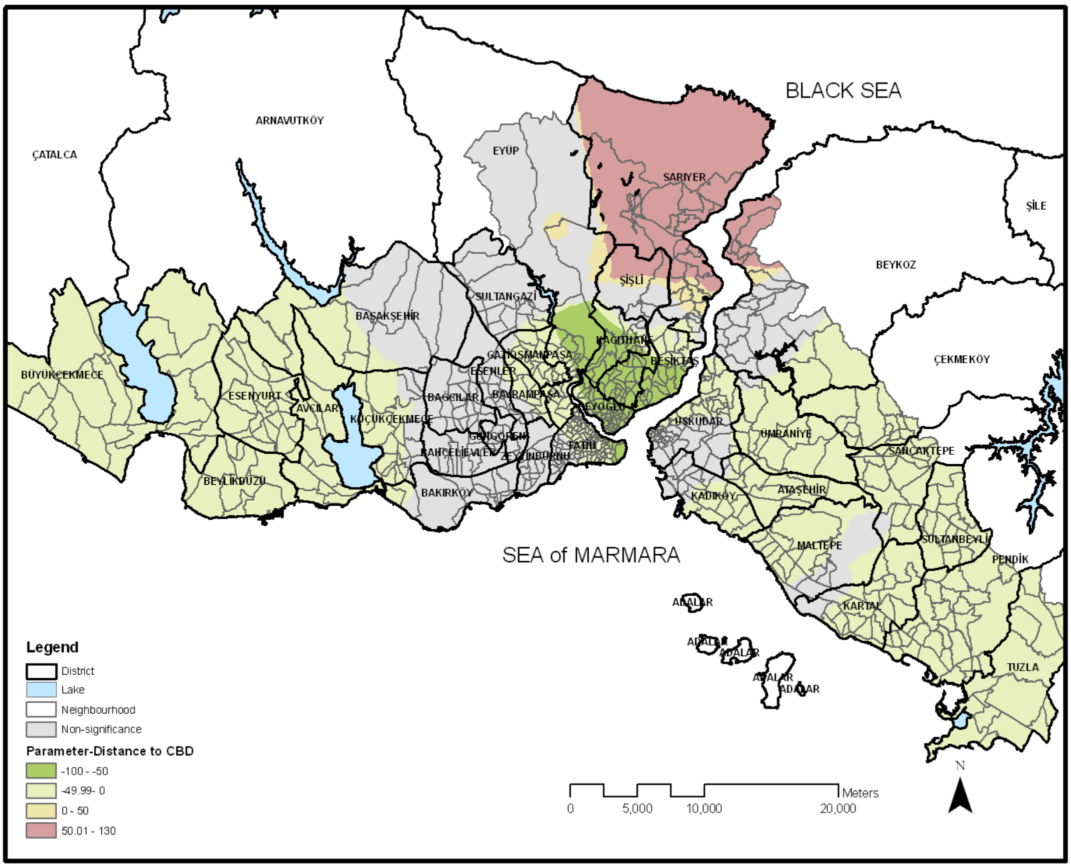


Figure 4.25 : Parameter estimates for the variable ‘distance to CBD’ in significant areas.

Apart from these, the factor of being in close proximity to the coastline can be effective on the outcomes of this relationship which is the last variable of the accessibility attributes in the analysis. For Istanbul being an important port city since the first settlement, sea and accessibility to the sea are important issues. Being close to sea can both mean having the sea view as well as having easy access to the seaside for recreation and transportation purposes. According to the GWR results, the relationship between distance to sea and house price is negative. Being close to the coast will result in having a higher value of the property compared to the situation of the same property located further away from the coast. As can be seen in Figure 4.26, even the general situation can be expressed in a single line, spatial variations are different across the study area. There are some spatial points - such as around the Beyoglu district – where the impact will be slightly different than

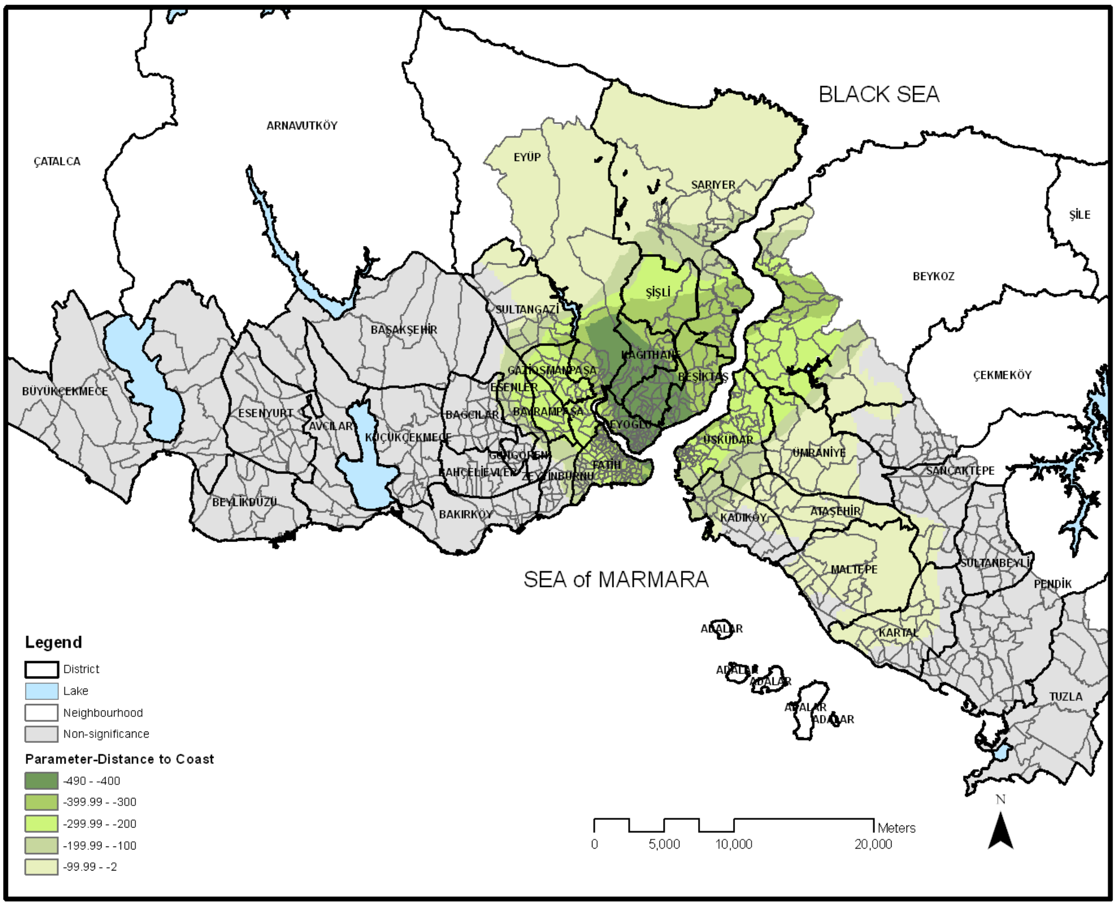


Figure 4.26 : Parameter estimates for the variable 'distance to coast' in significant areas.

the other locations where this function is significant. It is important to mention that, the affect of this variable is not causing huge differences like detached housing on the house price at different locations. This outcome is similar to the other distance variables. The house price will get higher values while moving from south to north direction on both sides of the Bosphorus. It is not surprising, since Bosphorus is a reference point for Istanbul. On the other hand, it is encouraging that the local modeling technique gives the advantage of detailed investigation. The facts that central locations being busy and dense and the changing Bosphorus view at different locations of the Bosphorus axis can be the other reasons for these spatially varying results.

The last variable of the model and the only representative of the socio-economic attributes in the house price function is the car ownership ratio. The local regression results show a dispersed pattern in this relationship based on the significance (Figure 4.27). So, there are basically two different regimes. One of them is generally around

Besiktas and Uskudar districts and the other one is starting from Kucukcekmece area and going up to the north through Sariyer district. The basic difference between these two different spatial regions is the type of the relationship. Starting from the first spatial region, increasing car ownership ratio will decrease the house price in this specific region which is around the Besiktas and Uskudar districts. An explanation can be that increasing car ownership rates in historical settlement areas and high density residential sites can result in increasing discomfort. Although car ownership can be thought as a representative of income level, the situation is actually more complex in Istanbul. This complex structure can lead to misinterpretation because some people who can afford a car choose not to own one because of the extra hassle involved in keeping a car in big cities.

On the contrary, for the other spatial region the relationship has an interesting pattern. According to these results, there is a positive relationship between house value and the car ownership ratio and this relationship gets stronger through Sariyer district. What is happening in this particular area is different than the central part of the city which is why the method is selected to analyse the city structure and the relations in this structure in Istanbul. The existing situation can be explained by the cause and effect relationship more easily. Less public transportation policies and more new suburban housing developments create the high demand for the car especially for these locations. Vice versa, the people who are wealthy enough to have a car mostly preferred to live in these locations and they can afford the high housing prices. Both cases support the outcome of the spatial local modeling technique.

On the other hand, the transportation mode to travel the 'distance' and also the cost to cover the 'distance' result in specific socio-economic groups living together in a specific location and having special settlement type. This can be one of the examples for the linkage between the distance decay theory and urban form. However, because of the multicentral structure of the city of Istanbul, it is not easy to explain the interactions based on one general location attribute. That is why the local expressions of the relationships are preferred to interpret the correlations in this study.

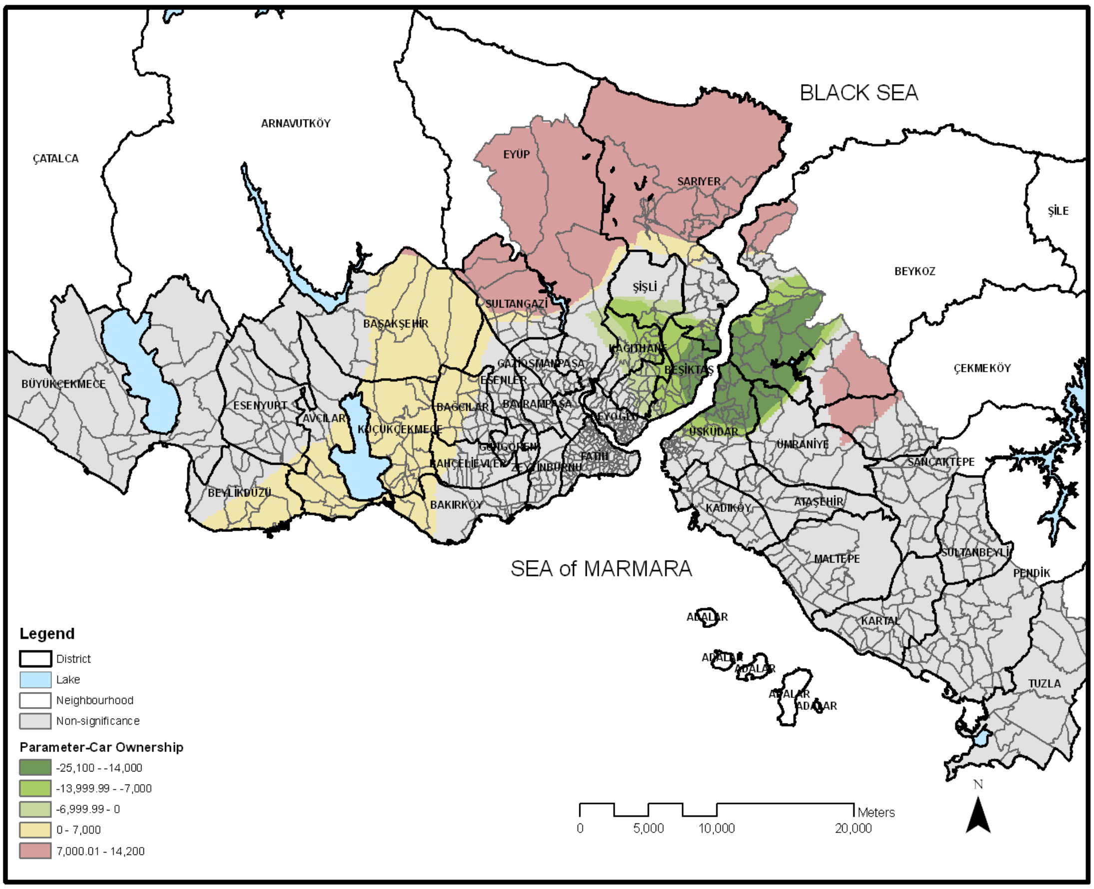


Figure 4.27 : Parameter estimates for the variable 'car ownership' in significant areas.

Other than the location attributes and some structural attributes of the housing unit, it is one of the important results of this research that urban form elements do not have an impact on the valuation of the house prices. It appears that property buyers do not consider this important criterion in their decision process. In other words, the physical properties of the house rather than the socio-economic properties/neighborhood properties are much more deterministic on the value of the house. Although the R^2 values are quite high as a result of the local modeling technique, there is still some part of this model that cannot be explained with the selected variables only in some areas.

4.6 Evaluation

The Geographically Weighted Regression model that accepts the principle that 'everything is related to everything else, but near things are more related than the distant things' as a structural characteristic is the model of this research. With this local regression modeling technique, the relationship between house prices and urban form is analysed. Different than the traditional regression models, GWR including the 'weights' with respect to the location of the data points in its structure helps to deal with the spatial heterogeneity. In other words, having each data point weighted differently in the model structure, take into consideration the effect of the spatial variation. Being aware of the spatial variation is extra important in the correlation studies.

The choice of variables and samples are just as important as the choice of the model. To analyse the effect of urban form elements on house prices, some urban form measures are included as the independent variables. These urban form measures consist of different types of urban attributes that are grouped under the urban form attributes/elements. *Urban structural attributes* such as type, age and height of the building, presence of a sea view, swimming pool, garden and car park; *Urban density attributes* like building coverage, floor area ratio, net building density, gross building density; *Urban morphological attributes* like street pattern, urban block size and topography; *Urban accessibility/location attributes* such as distance to the central business district, highway, coast and sub-centres (primary and secondary). For a comprehensive approach to the problem, housing physical properties (floor area, size of the living room, number of bathrooms and rooms, type of heating system and security system, presence of a balcony, terrace, veranda and garage) and socio-economic determinants (population density, number of household, education levels, income levels and car ownership rate) are the groups of attributes that are also included in the model. To perform the analysis in Istanbul with these variable groups, the city boundary, which is same as the metropolitan area border is selected as the study area. To examine the price differentiation of housing related to the independent variables, all different types of housing patterns (historical, planned and mass housing) in the city of Istanbul are included in the sample selection process. However, the unplanned housing pattern is left out since the housing market tendencies in these types of settlements are different than the formal house market trends and not to lead bias in the results.

After this stage, just before the application of the model there was another step for analysing and understanding the data. Descriptive examination of the possible explanatory variables, qualitative data assessment and statistical examination were done. A stepwise GWR procedure was computed to select the best model and to complete the process.

With the implementation of the model, the output layout can be followed in two parts. The global model part: with the diagnostic and the matrix of the information; the GWR part: with the estimation diagnostics, ANOVA test results and GWR parameter estimates. Other than these, the main output of the GWR is the local parameter estimates for each variable which can be visualised with the help of some other software.

The main finding is the differentiated situation of the global and the local results respect to the spatial variation and power of the model to explain the relationship. The geographically weighted regression outperforms the global model in terms of local variations and explanatory power. There are nine variables in the function for the explanation of the differing house prices. According to the global results, eight of the variables are significant in this relationship. With these variables, only 57 % of the variation of house prices can be explained by the global regression analysis and the AIC value is 18506. In summary, the most important component of the model is the floor area. Distance to CBD and detached house are the other most effective independent variables on house prices. Presence of a swimming pool is the fourth variable being significant and distance to highway is following this variable in the order. The other accessibility attribute in the house price model, distance to coastline, has an affect on the values. Presence of a car park and the car ownership rate are the other variables included in the house price model but have a less affect on the value. So, as a result of a global model, the general assumption is that the variable that is once significant will be significant at every point and the estimate will be the same for every point over the study area.

As mentioned earlier, the outcome of the global regression model is meant to be one general value for all points included in the study. This causes the lack of ability to focus on the local issues and to discuss the spatial pattern variation. This issue is covered by the local regression model since it allows focusing on the varying spatial characteristics. The local model can explain 87% of house prices function. In order to compare it to the global model a comparison of AIC value is needed. The AIC value which was 18506 decreased to 17777 with the local model. Other than this, the ANOVA test results also refer to the GWR performing better than the global regression model. Based on the structure of the geographically weighted regression, it is possible to see the varying significance level of each variable. So, it can be stated that for every variable the local significance varies over the study area. Not only the significance levels, also the parameter estimates of each variable show varying structure across the study area. The relationships exhibiting a spatial non-stationarity with mappable values give the opportunity to investigate the relationships in a broader perspective. With the detailed maps, the main outcomes are every variable is not significant at every point and have its own effective zone across the study area. Differing adjusted r-square values with respect to the spatial location is the other supporting point of this argument. So, complex spatial patterns of the variables; type of the housing (apartment or detached), floor area, presence of a swimming pool, presence of a car park, distance to highway, distance to CBD, distance to coastline and car ownership ratio in relation to house prices are represented by the GWR approach. The varying spatial pattern of the housing market dynamics are all discussed through the visualised maps.

This study shares the finding with the study of Dökmeci et al. (1996) for Istanbul that "residential preferences are a function of the household's income as well as their preference structure for spatial interaction and the spatial distribution of locational opportunities and amenities". On the other hand, this study is differing from the other studies (Ozus et al., 2007; Alkay, 2008; Keskin, 2008) done with the framework of house prices and some other urban attributes in Istanbul. The main reasons for this are that the method used differs in terms of the approach to the problem, the variables included in the study, the technique used for analysing the relationships and the outcomes.

As a result, limitations of global regression models are overcome by the local modeling technique. It is recognised that in Istanbul, house market dynamics are varying spatially. So, location is playing an important role in the differentiation of house prices in Istanbul. The attributes presenting this spatial non-stationarity structure in this research are from the, housing physical elements, structural elements, urban form elements and socio-economic elements' variable groups. However, except than the urban accessibility attributes other urban form elements representatives such as urban density attributes and urban morphological attributes are not part of the best explanatory model.

5. CONCLUSION

City is a system that is composed of several different determinants. Urban form element as one of the most important components of urban system is directly related to the concept of urban analysis. Urban form elements have potential to tell much about the city. The fact that urban form elements contain clues of different aspects of urban life and marks of the various transformations in the urban history means that it is important to focus on them.

In the literature, more attention was given to the qualitative dimensions rather than the quantitative ones in urban form. For a comprehensive approach in urban analysis, urban form elements should be the key parameters, especially in the quantitative studies. However, making urban form elements measurable is not that easy due to their structural properties.

With a quantitative approach, the relationships between various urban form elements and some economic indicators can be examined in terms of an economic perspective in urban systems. Mostly with the purposes of shaping the dynamics in the city, balancing urban economy and making the effective policies, the relationship between urban form and house price can be one of the possible relationships to analyse. There are several different ways of analysing relationships and interactions between the indicated variables. Starting with the hedonic price analysis, the basic goal was to analyse the correlations quantitatively. With spatial regression analysis, the new goal was to analyse the relationships quantitatively and spatially. One step ahead, the aim became to examine the interactions spatially but also locally. That was the time when the local spatial regression models were on the agenda. There are several different types of the local modeling techniques. One of these methods, a recently introduced one is geographically weighted regression, a spatial local regression modeling technique.

In this study, the analysis of the effects of urban form elements on house prices is examined in order to understand the varying relationships in the city of Istanbul by using a local modeling technique, GWR.

In the literature, the division is generally is made in two groups for regression models as global and local. The local models differ from the global/ traditional ones in the sense of;

1- Focusing on differences over the space rather than the similarities,
2- Being multi-valued rather than one average value,
3- Being spatial rather than being aspatial.

With Istanbul being a vast city with a dispersed settlement pattern and a multi-central structure, for a better interpretation of the interactions within the city, it is necessary to use a local modeling approach rather than a traditional one. As Fotheringham et al., (2000) stated, linear regression models being aspatial methods, cannot be adequate for modeling the spatial processes. It is normal to expect spatial variation in a big and active city such as Istanbul due to the dynamics structured the city for the last seventeen centuries. It is also presumable to notice the varying effect of location context since the urban system has many components/attributes.

GWR as a local modeling technique is differing from the other local models in terms of the level of dealing with spatial heterogeneity and spatial autocorrelation, the level of the explanatory power, accuracy and user-friendly application.

Therefore, the relationship between the independent variable groups such as urban form characteristics, housing physical and socio-economic characteristics and the dependent variable house price in Istanbul is investigated with the help of GWR and according to the findings the hypotheses are tested.

Hypothesis I: Urban form elements have measurable and comparable economic values.

Urban form characteristics are represented by some structural elements, urban density attributes, urban morphological attributes and urban accessibility attributes in this study. According to the final model results, some structural elements and urban accessibility attributes are included in the process of explaining house price differentiation. It can therefore be stated that in Istanbul, across the study area, these elements have measurable economic values. Based on the varying value of these determinants in the model results of the varying house prices prove that urban from elements that are included in the study are comparable as well.

Hypothesis II: The urban form elements affect house prices.

Parallel to the explanations for the hypothesis I, urban form elements being the determinants of the house price model represent the fact that they are effective on house prices in the Istanbul Metropolitan Area. However, it is important to mention that for the city of Istanbul, accessibility attributes such as distances to some important facility destinations play an important role compared to the other urban form attributes such as building coverage, floor area ratio, road area ratio or urban block size.

Hypothesis III: The type and the strength of the relationship will differ based on the varying urban form components.

With respect to the spatial analysis technique that is used in the research, it is possible to talk about the different explanatory power of the relationships based on the varying urban form components. Not only the strength but also the type of the relationship can vary based on the urban form element. These spatially varying patterns of relationships in Istanbul between house prices and urban form components can be followed in the figures in the fourth chapter.

Hypothesis IV: The relationship between the house prices and the urban form elements will vary with respect to location.

The fact of spatial variation that is generally ignored with the traditional regression models is something presumable for the city of Istanbul. The multi-dimensional, multi-functional and multi-central structure, of this big city is a starting point to look for the localities rather than the generalities.

As can seen in the figures in the fourth chapter, the parameter estimates and the significance levels of a variable in relation to house prices differ across the study area. In other words, they are not constant along the study area and they represent a spatial non-stationarity pattern. The spatial variability of the relationships provide opportunity to discuss the variations of the effect of each determinant on house prices with respect to the local dynamics in the city of Istanbul.

The choice of GWR as the model of the study provided an opportunity to present as well as to discuss the differences rather than the similarities within the city. With the application of the model, adding the spatial characteristics of the house for valuing the property was one of the biggest achievements in this study for the city of Istanbul since there is not any research done with this perspective. The multi-dimensional structure of urban dynamics is proven by the help of this method. This can also support the fact that a comprehensive approach is needed in order to interpret the relationships in a correct way, in the metropolitan area of Istanbul. Furthermore, related to the final outcomes, the model gives the opportunity to be aware of the factors that can mislead urban studies in Istanbul. On the other hand, the wider perspective provided by the various representatives of urban attributes of this special city and the greater study borders made the local modeling technique more interesting to work with.

What comes out in Istanbul with this study are worth to analyse. The first thing to mention before going through the interesting findings is that all of the variables are not significantly related to house prices at every location in the study area and they vary spatially. Starting with the housing physical element floor area variable, even though it is significant at every point across the study area, it is not adding much to the value of the property compared to the other variables in the study. The positive relationship between floor area and house prices represents a special pattern around Halic area. When the other variables are kept constant, the floor area criterion is much more effective around this area rather than the other areas in the study. Increasing size in square meters results in increasing price of the property, which makes more sense in the old parts of the city like Halic and historical peninsula rather than the new settlement areas. For the type of the structure the important finding is that the Halic area and the old city centre are again the focal point for apartments. On the contrary, for the detached housing some parts of Kadikoy and Uskudar districts are the hotspots for this parameter.

Furthermore, the other structural elements like the presence of a swimming pool and a car park present an interesting pattern. When we compare two houses having all the same properties, one located by the Bosphorus and the other one by the Marmara coast, the presence of a swimming pool in the house located by the Bosphorus will add more to the price than the other one. The presence of a car park is not showing a significant relationship at every point of the study area and the highest parameter estimates for the presence of a car park is mostly located around Besiktas, Sisli, Beyoglu, Fatih, Uskudar and Kadikoy districts. This finding is reasonable since car parking is a big issue in these districts.

Some of the variables of the urban accessibility group are also part of the spatial house price model. It is interesting that for the city of Istanbul distance to CBD, highway and coastline are playing a more important role compared to the other urban form attributes such as urban density and urban morphological attributes. Except than this general finding, there are some more outcomes of accessibility determinants to zoom in based on these variables. For instance, in the distance to CBD and house price relationship, there is not a one-dimensional situation. It is possible to talk about the varying three general issues across the study area. For the distance to the coastline variable, by using the advantage of the local modeling technique, it can be stated that even along the Bosphorus, house prices will vary based on location. In terms of the distance to the highway variable, one of the important hotspot is the area that is developed as a suburban settlement. Being away from the highway increases the house prices in that area since the settlement is based on this specific preference. Another local scale outcome of the model due to the car ownership ratio, the final map is following the pattern of the luxury housing (high-income) sites' locations in Istanbul. With the help of the model all these settlements' locations can easily be recognised on the outcome maps. Some parts of Cekmekoy and Beykoz on the Asian side and Sariyer and Eyup on the European side are the areas having a positive relationship. The higher house price areas are the spots of high car ownership rates. Less public transportation policies and more new suburban housing developments create the high demand for the car especially for these locations. Vice versa the people who are wealthy enough to have a car mostly prefer to live in these locations. Both cases support the outcome of the spatial local modeling technique.

In general, with this research;

- The spatial characteristics of the house on sale and urban form elements are added to the urban analysis which makes it first study with this perspective in urban planning in Turkey and therefore for Istanbul.
- The multi-dimensional structure of the urban dynamics/interactions was proven with a different aspect in the city of Istanbul.

- The correct interpretations of the relationships that exist in the city were investigated with the help of comprehensive approach and being aware of the misleading facts.
- It was proven that interactions are dynamic and varying spatially in the metropolitan area of Istanbul.

In conclusion, the findings of the study were carried out for the investigation of the spatial variations through the relationship of urban form elements and house prices. This relationship represents the existing dynamics of the urban structure in the city of Istanbul. Setting a bridge between the real estate market and urban planning studies and building up this with a spatial local regression modeling technique as a first study in urban planning in Turkey is a good start for both the academic arena and the private sector. The outcomes of the study will bring out the multi-perspective approach to urban studies, develop the theoretical background for urban form studies and the spatial modeling techniques.

With this study it is possible to;

- Present and discuss the differences in the city of Istanbul rather than the similarities.
- Represent the existing dynamics of the urban structure.
- Link the urban economy dynamics with urban planning studies.
- Develop the qualitative and quantitative background for urban form studies.
- Encourage the use of local modeling techniques rather than the global ones in urban planning.
- Control the house market (house price estimations can be made which is important for the private sector, as well as the academic environment)
- Lead the urban policies and planning studies.

The results and the interpretations of the findings of this research can be helpful for the urban studies/applications as well as to the urban planners, architects, local and governmental authorities, decision makers and the developers. Further studies can be developed for analysing the other spatial interactions within the Istanbul city using the local modeling techniques.

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APPENDICES

APPENDIX A : Maps of Istanbul Metropolitan Area.

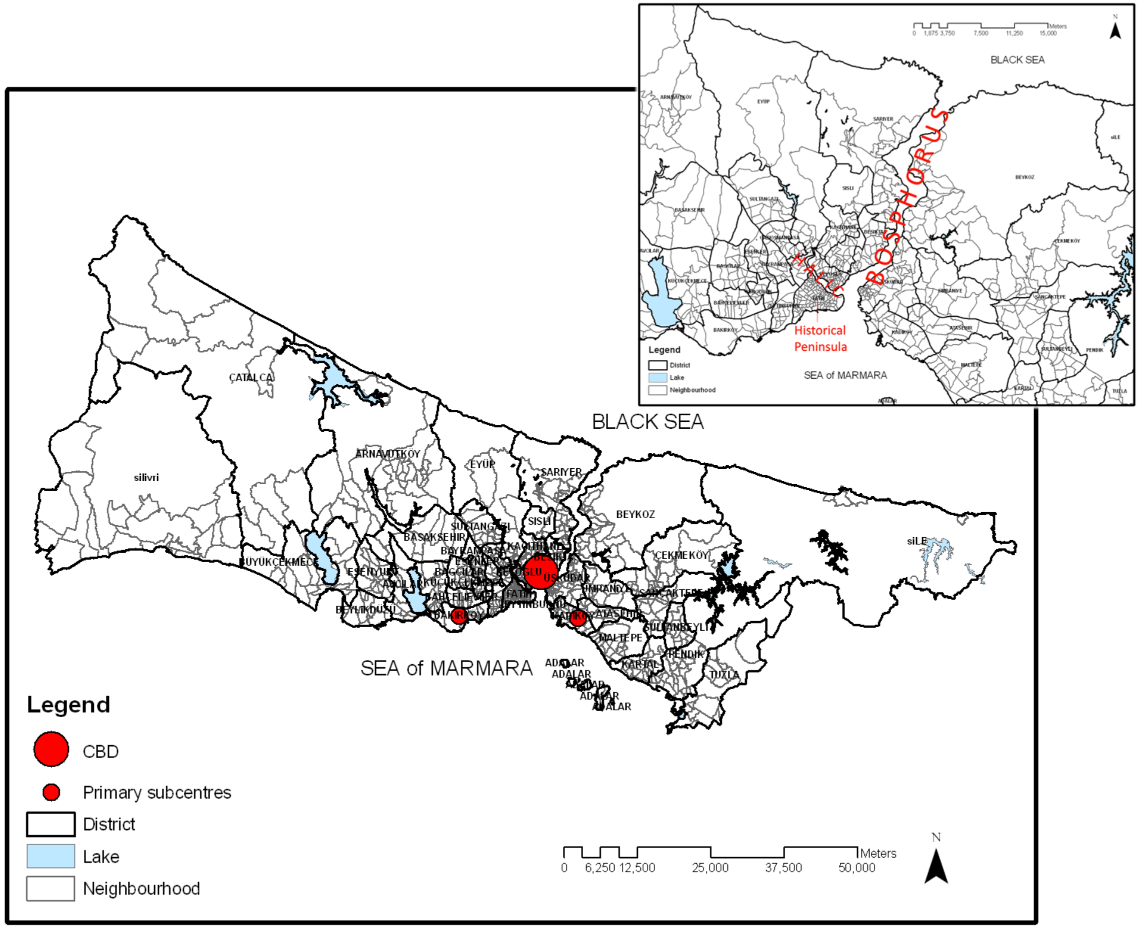


Figure A.1 : Map of Istanbul metropolitan area.

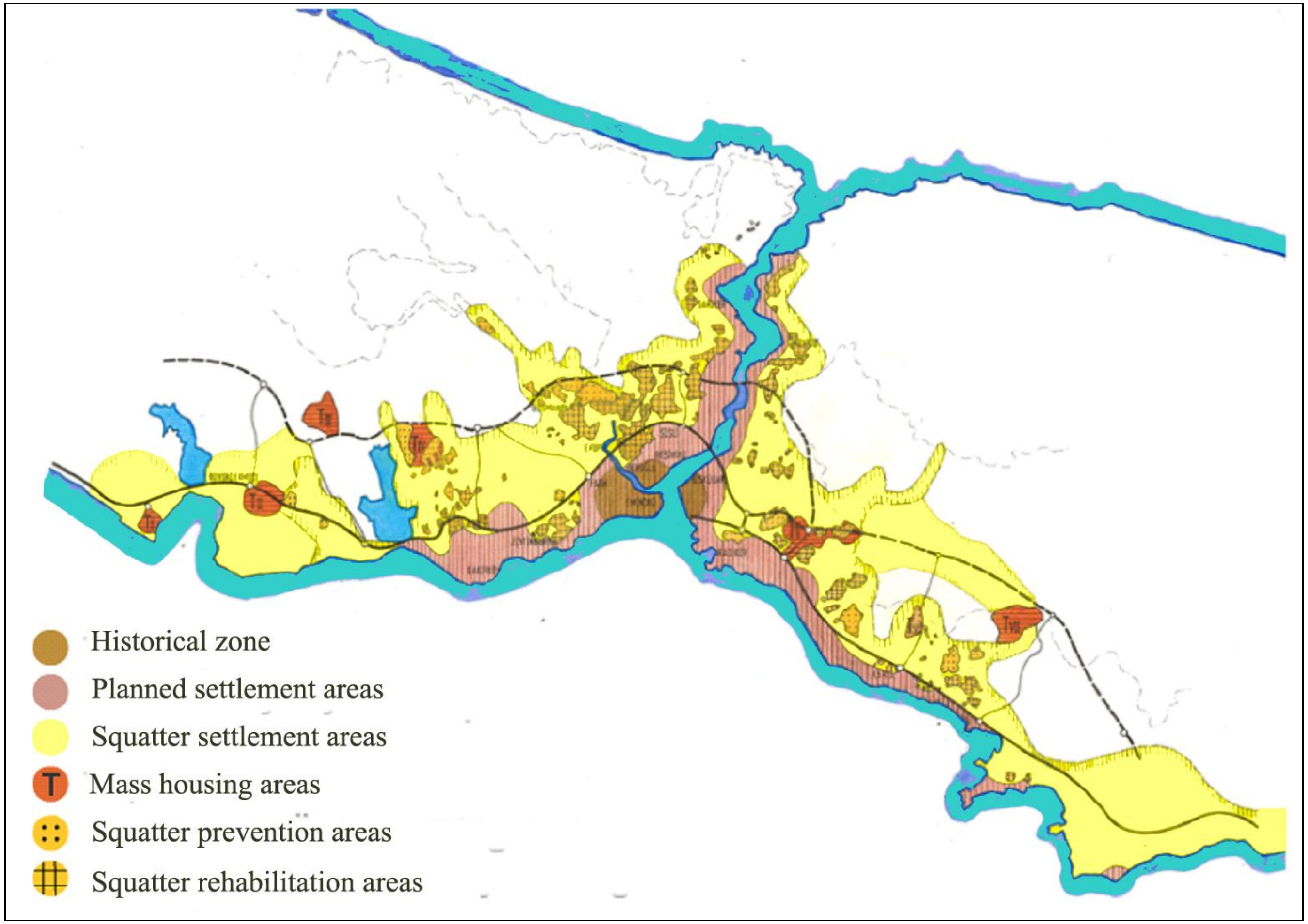


Figure A.2 : Map of settlement areas in Istanbul in 1995 (IMP 2010).

APPENDIX B : Standard Error Estimates of Each Variable.

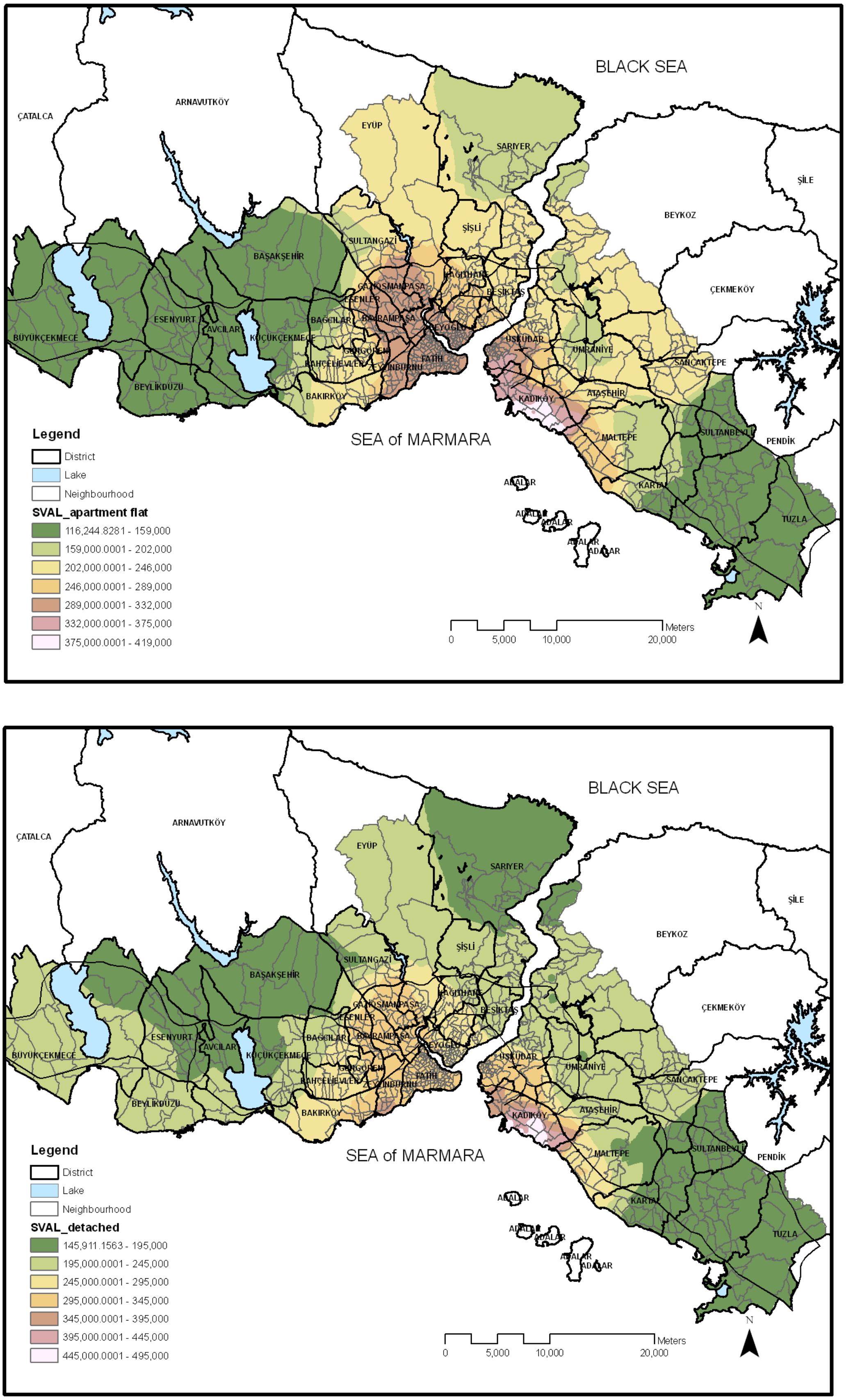


Figure B.1 : Standard error distribution of 'apartment' and 'detached' housing.

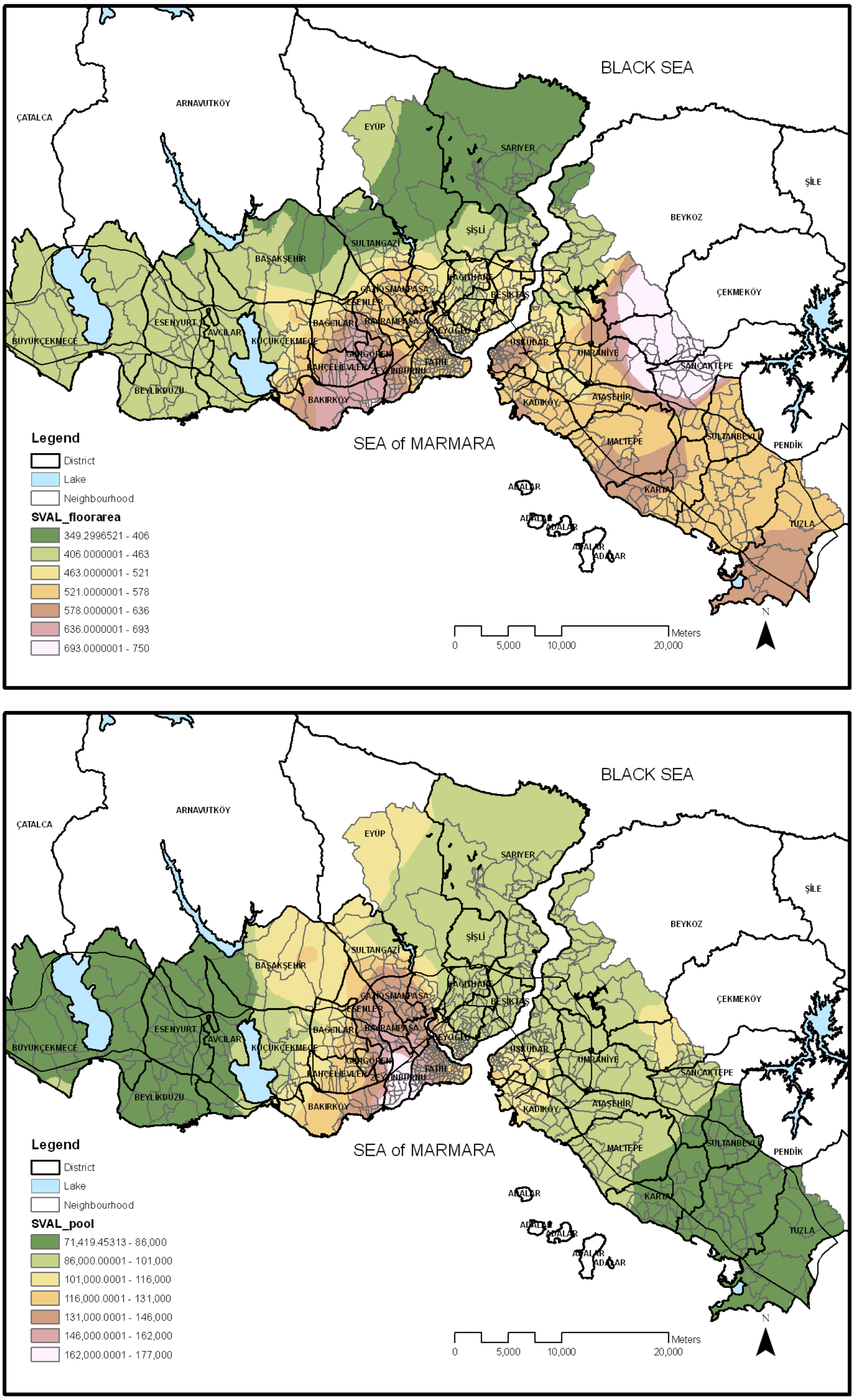


Figure B.2 : Standard error distribution of ‘floor area’ and ‘presence of a swimming pool’.

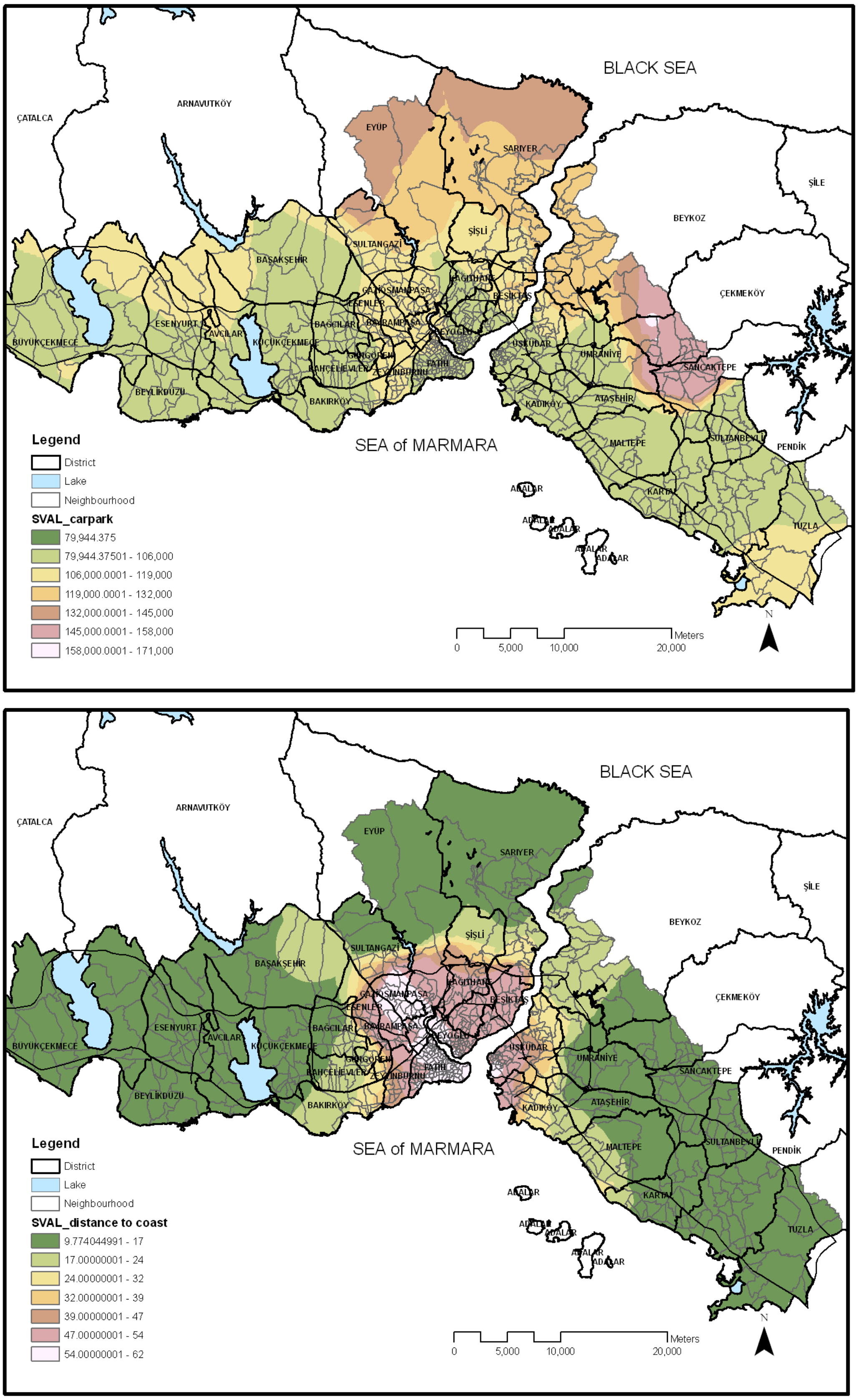
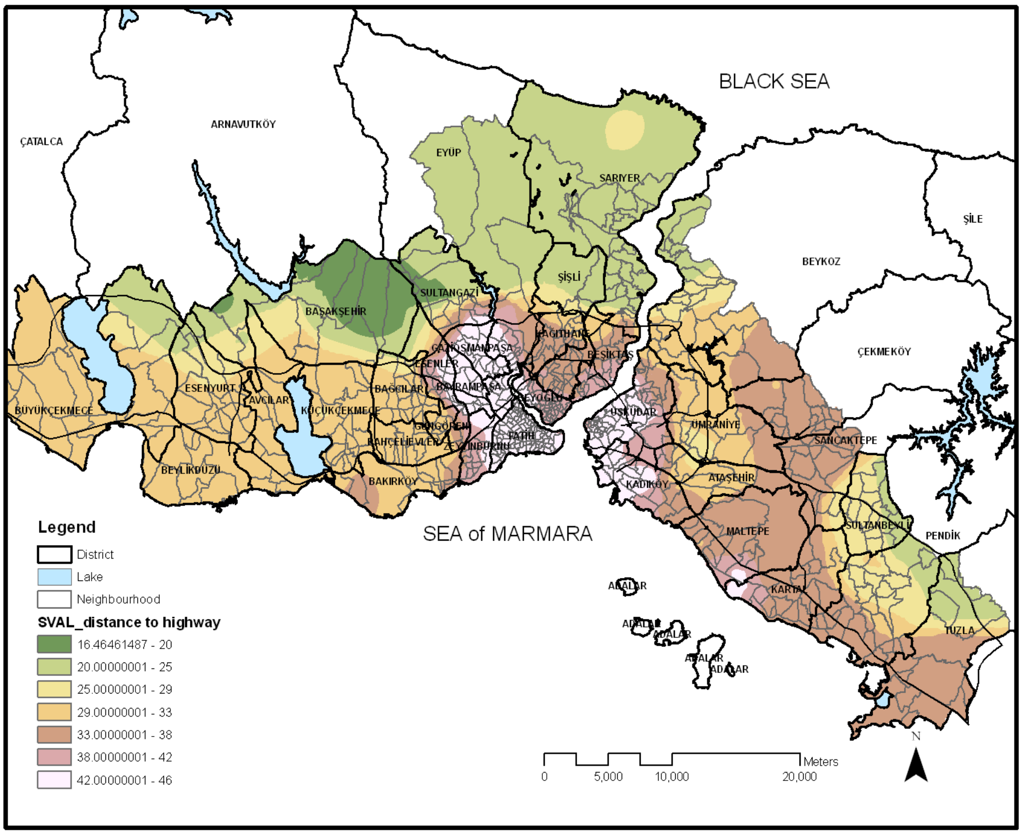


Figure B.3 : Standard error distribution of 'presence of a car park' and 'distance to coast'.



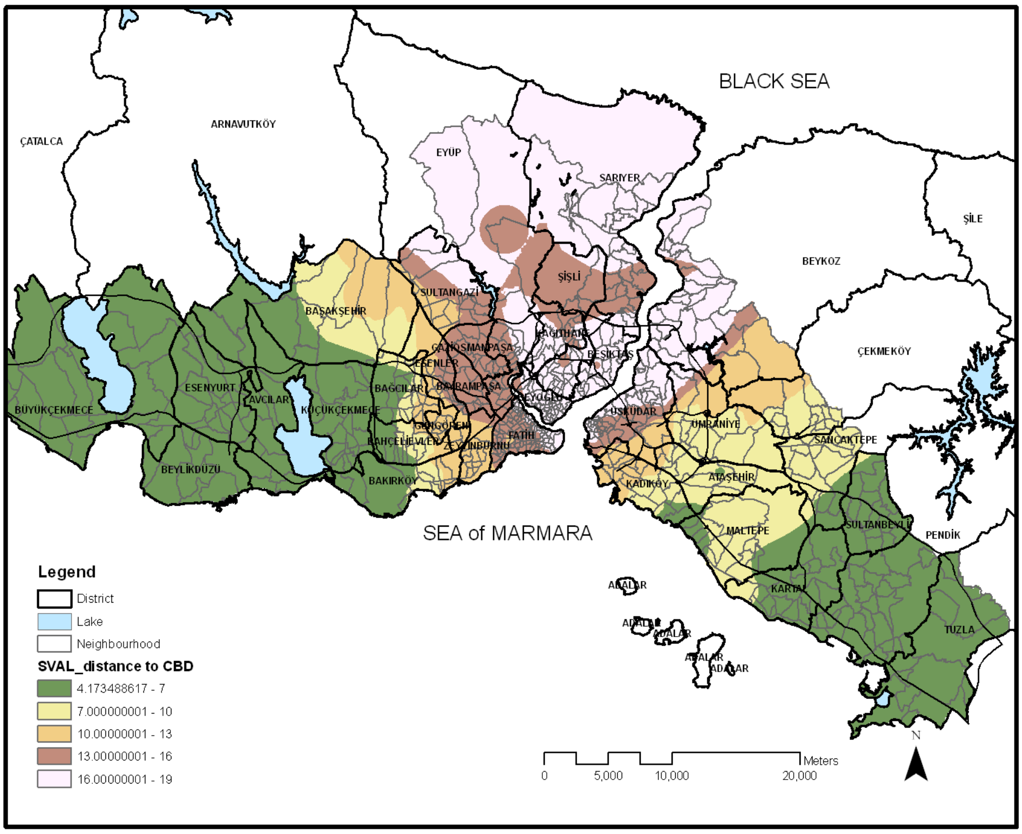


Figure B.4 : Standard error distribution of ‘distance to highway’ and ‘distance to CBD’.

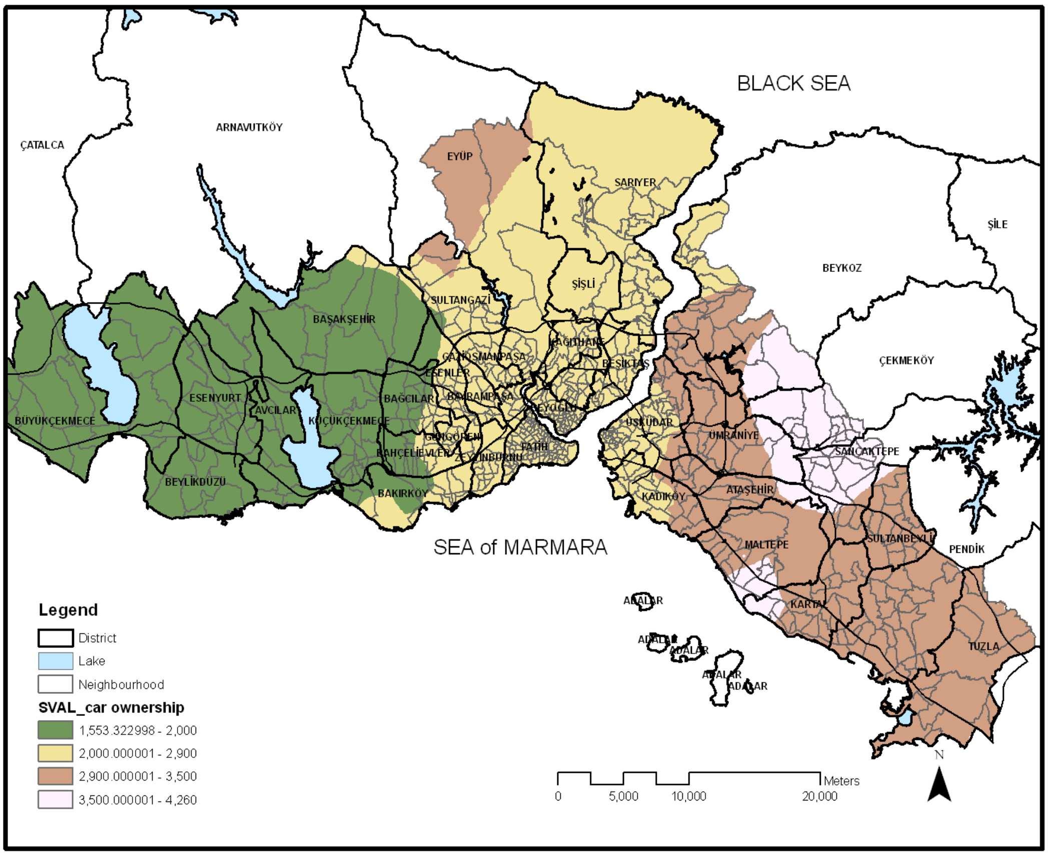


Figure B.5 : Standard error distribution of ‘car ownership’.

APPENDIX C : Distribution of House Prices Across the Study Area.

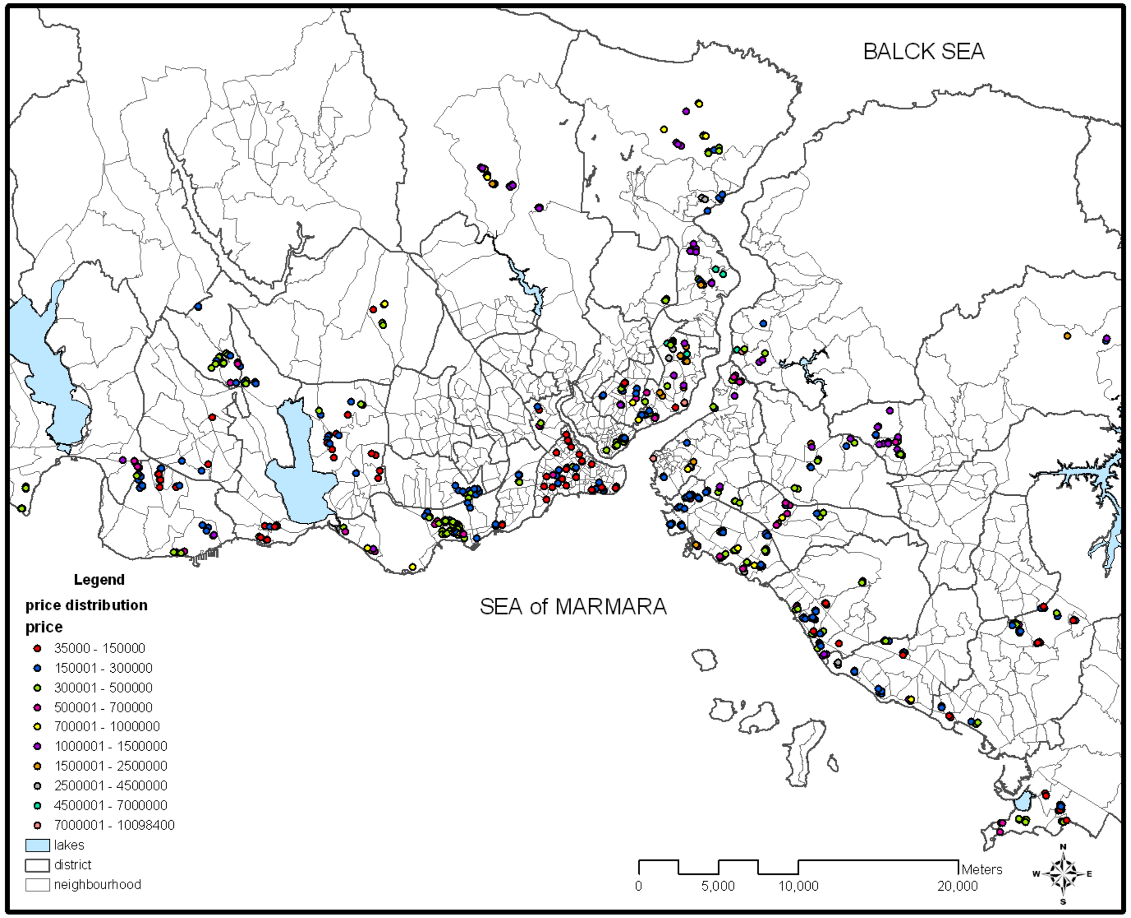


Figure C.1 : Distribution of house prices across the study area.

APPENDIX D : Distribution of Residuals.

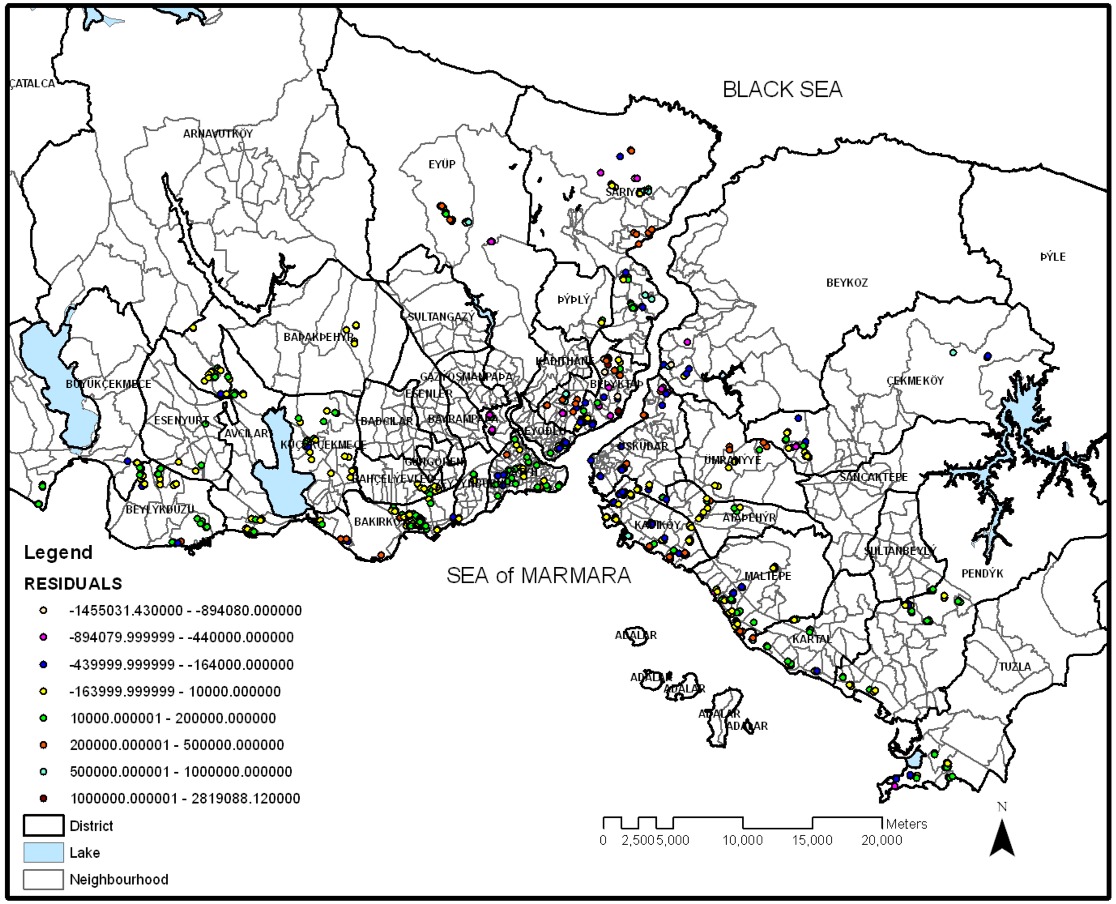


Figure D.1 : Distribution of residuals of the GWR model.

APPENDIX E : Distribution of Standardised Residuals.

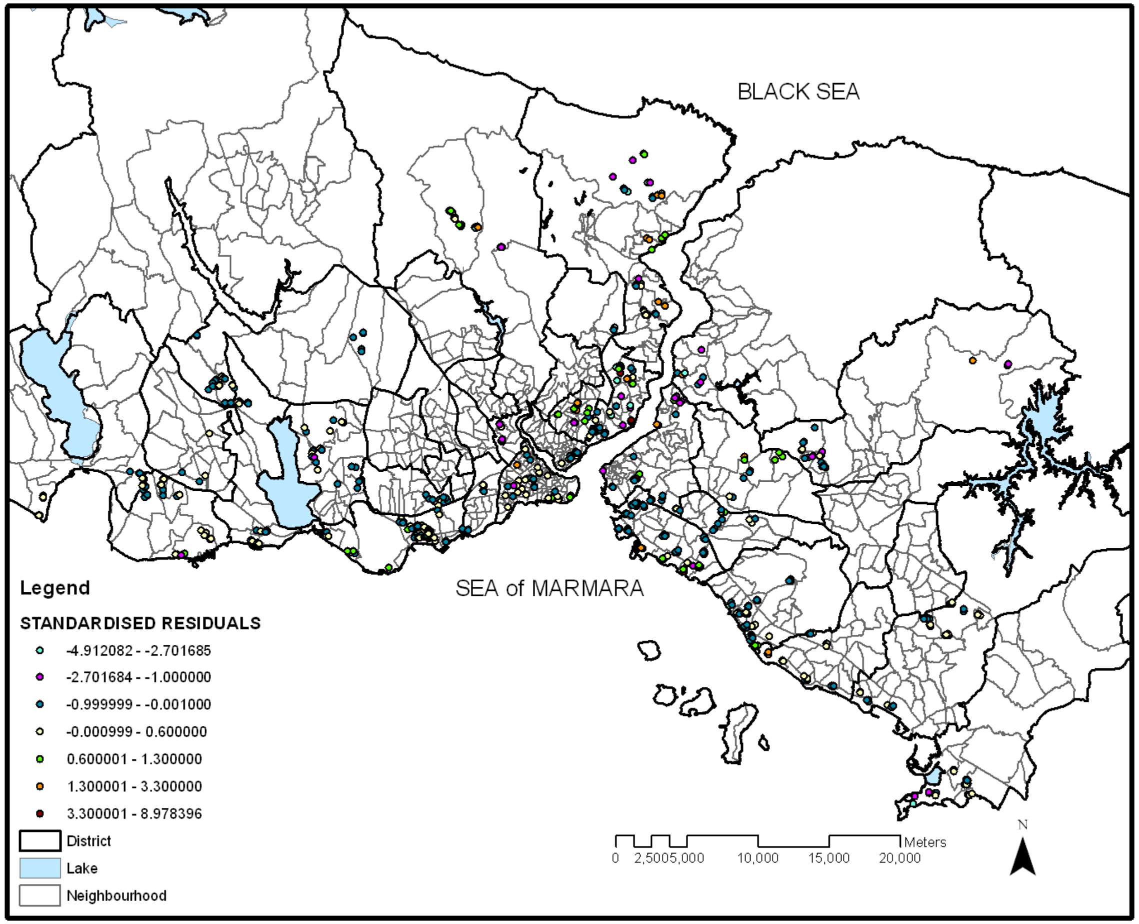


Figure E.1 : Distribution of standardised residuals of the GWR model.

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ITU-Prof. Tulay Kilincaslan - GPS usage (2002)
Istanbul Metropolitan Municipality (2001)

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Published Articles:

Dökmeci, V., Altunbaş, U. & Yazgı, B., 2007, Revitalisation of the main street of a distinguished old neighbourhood in Istanbul, European Planning Studies, 15, 1, p. 153-166.

Dökmeci, V., Yazgı, B. & Ozus, E., 2006, Informal retailing in a global age: the growth of periodic markets in Istanbul 1980-2002, Cities, 23, p. 44-55.

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Published Papers:

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Yazgı, B. & Dökmeci, V., 2009, New Approaches in Urban and Regional Planning, ITU Urban and Regional Planning Department & ITU Urban and Environmental Planning and Research Center, Proceedings Book.

Published Books:

Gülersoy-Zeren, N., Kundak, S., Günay, Z., Demircioğlu, E., Yazgi B., Gönül, D., Beyazıt, E., 2008, Improving Quality and Accreditation in Urban and Regional Planning Education in Turkey, İTU Publications, İstanbul. (ISBN: 978-975-561-323-9)

Published Projects:

IFHP Finland Summer School Report, Development of the New Residential Areas – Design/Workshop Studies, Finland (2004-11)

A Design Workshop for Amasya: Continuity and Change, Yapı, Turkey (2003-2)

Attended Congress/Conference/ Workshop:

Spaces&Flows: International seminar for extraurban studies, University of California Los Angeles, Los Angeles, US (December 2010)

Workshop on Regional and Urban Economics, University of Barcelona, AQR, Barcelona, Spain (September 2010)

Space and Settlement in the Middle Ages: the final frontier Conference, Trinity College, Dublin, Ireland (May 2010)

Conference of Irish Geographers, Sinking or Swimming?, National Univerisity of Ireland, Maynooth, Ireland-selected sessions (May 2010)

GWR (Geographically Weighted Regression) Workshop, NUIM, National Centre for Geocomputation (NCG), Ireland (February 2010)

New Approaches in Urban and Regional Planning, ITU Urban and Regional Planning Department & ITU Urban and Environmental Planning and Research Center, Taskisla, İstanbul (2008)

Real Estate in the Changing World, 14th Annual European Real Estate Society Conference, ERES Conference, CASS Business School, London (2007)

6th International Space-Syntax Symposium, İTÜ Faculty of Architecture, Taşkışla, İstanbul (2007)

Enlargement, Southern Europe and the Mediterranean, 46th Congress of European Regional Science Association, ERSA Congress, Volos (2006)

Built Environment and Information Technologies, 1st International CIB Student Chapters Postgraduate Conference, METU, Ankara (2006)

Making Spaces for the Creative Economy, 41st International Planning Conference, ISOCARP Conference, Bilbao (2005)

IFHP Finland Summer School, Development of the New Residential Areas Design Workshop, Jyvaskyla (2004)

City Architecture in Between Past and the Future, ITU Housing Research and Education Centre, Istanbul (as a lecturer) (2004)

A Design Workshop for Amasya: Continuity and Change, ITU Mimarlık Fakultesi, Amasya (2002)

National Congress Organizations:

Crisis and İstanbul, İstanbul Meetings 2009, TMMOB Chamber of Urban Planners Istanbul Branch İTÜ-YTÜ-MSGSÜ Urban and Planning Departments, Taşkışla, İstanbul (2009)

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Giritlioğlu, C., Ocakçı, M., Eyüpgiller, Gürler-Erbaş, E., Yazgı, B., Kandilli Urban Design Project, ITU & Uskudar Municipality partnership (2008/2009)

Giritlioğlu, C., Ocakçı, M., Yazgı, B., Küçükçekmece District, Istanbul Metropolitan Planning Centre Urban Design Department (2008/2009)

Giritlioğlu, C., Ocakçı, M., Eyüpgiller, K., Oruç, G.D., Yazgı, B., Şalgamcıoğlu, M.E., Erdem, M., Çengelköy Köyiçi Kentsel Sit Alanı Kentsel Tasarım Projesi, İTÜ Döner Sermaye İşletmesi & Üsküdar Belediyesi (2008)

Giritlioğlu, C., Ocakçı, M., Eyüpgiller, K., Oruç, G.D., Gürler-Erbaş, E., Yazgı, B., Beyazıt, E., Kuzguncuk Urban Design Project, ITU & Uskudar Municipality partnership (2007)

National Rapporteur/Jury Membership:

Istanbul Meetings 2008, Round Table 2 Rapporteur, TMMOB Chamber of Urban Planners Istanbul Branch İTÜ-YTÜ-MSGSÜ Urban and Planning Departments, Yıldız, İstanbul (2008)

32. World Urbanism Day Cooloquium, Short Film Competition, Jury Membership, TMMOB Chamber of Urban Planners Istanbul Branch, Istanbul (2008)

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