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The Impact of earthquake risk upon housing prices in the riverbeds: Istanbul Sample

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ABSTRACT

This essay attempts to answer the question to what extent the impact of earthquake risk upon housing prices differs between high-risk and low-risk areas in riverbeds in Istanbul, where the devastation of the 1999 Kocaeli earthquake was quite significant and a new earthquake with a magnitude greater than 7 is considered to be highly probable to take place before 2034. This research, conducted 16 years after the earthquake, rests upon the statistical analysis of the prices of the dwellings located in the visible risky riverbeds commonly found all over Istanbul and of those with the same attributes in the neighboring areas. The geological maps designate nearly 250-meter-long areas lying both to the left-hand and right-hand sides of the thalwegs of the four riverbeds in the center of Istanbul as high-risk zones, and those areas between nearly 250 and 500 meters to the left and right of the thalwegs as low-risk zones. The central question of the article is whether earthquake risk has any impact on housing prices in the riverbed areas in Istanbul, and if it does, what the price differentials are. The prices of dwellings on a number of buildings whose locations are checked on the geological map are examined using compare means analysis and regression analysis. Both types of statistical analysis yield the same results: the earthquake risk has a negative impact on two areas, while one area shows no price changes due to this risk, and the dwellings on one high-risk zone have higher prices. It has been found out that the change in housing prices occurs depending on the housing submarkets in the riverbeds. Moreover, in those areas where the price differentials are found to exist, the impact rate varies. The essay compares the findings of the two types of statistical analysis as well as demonstrating which variables are effective on the homogeneous submarkets formed through cluster analysis. The results of this study can be employed in similar research aiming to calculate the impact of earthquake risk or the change in the risk perception on housing prices.
Keywords: Housing prices, Earthquake, Riverbeds, Istanbul.

1. INTRODUCTION

The 1999 Kocaeli (Marmara) earthquake took 18,000 lives, injured 50,000 people, led to the collapse of 5,000 buildings, damaged 340,000 other buildings, and caused 14,513 businesses to close, leaving 150,000 people unemployed, and forcing 129,338 people to move to prefabricated houses [1].

The North Anatolian fault (NAF) forms a 1500-km-long margin between the Eurasian and Anatolian plateaus. According to the GPS data, the lateral motion is 2-3 centimeters along the fault line per year [2]. Moreover, this motion causes earthquakes along the NAF [3]. The NAF started to break in the twentieth century with the 1939 Erzincan earthquake in Eastern Anatolia, and progressed to the west with a series of earthquakes over a period of 60 years. The last disasters occurred in the Marmara region were the 1999 Kocaeli (M=7.4) and Düzce (M=7.2) earthquakes [4, 5, 6].

After the 1912 Şarköy (M=7.4) and the 1999 Kocaeli earthquakes, the probability of the occurrence of an earthquake or earthquakes with 7 or more magnitude (M) in the next 30 years was calculated to be quite high [7, 8]. According to Parsons' [8] temporal probability account, which included strain transfer between 2004 and 2034 in the Marmara Sea, the possibility of an earthquake which is greater than 7 is 53%±18.

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72% of all the residential buildings in Istanbul had been built before 2001 when no legal regulations concerning earthquake resistant constructions were in force [9]. The Istanbul Earthquake Master Plan (IEMP), which was started in 2002 and completed at the end of 2003, was prepared in consideration of the disaster risk facing the city. According to the IEMP, the abrogation of the Development Exemption Law and the Amendment Developments Plans is one of the most important steps to be taken for risk reduction. The factors such as the lack of settlement and urbanization policy and of the definition of the principles and goals, negatively impacted the implementation of short-term solutions [10].

A number of different methods are employed for the valuation of real property. One of them is the nominal valuation method, according to which the value distribution of real estate entities is estimated in an area where a large number of residential buildings exist [11]. The other method is hedonic price estimation. The model's accuracy concerning predicted market values can be significantly improved by incorporating the spatial relationships in hedonic equations, and this can also reduce estimation errors for submarkets [12, 13].

Most researchers now agree that a functional housing market operates as a series of linked, quasi-independent submarkets[14, 15, 16]. The identification of the submarkets can be done by grouping the administrative boundaries, employing the definition of experts or classification by statistical methods such as cluster analysis [17, 18, 19]. Keskin and Watkins state "agent-based methods for delineating submarket boundaries might be used with a degree of confidence by real estate analysts and planners in market contexts where rich micro-datasets are not readily available" [20]. Straszheim [21] argues that the housing market is a series of single markets (or submarkets) for which different hedonic functions can be estimated. If housing prices and trends tend to vary between different regions, it is very difficult to reach satisfactory results for the variable of location using hedonic analysis [22].

On the other hand, various studies have been conducted so far to determine the parameters affecting the house prices. The results of the study by Keskin (2008) reveal that housing prices are affected by these factors: living area size, being in a low storey building, being in a secured site (with swimming pool and garage), and age of the building [23]. In addition to these determinants, the length of time the inhabitants have lived in Istanbul, the average income of the household, neighborhoods satisfaction and earthquake risk of the area have effects on the residential prices in Istanbul. The prices of the houses vary according to the floors in the apartment. The floor variable has a non-linear effect on prices. The price of high floors increases but after a certain height prices fall [24].

Although several studies have been conducted to identify environmental impacts on housing prices, there are few studies on the impact of earthquake risks. Moreover, the existing studies used different methods to determine the effects of earthquake risk on the housing market, and produced somewhat different results [25]. Palm [26] conducted a group of studies on housing markets and earthquake risks in California. She investigated the effectiveness of mandated disclosure legislation there, according to which, real estate agents should inform all home buyers about the seismic risk related to the location of a house. Her study showed that people paid little attention to earthquake hazards. Another study by Murdoch, Singh and Thayer [27] showed the effect of the Loma Prieta earthquake on the housing prices. They observed a 2% reduction in the housing prices.

No evidence of a significant impact of soil type on housing prices has been found. However, it is possible that there is a non-linear relationship between soil type and housing prices. Another model that includes square of soil type is also estimated in order to find out any non-linear relationship. These findings indicate that housing values decline at low levels of soil type and that as the quality of soil increases, housing values increase significantly controlling for the distance from the fault lines and age of dwellings, distance from the central business district (CBD) and location of the neighborhood [25].

The earthquake of August 17, 1999 is a movement of ground that occurs as a result of movements at the western end of the North Anatolian Fault. The plate, in which Central Anatolia was located, moved 2.5 m westward along a 160 km long line. It was observed that this lateral deformation caused up to four meters of deformations in Gölcük. It is known that the ruptures at 16 km depth cause various geomorphological deformations on the earth crust surface. As a result of these deformations, the structures on the earth are damaged. In Kocaeli province, 31,625 houses were heavy, 29,068 houses were medium and 31,751 houses were lightly damaged. A total of 19,043 houses were heavy, 12,200 houses were medium and 18,712 houses were lightly damaged in Sakarya. A total of 9,462 houses were heavy, 7,917 houses were medium, 12,685 houses were slightly damaged in Yalova. In Bolu province, a total of 3,095 houses were heavy, 4,180 houses were medium and 3,303 houses were slightly damaged. In Bursa province, 63 houses are heavy, 434 houses are medium, 940 houses have suffered slight damage. Only the central district of Eskişehir was affected by the Izmit earthquake. In the central district, 80 heavy damages, 96 moderate damages and 314 light damages have occurred. In the province of Istanbul, a total of 3,073 houses were heavy, 13,339 houses were medium and 12,455 houses were slightly damaged [28]. There is no report on the damages of the houses located on the river banks in Istanbul. However, most of the damages in Istanbul have been occurred in Avcilar, Büyükçekmece, Bağcılar and Küçükçekmece. There are river beds and filling areas in these regions. These river beds appear as alluvium fields in geological maps and are indicated as first degree risky regions in earthquake maps. Considering this fact, it was wanted to investigate whether there is a significant difference in the prices of houses in risky stream beds compared to the houses in other regions.

This study attempts to answer the question to what extent the impact of earthquake risk on housing prices varies in the visible and risky riverbed areas in Istanbul. The earlier studies on the subject indicate that research on the basis of housing submarkets yield more accurate results. For this reason, each riverbed and the areas lying 500 meters to the left-hand and right-hand sides of them have been defined as a submarket. The riverbed areas in question are Ayamama, Tavukçu, Alibeyköy and Kurbağalıdere. Moreover, it has been examined whether it is possible to obtain more homogeneous schemes for these areas through cluster analysis. Thus, the Ayamama riverbed area has been divided into schemes. After surveying the data concerning the housing prices for buildings in high-risk alluvial areas and those in less risky neighboring areas (whose locations are checked on the geological map) in order to meet the statistical assumptions, the price differentials have been examined using compare means analysis and regression analysis. Both types of statistical analysis yield the same results: the earthquake risk has a negative impact on two regions (Ayamama and Kurbağalıdere), while a region shows no price changes due to this risk (Tavukçu), and the dwellings in the high-risk zone have higher prices than those in the low-risk area in the fourth case (Alibeyköy). Earthquake risk has a regionally variable impact upon housing prices.

It has been found out that the variables impacting upon housing prices in each housing submarket are different. Moreover, the accuracy of the results of the independent samples t-tests depends on the size of the sample.

The result of this study will be able to attract the attention of the banking sector, which gives home loans and of the insurance sector. In the houses located in risky areas, less credit will be given by banks and insurance costs will be raised. In addition, the regulation of the amount of property tax in these areas may also be brought into the agenda. People who buy or rent a house may have risky area perceptions as a result of the pricing of the banking sector. Thus; real estate valuation companies can use the risky field information as a variable in their evaluations. insurance sector, even if they do not know whether the house they are interested in is in a risky area.

2. MATERIALS AND METHODS

2.1. Study Design

Four maps which were prepared by the MTA (General Directorate of Mineral Research and Exploration) with a 1/100000 scale were used to detect the areas under earthquake risk. These are Istanbul F21; F22; G21; G22 sheets. In order to find out whether information on earthquake risk has an impact on the prices, four rivers which can represent all of Istanbul were selected from these sheets (Figure 1). These riverbed areas are shown as high-risk zones on MTA sheet legend and are located in regions where settlement density is high. Moreover, all the people are undoubtedly aware of the existence of these running rivers. The selected rivers are Kurbağalı on the Anatolian side and the Alibeyköy, Tavukçu, and Ayamama rivers on the European side.

According to the records of Istanbul metropolitan municipality, there are 67 streams totaling 473,5 km in Istanbul. Only 12 km of the streams, which have been rehabilitated in the 240 km section, continue to be rehabilitated. The selected Ayamama, Alibeyköy, Tavukçu and Kurbağalı creek beds are the most affected by floods and flood areas. According to the information in the December 2017 edition of Tech Istanbul magazine prepared by Istanbul Metropolitan Municipality, it was stated that 1 million 528 thousand 782 dwellings were located within the borders of Istanbul. There is no information on the number of dwellings found in the stream beds in Istanbul. To examine these stream beds regions in terms of quality of life; when we look at the "Quality of Life Research in Istanbul" conducted by Istanbul University at 39 district level in Istanbul; the index score of the district of Küçükçekmece where Ayamama stream passes was 0.114. This score; it was 0.053 for the district of Bahçelievler where the Tavukçu stream was crossed, 0.183 for the district of Eyüp where the Alibeyköy stream passes, and 0.886 for the district of Kadıköy where the Kurbağalı stream passes.

The area carrying the risk of loss of life and property due to the soil structure or the structuring has defined as the risky area in law with the number 6306. When we look at the places where the risky area is declared to the law, it is seen that a large part of the Alibeyköy stream and some parts of the Kurbağalı stream are taken within the risky area. According to the information obtained from the Istanbul environmental council, the total length of Ayamama Creek is 42 km. As a result of the flooding of this stream in 2009, 31 people died, hundreds of workplaces and vehicles remained under water. The Tavukçu stream is 50 kilometers long. In 2004, about 100 workplaces and basement floors in Şirinevler were flooded. Tavukçu stream which was said to have been rehabilitated in 2010 overflowed in July 2014 again and the houses in Bağcılar Fatih Sultan neighborhood were flooded. Alibeyköy stream is 50 kilometers long. As a result of the overflowing of the stream in 2004, the streets in Karadolap were flooded. Kurbağalı stream; with its length of 67680 meters, it is the longest stream of Kadıköy area. The 15860 meters have been rehabilitated. As a result of the overflow of the stream in 2010, the main artery and the intermediate road flooded, dozens of vehicles in places found two meters in the flood. A municipal worker fell into the water and disappeared. In 2014, after about 40 minutes of torrential rainfall, the river overflowed. The streets were flooded in Ataşehir and Kadıköy. As a result of the overflow of Kurbağalı stream in 2015, the houses and businesses near the stream were flooded. Overflowing water from Kurbağalı stream reached the E-5 Highway. Because of the water, traffic at E-5 came to a halt at times.

The width of the river areas which are designated as alluvial on MTA maps are about 250 meters away to the right and to the left of the thalweg line. The buildings which are located in a 500-meter wide strip along the riverbed area (up to 250 meters away to the right and to the left of the thalweg line) were taken to be under high risk. The buildings in the zones adjacent to the high-risk areas were considered to be under low risk.

The alluvial risk areas of these rivers were digitized from 1/100000 scaled MTA maps by NETCAD software. Then, these data were transferred to Google Earth and they were identified as high-risk areas. The digitized riverbeds and lines overlapped with the river lines seen on Google Earth. The locations of residential buildings in the sample were chosen from the alluvial lines as seen on Google Earth.

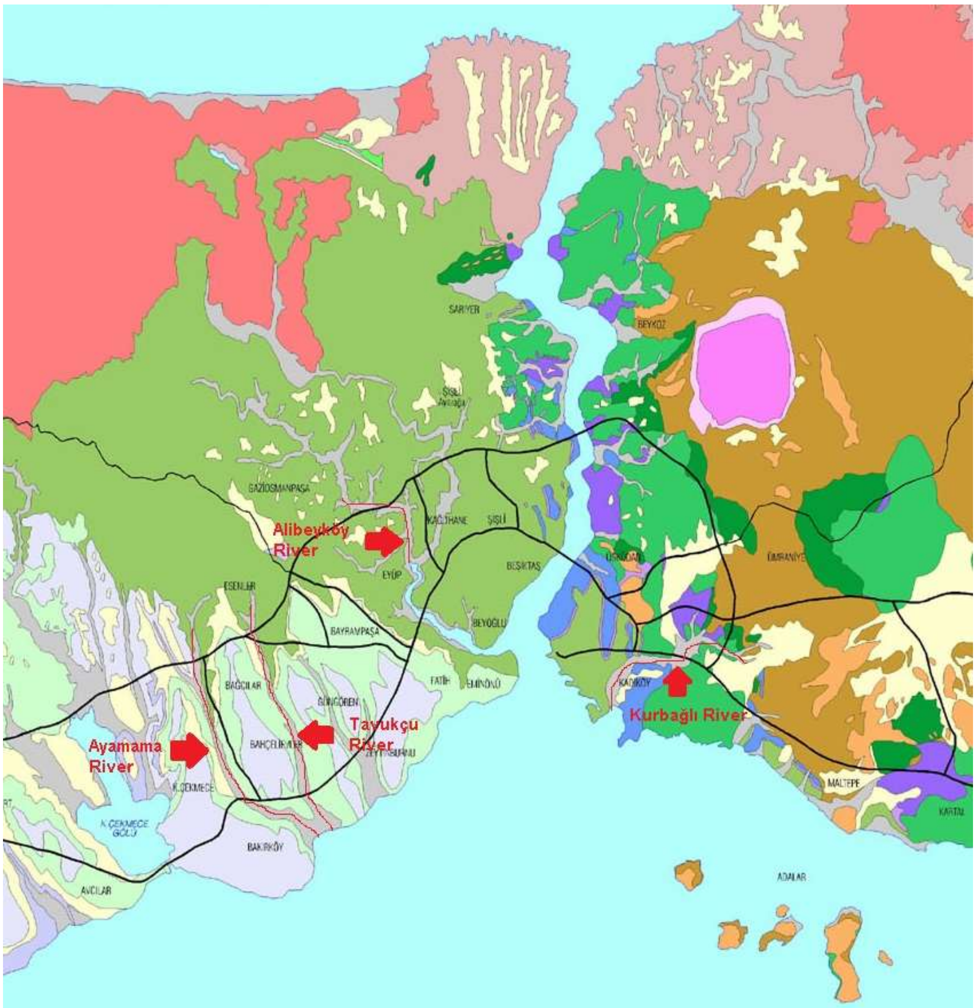

Figure 1. Selected Four Rivers (geological map of Istanbul with scale 1/100 000)

2.2. Data Collection

The prices of the dwellings in the high-risk areas and in the neighboring areas (low-risk areas) were obtained from internet web sites covering real estate agencies and other sales sites because there was no regular information about valuation for these particular areas. All of the dwellings available for sale were taken as the sample.

The data set was collected in such a way that the sample set was homogeneous. The data of the prices of the dwellings for sale with similar attributes were collected to ensure homogeneity in the sample. Housing prices in the collected sample belong to the dwellings with three or four rooms. Those apartments on the ground or top floors were not included in the sample. Data were collected in July and August 2015.

Empirical results suggest that while a residential property of a larger size, higher floor level, and better dwellingview commands a higher transaction price, a dwelling that is closer to the mass transit railway

station also commands a price premium [24]. When dividing the floors into categories, we find the coefficients for lower floor categories to be more negative than the floors in higher categories. Thus, the higher-floor premium appears to increase monotonically from lower to higher floors [29]. On the basis of these studies, the items to be considered in the data are as follows: price, stocks
area, age, the floor on which the apartment locates (floor level), the total number of floors in the building (the height of a building as measured by total number of floors) in ratio scale and number of rooms, the presence of elevator, part of a housing complex or block and earthquake risk information in nominal scale about the building. The buildings which were located in a 500-meter-wide strip along the river area (up to 250 meters away to the right and to the left of the thalweg line) were considered risky. The buildings on the zones adjacent to the high-risk areas were designated as low-risk.

The total number of the dwellings about which data have been obtained is 820 and their distribution by regions is as follows: 165 in Alibeyköy, 310 in Ayamama, 182 in Tavukçu and 163 in Kurbağalıdere. 331 dwellings of them were located in the areas with high earthquake risk, while 489 of them were in the low-risk areas.

2.3. Data Management

In this study, statistical information was obtained by using the IBM SPSS Statistics 21 program.

Missing values and normality tests

The data point about the floor level of only one dwelling in the Tavukçu riverbed area was missing. Since it would not have any impact on the entire data set, that dwelling was taken out of the research. In the Alibeyköy riverbed area, the logarithmic transformation was applied to the variable of "the age of the dwelling," while the square root transformation was applied to the variable "the floor level," thus obtaining a normal distribution for the variables.

In the Ayamama riverbed area, the square root transformation was applied to both variables ("the age of the dwelling" and "the floor level"). Since the three transformation operations did not yield a normal distribution for the age of the dwelling in this area, this variable was left out.

In the Kurbağalıdere riverbed area, the square root transformation was applied to the price variable. In the Tavukçu riverbed area, the inverse transformation was applied to the variables of price and the number of floors, while the logarithmic transformation was applied to the variable of "the age of the dwelling."

2.4. Analysis of Univariate Outliers

Those variables with a z-score greater than 3.29 ($N<1000$, $p<0.001$ and two-tailed tests) are considered to be univariate outliers [30].

In the Alibeyköy riverbed area, the z-score was greater than 3.29 for one case concerning the price variable and for two cases concerning the variable of the floor level. In the Kurbağalıdere riverbed area, the z-score was greater than 3.29 for one case concerning the number of floors, and in the Tavukçu riverbed area, the same was true. Since these data values were insignificant for the the relevant variables, they were deleted.

For the nominal scale data, a variable containing a category with 10% of the data was deleted [30]. The variable of the housing complex in Alibeyköy contained less than 10% of the data, so did the variables of the housing complex and the presence of elevator in Ayamama. The same was true for one group of the variable of the housing complex in Kurbağalıdere. All these were deleted.

2.5. Analysis of Multivariate Outliers

Multivariate outliers were identified with the use of Mahalanobis distance, $p<0.001$ Ӽ2 [30]. Only two data points in Alibeyköy were found out to be multivariate outliers, and they were deleted because they appeared not to be properly part of the population.

2.6. Bilinearity and Covariance

The bilinearity of the variables was examined by checking double scatter plots [30]. The results showed that the bilinearity and covarience conditions were satisfied to a considerable degree for the transformations conducted.

2.7. Multicollinearity and Singularity

For the multicollinearity and singularity assumptions to hold, VIF values must be less than 10 and tolerance values must be greater than 0.2 [30].

In Alibeyköy, Ayamama, and Tavukçu, since the variables of the size and room numbers of the dwelling were multicollinear, the variable of room numbers was deleted.

2.8. Cluster Analysis

In order to find out whether the data was homogenous or whether it was possible to construct submarkets from the available data, a cluster analysis was conducted both on the data points and the variables. First, the dendrograms which were obtained by the hierarchical cluster analysis using the single linkage method were examined and it was found how many clusters could be used to divide the available data. In this analysis, the closest proximity and the Euclidean distance measures were taken as the basis. Then, a non-hierarchical cluster analysis using Mac Quenn's k-means method was conducted to cluster the available data [31].

In order for the variables not to be impacted by the difference amongst the variance ratios, the cluster analysis was conducted with the standardized values. The analysis revealed that only the Ayamama area could be divided into two submarkets.

Moreover, the examination of the dendrograms in the cluster analysis on the variables demonstrated that the size and price variables constituted a single group with very close values. Then, a variable for the "price/m2" was introduced by dividing the price variable into the area. Univariate outliers for the "price/m2" variable were checked, and two data points in Ayamama and one data point in Tavukçu were deleted. Then, the normality assumption was checked for the "price/m2" variable and it was found that the assumption was violated only in the Tavukçu area. It was also calculated that the normality assumption was met when the inverse transformation was conducted. Thus, this variable was used in the compare means tests.

2.9. Descriptive Statistics

Tables 1-5 show the descriptive statistics of the data which were processed to be analyzed using compare means tests and regression analysis.

Table 1. Descriptive Statistics on the First Submarket in Ayamama.

		Price m^2	Price TL	Area m^2	SQRT building age year	SQRT floor	Earthquake risk
N	Valid	99	99	99	99	99	99
	Missing	0	0	0	0	0	0
Mean		2494,1036	281727,27	113,83	,7227	1,6938	1,51
Std. Deviation		359,68945	32478,821	9,879	1,09403	,22550	,503
Skewness		-,246	-,931	,216	1,671	-,001	-,021
Std. Error of Skewness		,243	,243	,243	,243	,243	,243
Kurtosis		2,669	,578	,262	2,987	-1,326	-2,041
Std. Error of Kurtosis		,481	,481	,481	,481	,481	,481
Minimum		1414,29	190000	90	,00	1,41	1
Maximum		3858,70	355000	140	5,10	2,00	2

Table 2 Descriptive Statistics on the Second Submarket in Ayamama

		Price m2	Price TL	Area m2	SQRT Building age year	SQRT floor	Earthquake risk
N	Valid	210	210	210	210	210	210
	Missing	0	0	0	0	0	0
Mean		2344,3780	217866,67	93,57	1,9376	1,7059	1,53
Std. Deviation		295,85110	22702,388	8,416	1,32253	,22781	,500
Skewness		-,074	,368	,550	,225	,054	-,135
Std. Error of Skewness		,168	,168	,168	,168	,168	,168
Kurtosis		,668	-,039	2,634	-,878	-1,053	-2,001
Std. Error of Kurtosis		,334	,334	,334	,334	,334	,334
Minimum		1363,64	150000	65	,00	1,41	1
Maximum		3070,59	270000	130	5,00	2,24	2

Table 3 Descriptive Statistics of the Tavukçu Riverbed Area

		INV price m^2	INV Price TL	Area m^2	Building age year	LG10 floor	INV no. of floors	Presence of elevator	Housing complex	Earthquake risk
N	Valid	178	178	178	178	178	178	178	178	178
	Missing	0	0	0	0	0	0	0	0	0
Mean		,00038482	,0000	108,42	12,73	,4635	,2135	1,43	1,15	1,51
Std. Deviation		,000131142	,00000	17,322	12,255	,15446	,06690	,497	,360	,501
Skewness		,088	,146	,249	,252	,707	,100	,274	1,959	-,023
Std. Error of Skewness		,182	,182	,182	,182	,182	,182	,182	,182	,182
Kurtosis		,597	,578	-,865	-1,544	,055	,019	-1,947	1,857	-2,022
Std. Error of Kurtosis		,362	,362	,362	,362	,362	,362	,362	,362	,362
Minimum		,000117	,00	80	0	,30	,06	1	1	1
Maximum		,000799	,00	152	35	,95	,33	2	2	2

Table 4 Descriptive Statistics of the Alibeyköy Riverbed Area

		Price m^2	Price TL	Area m^2	LG10 Building age (years)	SQRT floor	Number of floors	Presence of elevator	Earthquake risk
N	Valid	160	160	160	160	160	160	160	160
	Missing	0	0	0	0	0	0	0	0
Mean		3033,0020	289371,88	95,99	,1604	1,8176	5,47	1,88	1,26
Std. Deviation		382,53082	45297,002	13,803	,30754	,33115	1,689	,325	,441
Skewness		-,165	,723	,951	1,604	,589	,851	-2,379	1,090
Std. Error of Skewness		,192	,192	,192	,192	,192	,192	,192	,192
Kurtosis		-,079	,492	,107	,927	,129	1,075	3,708	-,823
Std. Error of Kurtosis		,381	,381	,381	,381	,381	,381	,381	,381
Minimum		2035,71	205000	68	,00	1,41	2	1	1
Maximum		4000,00	425000	140	,90	2,83	10	2	2

Table 5 Descriptive Statistics of the Kurbağalıder Riverbed Area

		Price m^2	SQRT priceTL	Area m^2	Building age (years)	floor	Number of floors	Number of rooms	Presence of elevator	Earthquake risk
N	Valid	160	160	160	160	160	160	160	160	160
	Missing	0	0	0	0	0	0	0	0	0
Mean		4954,8473	746,8101	115,84	16,94	3,47	6,00	3,64	1,56	1,21
Std. Deviation		1283,50131	139,22382	27,387	11,850	1,678	2,515	,482	,498	,410
Skewness		,553	,723	,266	-,214	1,251	,972	-,577	-,254	1,419
Std. Error of Skewness		,192	,192	,192	,192	,192	,192	,192	,192	,192
Kurtosis		,061	,127	-,373	-1,363	1,124	,061	-1,688	-1,960	,013
Std. Error of Kurtosis		,381	,381	,381	,381	,381	,381	,381	,381	,381
Minimum		2041,67	494,97	65	0	1	1	3	1	1
Maximum		9166,67	1140,18	200	43	9	12	4	2	2

2.10. Examination of Sample Size

In each submarket, the compare means tests were conducted on the samples to calculate the price differences. The calculation operation for the first submarket in Ayamama was given below. The results for the other submarkets for which the same operation was performed can be seen in Table 6.

Examination of sample size in the Ayamama River's first group:

1. Level of significance α=0.05 (type I error),
2. Test power β=0.90 (type II error),
3. Using the standard deviation calculated from the sample of the first group by the Ayamama River,

(424.73796 for the high-risk areas and 267.05466 for the low-risk areas),

The minimum difference that could arise was calculated using the formula given below [32]:

$$\sigma^2 = \frac{\sigma_1^2+\sigma_2^2}{2} \qquad (1)$$

In the formula (1);

σ^2 : The common variance of the two groups

σ_1^2 : The variance of the first group

σ_2^2 : The variance of the second group

$$(\mu_1 - \mu_2)^2 = \frac{2*\sigma^2(Z_{\alpha/2}+Z_\beta)^2}{n} \qquad (2)$$

In the formula (2);

σ^2: The common variance of the two groups

$Z_{\alpha/2}$, Z_β: The probability value of the standard normal distribution.

μ_1, μ_2: Means to compare

When dealing with the two categories composed by the data in low-risk and high-risk areas, the sample size of the category with the fewer data points was taken into consideration, the minimum price that could be obtained by the test:

$$(\mu_1 - \mu_2)^2 = \frac{2 * 125860.1781 * (1,96 + 1,282)^2}{49} = 232.37\ TL$$

In conclusion, significant differences greater than 232.37 TL can be detected at level of significance α=0.05 and test power β=0.90 by mass of the obtained sample.

Table 6 Minimum Price Differences That Could Be Obtained on the Basis of the Available Samples

River	Sample size		Standart deviation		Minimum price difference
	Less risk	More risk	Less risk	More risk	TL
Ayamama first group	49	50	267.05	424.74	232.37
Ayamama second group	98	112	274.90	283.24	129.26
Tavukçu	88	90	1798.12	1480.96	805.06
Alibeyköy	118	42	359.57	410.16	272.87
Kurbağalıdere	126	34	1255.67	1274.93	994.94

2.11. Compare Means Tests

Analysis of the impact of location upon housing prices in the high-risk riverbed areas in Istanbul

This study examined whether there was a significant difference in the housing prices in the alluvial areas (high-risk areas) and in the areas adjacent to the alluvial ones (low-risk areas). Our case was about the comparison of these two data sets, therefore the appropriate statistical tests comparing the two groups were used. The variables of the data sets were independent of each other and included continuous numerical data. According to these requirements, this study was conducted with an independent sample student t test (parametric test) if the assumptions were satisfied and with Mann Whitney U test (non-parametric test) if the assumptions were not satisfied [33].

Hypothesis

H_0: There are no significant differences between the housing prices in the alluvial areas (high-risk areas) and in the areas adjacent to the alluvial ones (low-risk areas).

H_1: There are significant differences between the housing prices in the alluvial areas (high-risk areas) and in areas adjacent to the alluvial ones (low-risk areas).

When the groups in each area display a normal distribution with homogeneous variances, an independent sample student test was used. When the groups did not have a normal distribution and/or homogeneous variances, Mann Whitney U test was conducted.

The calculation operation for the first group in Ayamama was given below. The results for the other groups for which the same operation was performed can be seen in Table 7.

Normality and significance test results for the first submarket in Ayamama:

The number of measurement was smaller than 50, therefore the result of Shapiro-Wilk test was used. Because Sig > α (at level of significance α=0,05) the distribution of the two groups is not a normal distribution for the first group of the Ayamama River. So Mann Whitney U test (nonparametric test) was applied.

Because Mann Whitney U test's result is Sig > α (at level of significance α=0.05), there is no price difference between the less-risk and more-risk categories.

Table 7 Significance Tests Results

River	Distribution		Variance	The type of test	Result
	Less risk	More risk			
Ayamama first submarket	normal	not normal	homogeneous	Mann Whitney U	No difference
Ayamama second submarket	normal	not normal	homogeneous	Mann Whitney U	No difference
Tavukçu	not normal	not normal	homogeneous	Mann Whitney U	No difference
Alibeyköy	normal	normal	homogeneous	Independent Samples T test	There is a difference
Kurbağalıdere	normal	not normal	homogeneous	Mann Whitney U	There is a difference

2.12. Regression Analysis

The validity of the assumptions of the regression analysis was checked during the data management phase. The regression analysis was conducted using the variables modified to meet the assumptions and the relevant data, the impact of earthquake risk in the riverbed areas was examined in terms of prices.

Indicator (dummy) variables are more informative for the problems with a qualitative factor "because they do not force any particular metric on the levels of the qualitative factor" [34]. In this study, the impact of earthquake risk was taken as the indicator variable, and a regression analysis was conducted using the code "0" for the low-risk areas and the code "1" for the high-risk areas.

The stepping method was employed in this analysis, in which the probability of Fisher entry=0.05 and removal= 0.10. The price variable was taken as the dependent one. Since the square-root transformation was performed on the price variable in Kurbağalıdere, the transformed values were used as the dependent variable there.

A “simple rule of thumb” for determining the required sample size is $N \geq 104+m$ (where *m* is the number of independent variables) for testing individual predictors [30]. The sample size in each submarket where a regression analysis was conducted was greater than the required minimum size calculated using this formula.

In the two submarkets in Ayamama, the regression analysis showed that R^2=0.083 for the first submarket with 99 data points and that R^2=0.078 for the second one with 210 data points. Since the coefficients of determination were very small, Ayamama was examined as a single submarket.

The table of regression coeffictions for Ayamama can be found in Table 8.

Table 8 Regression Coefficients in Ayamama

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	66359.020	14553.240		4.560	.000
	Area m2	1718.622	144.236	.562	11.915	.000
2	(Constant)	81476.356	14174.943		5.748	.000
	Area m2	1643.709	138.492	.538	11.869	.000
	Building age year	-1780.073	323.658	-.249	-5.500	.000
3	(Constant)	84266.086	13658.449		6.170	.000
	Area m2	1706.950	133.930	.559	12.745	.000
	Building age year	-1784.886	311.608	-.250	-5.728	.000
	Earthquake risk	-17351.943	3461.512	-.219	-5.013	.000

The best fitting model for Ayamama was found to be the one with R^2=0.425 and three independent variables. The following two-way confidence interval was constructed at the significance level α=0.05:

$-17351.943 - t_{0.025;305} \times 3461.512 \leq \text{price} \leq -17351.943 + t_{0.025;305} \times 3461.512$

$-24136.51 \text{ TL} \leq \text{price} \leq -10567.38 \text{ TL}$

The comparison between the housing prices in the low-risk areas and those in the high-risk ones revealed that the former were greater than the latter, the average difference being between -10567.38 and -24136.51 Turkish liras.

Table 9 shows the regression coefficients in Tavukçu.

Table 9 Regression Coefficients in Tavukçu

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.832E-6	.000		40.588	.000
	Housing complex	-1.451E-6	.000	-.411	-5.986	.000
2	(Constant)	6.031E-6	.000		11.420	.000
	Housing complex	-1.365E-6	.000	-.387	-5.872	.000
	Area m2	-2.040E-8	.000	-.278	-4.226	.000
3	(Constant)	6.274E-6	.000		12.272	.000
	Housing complex	-1.157E-6	.000	-.328	-5.040	.000
	Area m2	-2.033E-8	.000	-.277	-4.382	.000
	Presence of elevator	-6.522E-7	.000	-.255	-3.937	.000
4	(Constant)	6.974E-6	.000		12.418	.000
	Housing complex	-1.027E-6	.000	-.291	-4.462	.000
	Area m2	-2.073E-8	.000	-.283	-4.551	.000
	Presence of elevator	-6.712E-7	.000	-.263	-4.126	.000
	LG10 floor	-1.441E-6	.000	-.175	-2.773	.006

The best fitting model for Tavukçu was found to be the one with R^2= 0.337 and four independent variables. Since the variable of earthquake risk did not appear in the model, it was decided that this did not have any impact on the housing prices.

Table 10 shows the regression coefficients in Alibeyköy.

Table 10 Regression Coefficients in Alibeyköy

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	107052.882	20646.852		5.185	.000
	Area m2	1899.280	212.909	.579	8.921	.000
2	(Constant)	78136.828	21991.121		3.553	.001
	Area m2	1940.525	207.295	.591	9.361	.000
	Presence of elevator	28319.770	8817.266	.203	3.212	.002
3	(Constant)	71087.895	21780.077		3.264	.001
	Area m2	1977.058	204.171	.602	9.683	.000
	Presence of elevator	27447.546	8669.989	.197	3.166	.002
	Earthquake risk	16421.368	6378.709	.160	2.574	.011
4	(Constant)	51793.180	23228.393		2.230	.027
	aream2	1991.819	201.803	.607	9.870	.000
	Presence of elevator	25390.377	8615.438	.182	2.947	.004
	Earthquake risk	15303.581	6321.644	.149	2.421	.017
	No of floors	3654.234	1657.948	.136	2.204	.029

The best fitting model for Alibeyköy was found to be the one with R^2= 0.420 and four independent variables. The following two-way confidence interval was constructed at the significance level α=0.05:

$$15303.581 - t_{0.025;155} \times 6321.644 \leq \text{fiyat} \leq 15303.581 + t_{0.025;155} \times 6321.644$$

2913.16 TL ≤ fiyat ≤ 27694.00 TL

The comparison between the housing prices in the low-risk areas and those in the high-risk ones revealed that the former were less than the latter, the average difference being between 2913.16 and 27694.00 Turkish liras.

Table 11 shows the regression coefficients in Kurbağalıdere.

Table 11 Regression Coefficients in Kurbağalıdere

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	327.246	33.777		9.689	.000
	Area m2	3.622	.284	.712	12.762	.000
2	(Constant)	309.199	32.629		9.476	.000
	Area m2	3.105	.301	.611	10.309	.000
	No. of floors	12.985	3.280	.235	3.959	.000
3	(Constant)	322.111	32.135		10.024	.000
	aream2	3.046	.295	.599	10.341	.000
	No. of floors	13.840	3.213	.250	4.307	.000
	Earthquake risk	-52.892	17.759	-.156	-2.978	.003
4	(Constant)	303.714	32.396		9.375	.000
	Area m2	3.019	.290	.594	10.419	.000
	No. of floors	10.456	3.426	.189	3.052	.003
	Earthquake risk	-52.487	17.455	-.155	-3.007	.003
	floor	12.051	4.726	.145	2.550	.012
5	(Constant)	311.711	32.189		9.684	.000
	Area m2	2.938	.288	.578	10.189	.000
	No. of floors	7.955	3.564	.144	2.232	.027
	Earthquake risk	-56.753	17.341	-.167	-3.273	.001
	floor	11.208	4.682	.135	2.394	.018
	Presence of elevator	35.862	16.082	.128	2.230	.027

The best fitting model for Kurbağalıdere was found to be the one with R^2=0.606 and five independent variables. The following two-way confidence interval was constructed at the significance level α=0.05:

$-56.753 - t_{0.025;154} \times 17.341 \leq \text{price} \leq -56.753 + t_{0.025;154} \times 17.341$

-90.74136 TL ≤ price ≤ -22.76464 TL

After transforming the value of the price variable:

-8233.99 TL ≤ price ≤ -518.23 TL

The comparison between the housing prices in the low-risk areas and those in the high-risk ones revealed that the former were greater than the latter, the average difference being between -518.23 and -8233.99 Turkish liras.

Before the regression analysis, the validity of the assumptions was checked during the data management phase. Moreover, after the completion of the four regression analyses, scatter plots were used to examine the independence, normality, linearity, and homoscedasticity of residuals, demonstrating that the assumptions were met.

3. RESULTS

The compare means tests revealed that the average housing prices per square meter in the high-risk areas were lower in some regions examined: the difference being at least 232 Turkish liras in the first submarket in Ayamama, at least 129 Turkish liras the second submarket in Ayamama, and at least 995 Turkish liras in Kurbağalıdere. In Alibeyköy, however, the average housing prices per square meter in the high-risk areas were at least 273 Turkish liras *higher*. The ratios of these figures to the average housing prices per square meter were 0.09 in the first submarket of Ayamama, 0.06 in the second submarket of Ayamama, 0.09 in Alibeyköy, and 0.20 in Kurbağalıdere.

The regression analyses showed that the variables of the area, age, and earthquake risk of the residential unit significantly affected the housing prices in the first zone of Ayamama—the combined impact of these variables altogether accounted for 42.5% of the dependent variable, i.e. the housing price. In Alibeyköy, it was found that the area, the number of floors, the elevator, and earthquake risk of the dwelling were significant: the combined impact of all these variables on the housing prices were 42%. In Kurbağalıdere, the significant variables appeared to be the area, the age, the number of floors, the presence of elevator, and earthquake risk of the dwelling: they accounted for 60.6% of the prices of the dwellings. Finally in Tavukçu, the analyses revealed that the significant variables were the area, the number of floors, the presence of elevator, and the housing complex, all of which accounted for 33.7% of the dependent variable, i.e. the housing prices. It was also found that earthquake risk had no impact on the housing prices in Tavukçu.

The regression analyses also demonstrated that earthquake risk had an impact of -518 and -8234 TL upon the housing prices in Kurbağalıdere in the confidence interval of 95%, while the ratio of this impact to the average housing prices there was between 0.001 and 0.015. In Alibeyköy, the difference in housing prices was between 2913 and 27694 Turkish liras, the ratio being 0.010 and 0.096. In Ayamama, the same figures were between -0567 and -24137 Turkish liras and between 0.044 and 0.101 respectively.

Both compare means tests and regression analyses yielded similar results: the housing prices were found to be lower in high-risk areas in Kurbağalıdere and Ayamama, whereas they were higher in Alibeyköy. In Tavukçu, earthquake risk had no impact whatsoever upon the housing prices.

4. DISCUSSION

The impact of the sub-market appears to be the most important factor in the housing prices at the metropolitan level, the other variables change from one district to another [35]. MacLennan et al. [36] divides urban areas into sub-districts: some sub-districts with similar dwelling stocks and socioeconomic characteristics, while others have a more heterogeneous housing stock. The homogeneity of the local housing stock may influence hedonic prediction accuracy, hedonic techniques should produce more accurate value estimates in the neighborhoods of similar homes compared with the neighborhoods where the housing stock is heterogeneous [37]. The study by Murdoch, Singh and Thayer [27] showed the effect of the Loma Prieta earthquake on the housing prices. They observed a 2% reduction in housing prices.

Previous studies suggest that an earthquake can influence the housing market in the shorter term [38]. Also in Istanbul, in 2000, one year after the 1999 Kocaeli earthquake, the number of people who wanted to examine their buildings construction systems with respect to eartquake resistance was nil [25]. According to a recent study, "there are variations in the size of price discounts in submarkets resulting from the differential influence of a recent earthquake activity on perceived risk of damage" [39].

In a study, in which regression analysis was conducted for the years 1995 and 2000, it is found that as the distance from the fault lines increases, the value of dwellings increases. The measures of earthquake risk seem to explain 0.0928 (adjusted R^2) of the variation in the percentage change in house values. Furthermore, as expected, the impact of earthquake risk increases after the earthquake [25].

In another study, it is found that earthquake risk as a locational variable with a negative impact. In this study conducted using the hedonic model for housing prices in Istanbul, the data sets are about 348 submarkets chosen from 946 neighborhoods in 32 districts. The factors affecting the housing prices are presented as 26 variables. The average transaction price for the 2,175 units is $251,082, ranging from $34,000 to $8,000,000. The standard deviation of the average transaction price is $382,467.37. As a result, it is found that 1% increase in the earthquake risk percentage in a neighborhood will have a significant impact on residential prices [23].

The use of statistical comparison tests is appropriate in the research about the relative impact of earthquake risk on housing prices for high-risk and low-risk areas, if a) a sufficiently large sample is avaliable so that a price difference can be detected as a significant factor, and b) all the variables apart from earthquake risk are similar in the homogeneous submarkets in question. In similar research to be conducted on this question in the future, the findings of the present study will be informative about the variance values for the calculation of the appropriate sample size.

As for regression analysis, in order to obtain more informative results, a modelling should be made with the lowest number of variables [30], which provide the highest determination coefficient for the dependent variable, i.e. housing prices, in homogeneous submarkets, while the impact of earthquake risk is taken as an indicator variable [34].

Furthermore, in the submarkets with price differences in either direction, the researcher should check whether this difference might be due to some variable other than the available ones. Compare means tests do not yield any meaningful results for solving this problem, but regression analysis appears to be functional here. Clearly, it is necessary to find out whether there exist one or more variables accounting for the part which is not explained by the determination coefficient—in particular, in cases, when a very low coefficient is obtained.

Like the earlier studies on the subject, the present research too shows the necessity of constructing homogeneous submarkets. Moreover, it also demonstrates that there can be different variables affecting housing prices in each submarket and that these prices are not very much affected by earthquake risk in Istanbul due to the long period elapsing since the 1999 Marmara earthquake, which had devastating effects in the city—in fact, the negative impact of earthquake risk on the housing prices can be observed only in some regions. Regression analysis reveals the ratio of this impact is between 0.001 and 0.015 in Kurbağalıdere and between 0.044 and 0.101 in Ayamama. Statistical comparison tests show that these figures are 0.20 for Kurbağalıdere and 0.06 for Ayamama.

In Kurbağalıdere, the compare means tests allow us to identify only those price differences higher than 0.20 due to the insufficient size of the sample, but the the difference calculated there turns out to be greater than this high ratio. Since five different variables are used in the regression analysis for Kurbağalıdere, the figures can be considered to have more explanatory power. As for Ayamama, the ratio obtained by statistical comparison tests is between the highest and lowest figures obtained by regression analysis.

The higher housing prices in the high-risk zone in Alibeyköy indicate that it is necessary to research for the other variable(s) (such as scenic view) affecting the price levels more than earthquake risk.

5. CONCLUSION

In order to find out whether or not the earthquake risk has a negative impact upon housing prices in the riverbed areas in Istanbul, this study compares the prices of the dwellings in the risky and visible riverbeds, which are very common all over the city, and those of the similar buildings in the neighboring areas (just outside the riverbeds). Even though a major earthquake shook the city in the near past and another one is highly probable to occur in the near future, the research shows that earthquake risk has a negative impact on housing prices only in certain areas, while there are different variables affecting the prices in each region.

The regression analysis demonstrates that earthquake risk has a negative impact on the housing prices in two areas—in Kurbağalıdere, the ratio of the impact is found to be between 0.001 and 0.015, whereas it is between 0.044 and 0.101 in Ayamama (with a confidence interval of 95 percent).

The results of this study employing two statistical methods can be used in similar research aiming to measure the impact of earthquake risk on housing prices over time. Moreover, other researchers might also use these results in the determination of the appropriate sample size when they want to find out whether a significant price difference exists between low-risk and high-risk regions.

The results of this study provide information to the banking sector and insurance sector on how home prices are affected in risky areas. More comprehensive study can be done at a later time and the results of the study covering all river areas and other risky areas in Istanbul can be used in the insurance sector and the banking sector. In fact, the relevant institutions can benefit from the results of the work to be done in the setting of the tax amount in the risky areas.

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