SIGNIFICANCE OF RENT ATTRIBUTES IN PREDICTION OF EARTHQUAKE DAMAGE IN ADAPAZARI, TURKEY

Gökmen Tayfur[*], *Birkan Bektaş*[†], *Yavuz Duvarci*[‡]

Abstract: This paper analyses rent-based determinants of earthquake damage from an urban planning perspective with the data gathered from Adapazari, Turkey, after the disaster in 1999 Eastern Marmara Earthquake (EME). The study employs linear regression, log-linear regression, and artificial neural networks (ANN) methods for cross-verification of results and for finding out the significant urban rent attribute(s) responsible for the damage. All models used are equally capable of predicting the earthquake damage and converge to similar results even if the data are limited. Of the rent variables, the physical density is proved to be especially significant in predicting earthquake damage, while the land value contributes to building resistance. Thus, urban rent can be the primary tool for planners to help reduce the fatalities in preventive planning studies.

Key words: *Earthquakes, urban rent, urban development, regression analysis, artificial neural network*

Received: March 12, 2014 **DOI:** 10.14311/NNW.2014.24.036
Revised and accepted: December 12, 2014

1. Introduction

After the terrible 1999 Eastern Marmara Earthquake (EME), when more than 20 thousands people died, many authorities immaturely stated that the uncontrolled urbanization, basically resulting from the rampant rent-seeking urges accompanied by lack of adequate planning measures, was the major culprit for the increased death toll [1, 4]. However, earthquake-related planning literature to date is weak in proving this hypothesis. The methods of disaster evaluation in planning have not been matured and a few studies point rather only to the major role of planning initiatives in mitigating the earthquake impacts [3, 15, 19]. Furthermore, data

[*]Gökmen Tayfur – Corresponding Author, Dept. Civil Engineering, Izmir Institute of Technology, Izmir, Turkey, Phone: +90 232 7506802, Fax: +90 232 750 6801, E-mail: gokmentayfur@iyte.edu.tr

[†]Birkan Bekta, Izmir Greater City Municipality, Izmir, Turkey, Phone: +90 232 2931425, E-mail: bektas.birkan@gmail.com

[‡]Yavuz Duvarci, Dept. Urban Planning, Izmir Institute of Technology, Izmir, Turkey, Phone: +90 232 7507044, E-mail: yavuzduvarci@iyte.edu.tr

about disasters for planning studies are inefficient and incomplete most of the time. Major problem is to obtain inferable data from the scarce resources for modeling efforts to find causes of disasters from the planning point of view.

Turkey is one of the most vulnerable countries to earthquake hazards, and due to the vulnerable settlement structure, more effective planning policies for mitigation of the damages need to be urgently addressed. The planning practice in Turkey has rather served as creation and sharing of urban rent. This process is highly political; excessive demand for property puts pressure on the local municipalities. Besides, the priority concern for earthquake resistant settlements shifts away against rent-seeking urges. Thus, the planning research should lend itself in examining urban rent in the analysis of earthquake damage for safer environments.

This study argues that improper rent control, which has been a neglected concern in pre-disaster planning studies, rather than rent itself may cause improper land use decisions. As a result, ill-defined urban developments (such as developments on fault lines) increase vulnerability of settlements and number of fatalities. This is, indeed, true for developing countries where rapid urbanization takes place. According to the United Nations Development Program (UNDP) report [16], analyses of vulnerability indicators showed that physical exposure and urban growth rate acted together in association with the earthquake fatalities.

This study, adopting the post-disaster approach, as it is explained in the next section, aims to analyze primarily the alleged role of rent on earthquake damage. In this respect, three basic attributes of rent (physical density, land value, and the distance to the central business district (DCBD) are considered in models to see which particular rent dimension(s) play(s) the greatest role in predicting the damage. Due to the data scarcity, the second main quest is to verify the relationship between the rent parameters and earthquake damage, employing linear regression, log-linear regression and ANN models.

Note that many parameters such as building quality and geological factors, in addition to the rent attributes, could be affecting the earthquake damage. However, within the scope of this paper, only the effectiveness of the "rent-related" parameters were considered. The error margins in the models are probably related to the effects of neglected parameters.

The next section provides disaster analysis approaches and some information on the rent concept, which is at the core of vulnerability concept of settlements. The third section explains the data. The fourth section gives the analysis method. In the fifth section, the modeling approaches are explained. The sixth section discusses the findings obtained from model runs. After comparing and discussing the findings in the sense that all models performed equally well, a general conclusion was drawn.

2. Rent Concept in Relation to Earthquake-Resistance

2.1 Hazard Estimation Approaches

There are basically three approaches in studying the hazard [14]: Pre-disaster approaches, scenario-based approaches and post-disaster approaches.

Pre-disaster approaches try to predict time, place, and magnitude of earthquakes (hazard models) and do not focus on pre-disaster mitigation plans. Hence, it could be said that it is less related to planning. Moreover, the frequency of future earthquake occurrence is mostly computed from past earthquakes [13, 17].

The scenario-based approach is a sort of cost/benefit analysis to estimate the damage and probable costs for a hypothetical earthquake of a given magnitude within a defined geographical area. Thus, building damage, financial losses, and causalities are estimated according to the expected earthquake magnitude. These methods are extensively used in risky areas, such as Istanbul Metropolitan area and Metro Manila [9, 10, 12].

The post-disaster approaches help to establish a set of models for damage evaluation based on actual and historical earthquakes. These models seek relations between pre-disaster structures and the resulting damages [2, 5, 18, 23].

2.2 Rent Concepts

Planning bodies are supposed to propose earthquake-resistant environments.

However, for planners, it is not clear what forms of land use or densities may cause the escalation of earthquake damage, which all meet in rent relations. Rent can be exchanged due to one attribute of space scarcity which is completely inelastic in supply. It can also arise due to different transportation cost in distance to the market place. In the city centre, land and property values tend to be peaking due to the uniqueness and scarcity of space [11]. If purchasing power is low in the housing market, then it can be partitioned into increased floor numbers, resulting in a density increase. If differential rents are dominant, then it is the "use" which determines land value.

Earthquakes showed that housing stock in Turkey is not physically safe or durable against earthquake disasters [19]. High demand for housing creates uncontrolled rents causing the exaggerated "monopoly rent" earnings and the alleged deteriorated environment.

3. Data

The data were collected from the city of Adapazari, which is about 130 km east of Istanbul. In 1999 the EME occurred at 03:02 a.m. with the epicenter about 35 kilometers southwest of the city. Adapazari is located on the fertile Sakarya delta in the Northwestern side of Turkey with a population around 300,000, of which the economy is largely dependent on heavy industry and agriculture (Fig. 1). The North Anatolian fault passes very closely, and the city has outstretched to it. The majority of the population is composed of the middle or low income worker groups because of the industrial development. The city shape conforms to the compact form with relatively high density decreasing towards the city outskirts.

Adapazari had three big earthquakes in 1943, 1967 and 1999. After the 1967 earthquake, experts suggested that the height of any construction be limited to only three floors because of the weak ground and the high level of underground water [19]. However, the planning studies of 1985 called for the development of new areas towards the Sakarya River. This violated the basic principles set by the 1957 plan

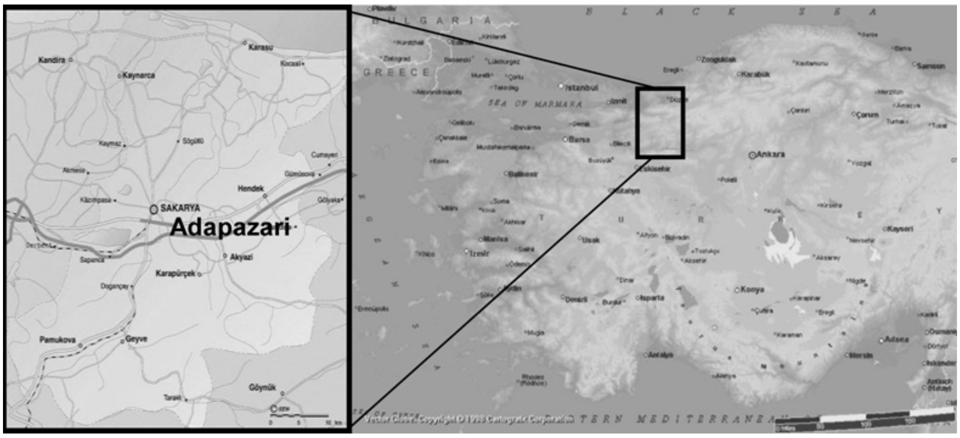

Fig. 1 *City of Adapazari located in western Turkey.*

that prohibited any construction in this direction because of geological concerns. Again in the 1990s, improper changes prevailed; thus, growth increased towards the South with the establishment of various new industrial regions including the Toyota automobile plant. All are located on alluvial agricultural areas in proximity to the risk areas (Fig. 2). The gross density of the entire city increased to 350 persons per hectare by 1997 while the city center rose up to 600 persons per hectare, for which

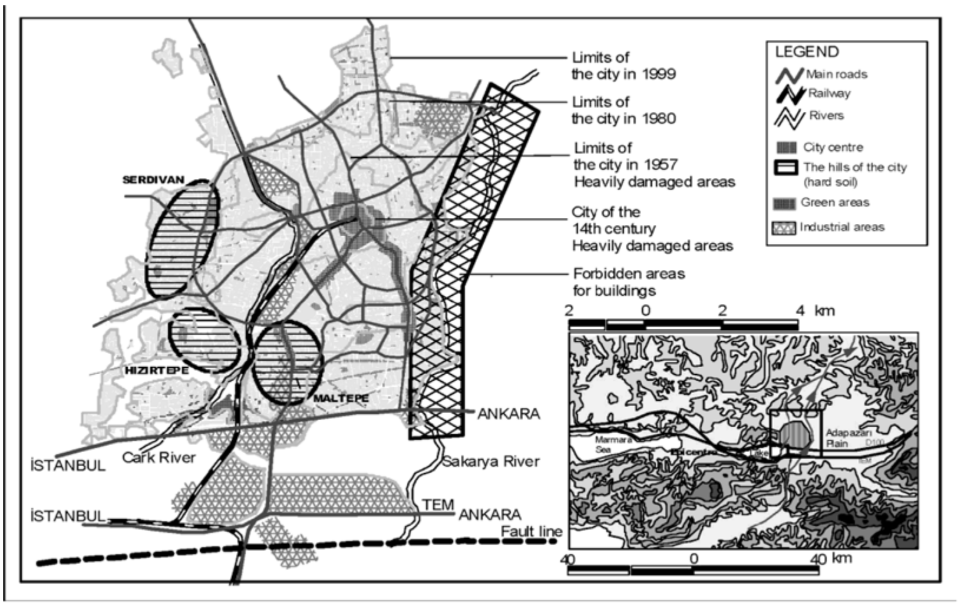

Fig. 2 *Planning Developments of Adapazari (Source: Sengezer and Koc, 2005).*

the last one is very high. In response to rental increases, numerous plan revisions were made in order to increase building densities regardless of ground conditions and risk of earthquakes. Adapazari city centre was only 8 km from the major fault line and located on the alluvial plain.

In this study, mahalle (district), with an average of 10,000 population, was taken as the data (aggregated) collection and analysis unit representing the various parts of the urban area. 26 district—based (mahalle) data on earthquake damage, land value, distance to city centre, and physical density are provided in Tab. I. These variables are explained as follows:

a) **Earthquake damage ratio (Y)** is found by dividing the number of demolished buildings to the total number of parcels in each district. This ratio is treated as a dependent variable in the modeling (output variable).

b) **Land value (urban rent) (X_1):** It is hypothesized that if land price or urban rent becomes high, then earthquake damage becomes high. This is because high land rent, as previous argument, causes physically undesired dense settlements. However, the density effect of land value could completely be represented under the distinct "density" variable. Rent seeking contractors in developing countries such as Turkey usually tend to pay less attention to the material used in buildings and, thus, buildings become less earthquake-resistant.

c) **Distance to city centre (X_2):** This variable is calculated by measuring distances to the city centre and finding averages of distances from demolished buildings per zone as measured from each district. It is hypothesized that the earthquake hazard was expected to decrease from DCBD towards fringe of the city. The earthquake damage ratio usually decreases at the fringe of the city.

d) **Physical building density (floor area ratio) (X_3):** This represents the ratio of floor number to total construction area of building. If the floor area ratio is high, then building damage may increase. Attached buildings influence each other (domino impact) and demolishing rate increases due to the high rate of physical density. Damage ratio can increase due to less open space.

The raw data as the number of destroyed buildings (dependent variable) and the indexed land values by districts were compiled from the Greater City Municipality of Adapazari in 2003, approximately 4 years after the date of the earthquake. The data such as land value were dated to the pre-occurrence of the disaster. The data were processed as the average values of districts (zone). The districts were not subdivided or merged for homogeneity concerns in order not to intervene the authenticity of values. The basic damage inventories of EME in Adapazari and the land use characteristics, such as land value and physical density, were analyzed and depicted as zone averages, as seen in Fig. 3. It can be noticed that damage density seems to coincide with urban density and land value towards the city centre. In total, about 9018 observations (damaged buildings) were used which comprise heavily and moderately damaged buildings and lie within the municipal boundaries of the city. Unfortunately, the data on the general characteristics (e.g.; building quality, the material used, the year built, etc.) of the damaged buildings were not available when the data were gathered for this study. This was may be due to the fact that the building characteristics data were generally scarce before the year 2000. However, it can confidently be stated that, most of the buildings were reinforced concrete, as it is the common case in cities in Turkey.

Districts	Earthquake damage ratio (Dependent, $\boldsymbol{Y}$)	Land value (urban rent, $\boldsymbol{X_1}$) (TL/m^2)	Distance to city center ($\boldsymbol{X_2}$) (Km)	Physical building density (floor area ratio) ($\boldsymbol{X_3}$) (Built/Lot)
Tepekum	2.8	91	231	125
Tekeler	7.1	110	179.9	105
Mithatpasa	8.3	124.1	172.5	130
Akincilar	19	131	112.5	160
Kurtulus	10	207.2	56.7	120
Yenicami	30.6	240	93.8	160
Papuccular	25.5	319	97.1	150
Orta	14.3	406	64.5	160
Ozanlar	9.3	98	135.7	120
Hizirtepe	1.1	109.2	320.9	120
Seker	13.5	114.9	133.8	120
Yagcilar	11	116.6	140	130
Istiklal	31.5	134.2	78.9	140
Tuzla	7.4	135.2	168	90
Sakarya	6.8	135.2	119.2	120
Cukurahmediye	25.7	145	88.1	160
Gulluk	6.2	146.3	252.2	140
Sirinevler	2.4	158.9	265.3	140
Yenigun	18.4	200	111.5	160
Karaosman	27.4	235	93	160
Yenidogan	27.9	251.6	91.5	150
Tigcilar	26.1	320	51.1	160
Semerciler	22.7	388	71.3	140
Maltepe	0.2	109	463	120
Cumhuriyet	14.3	687	53	140
Yahyalar	10	207	57	120

Tab. I *Data of earthquake damage and rent-related parameters of the Adapazari districts.*

4. Analysis Method

In this study, the analysis is done through a multi-variate approach using three independent variables representing the composite rent variable. The use of a narrow set of rent measures may potentially make it difficult to identify which one is

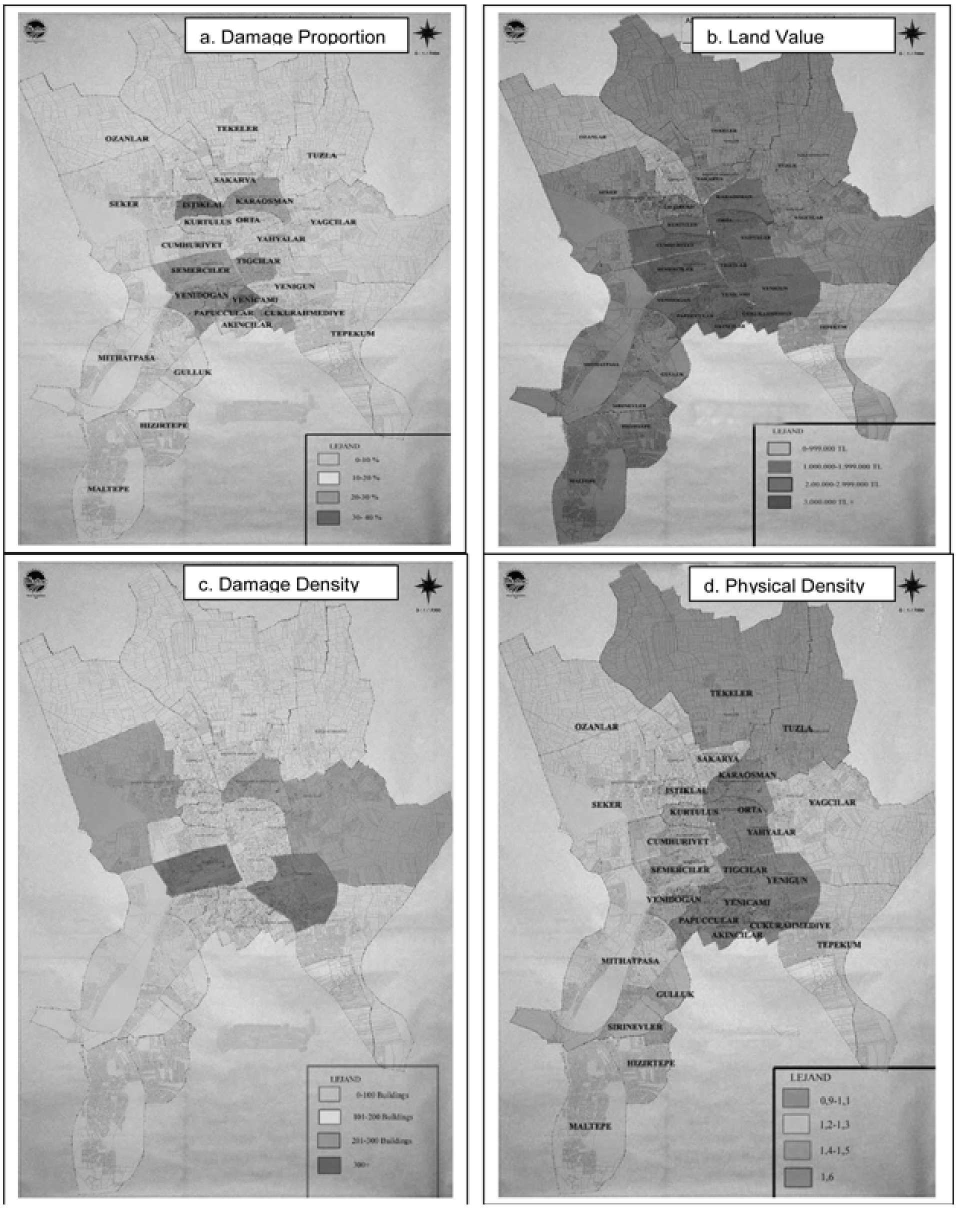

Fig. 3 *Earthquake damage and land use characteristics of Adapazari, Turkey.*

actually responsible for damage impact of earthquakes Here, it is tried to verify the robustness of the results through various modeling approaches for a few particular dimensions of rent. Although the use of small sample data may be unsuitable for the concerned models [6, 8], the robustness of the results is to be tested by comparison (cross-verification).

In addition to ANN modeling a multi—regression analysis was also performed for the proposed datasets. All variables share the same dependent attributes for model buildings as a way of comparing the differences—similarities between models. The modeling analysis methodology contains three phases (Fig. 4): Alleged rent variables were first tested using a two-stage instrumental variable approach where the endogenous "*explanatory*" rent attributes are first regressed on instruments

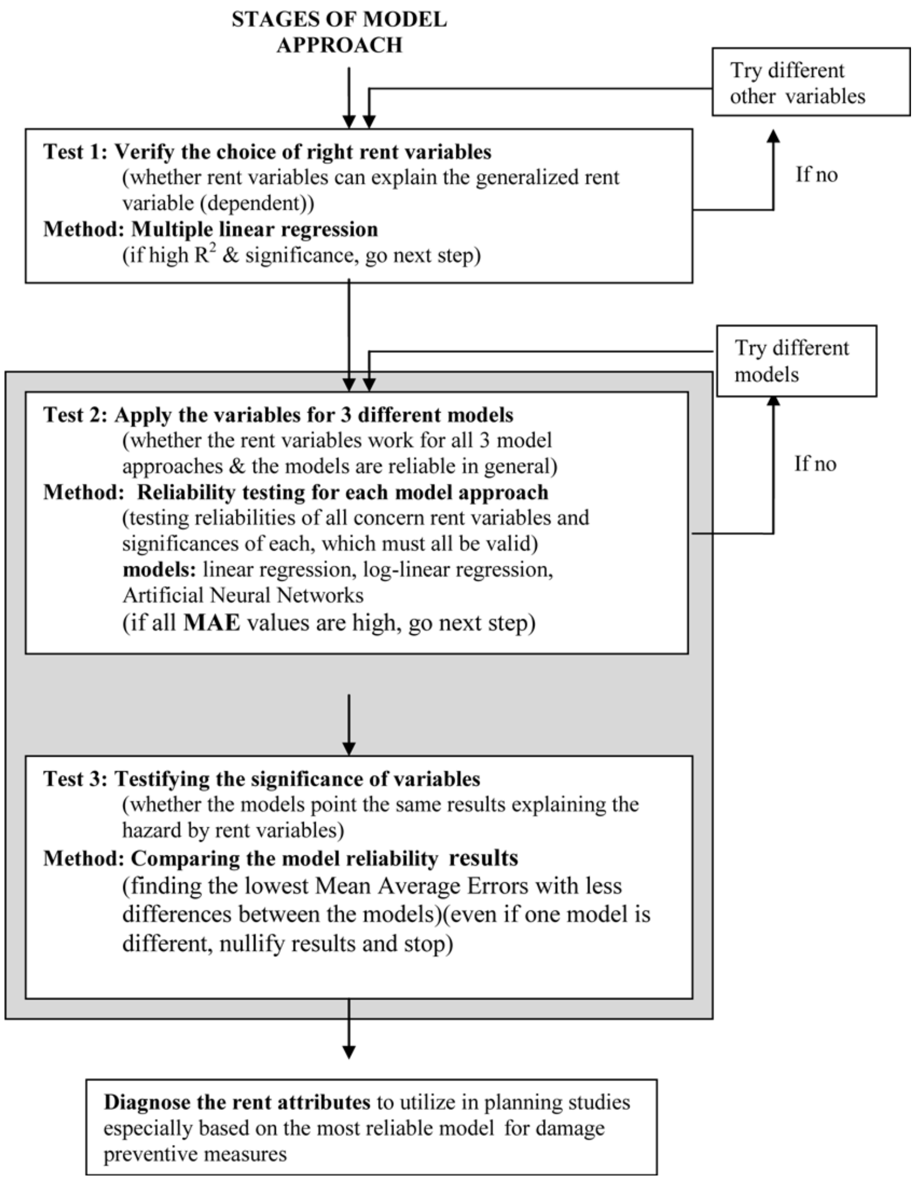

Fig. 4 *The stages of modeling method.*

that are related to the rent attributes Then in the second stage, the determined variables were fitted for earthquake damage In the third phase; the predicted values of the rent attributes from the first regression were subsequently introduced as independent variables in the damage relationship.

4.1 The first stage of analysis

To determine representative variables for a generalized rent term the most representative rent variable, "*land value*", is considered as the dependent variable. This is because there is actually no single concrete rent variable in reality but a composite one. It is observed that almost all variables chosen were significant enough to be used in the prominent models. However, due to the relationship observed between the "*land value*" (as dependent variable) and other two rent component variables, "*distance to the city centre*" and "*building density*", they are considered as appropriate variables for the proposed models.

4.2 The second stage of analysis

Since all three rent variables are nominated as the variable attributes for rent, they are employed in the selected model approaches. In this section, these three attributes are tested in order to identify their suitability to explain the earthquake damage. Thus, this is the stage to determine the relationship between the rent attributes and the damage.

To see the individual impacts of rent components on the observed damage; employed model results are compared for verifying the robustness of the chosen variables. The comparison is performed by computing Mean Absolute Error (MAE) and Mean Absolute Relative Error (MARE). Since MARE is percentage of error, it is expected to provide more comparable results [7, 21].

4.3 The third stage of analysis

Data are divided into two sets: 18 observations were used for the training (calibration) and 8 for the testing (verification) (Tab. II) the linear regression, log-linear regression, and ANN models. The details in constructing the models are given in the next section.

5. Model Constructions and Applications

5.1 Linear Regression Model

In all models, earthquake damage was used as dependent variable ($\boldsymbol{Y}$), while rent, distance, and density were treated as independent variables ($\boldsymbol{X}_1$, $\boldsymbol{X}_2$, and $\boldsymbol{X}_3$, respectively). Using the 18 data sets, the constructed linear model is expressed as follows:

$$\boldsymbol{Y} = -10.96 - 0.0095\boldsymbol{X_1} - 0.0558\boldsymbol{X_2} + 0.265\boldsymbol{X_3} \tag{1}$$

Training Data			
Earthquake Damage (Output)	**Rent**	**Distance**	**Density**
9.3	98	135.7	120
1.1	109.2	320.9	120
13.5	114.9	133.8	120
11	116.6	140	130
31.5	134.2	78.9	140
7.4	135.2	168	90
6.8	135.2	119.2	120
25.7	145	88.1	160
6.2	146.3	252.2	140
2.4	158.9	265.3	140
18.4	200	111.5	160
27.4	235	93	160
27.9	251.6	91.5	150
26.1	320	51.1	160
22.7	388	71.3	140
0.2	109	463	120
14.3	687	53	140
10	207	57	120
14.55 (average)	**205.06**	**149.64**	**135**
Test Data			
Earthquake Damage (Output)	**Rent**	**Distance**	**Density**
2.8	91	231	125
7.1	110	179.9	105
8.3	124.1	172.5	130
19	131	112.5	160
10	207.2	56.7	120
30.6	240	93.8	160
25.5	319	97.1	150
14.3	406	64.5	160
16.8 (average)	**232.61**	**144**	**158.57**

Tab. II *Training and testing data of the damage and rent-related parameters.*

When Eq. (1) is tested against the remaining 8 data sets, the determination coefficient R^2 was found to be 0.74, showing a relatively strong relationships between dependent and independent variables. Also, the F-test value is computed to be 13.07, with significance value of 0.00024 for 0.01 error margin level.

5.2 Log-Linear Model

The log linear model is constructed using the same training (18 observations) data sets as follows:

$$\log(\boldsymbol{Y}) = 2.718 - 0.783\log(\boldsymbol{X}_1) - 2.0\log(\boldsymbol{X}_2) + 1.967\log(\boldsymbol{X}_3) \tag{2}$$

When Eq. (2) is applied to the testing data sets, $R^2 = 0.78$, F-value = 17.03 with significance value of 0.00006 for 0.01 error margin level are obtained.

5.3 ANN method

A three-layer feed-forward type of artificial neural network is considered (Fig. 5). Before its application to any problem, the network is first trained, whereby the error is minimized by adjusting the weights and biases through a training algorithm. The combination of the weighted inputs is represented as [22]:

$$\mathrm{net}_j = \sum x_i v_{ij} - b_j \tag{3}$$

where net_j is the summation of the weighted input for the j-th neuron; x_i is the input from the i-th neuron to the j-th neuron; v_{ij} is the weight from the i-th neuron in the previous layer to the j-th neuron in the current layer; and b_j is the threshold value, called the bias, associated with node j.

A pre-determined error function has the following form [22]:

$$E = \sum_P \sum_p^{(y_i - t_i)^2} \tag{4}$$

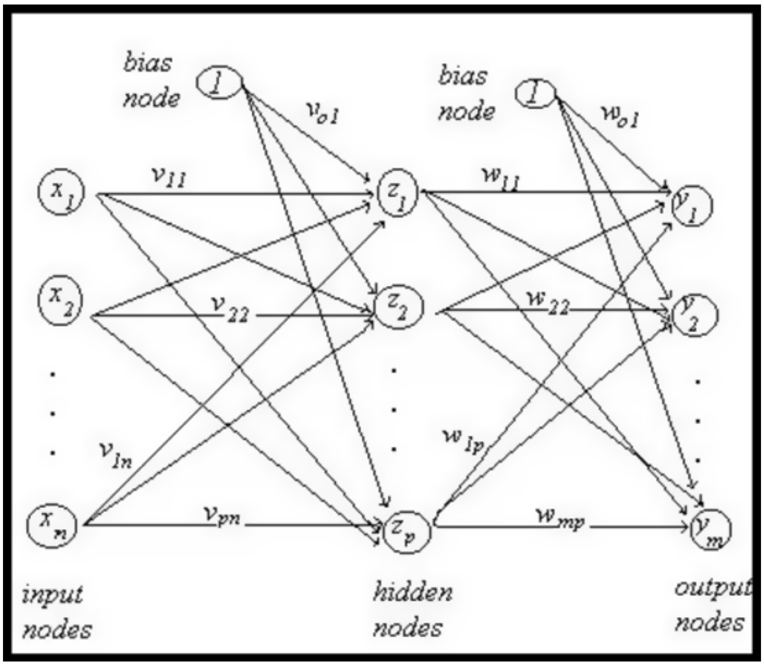

Fig. 5 *Schematic representation of feedforward three layer ANN.*

where y_i is the component of an ANN output vector $\boldsymbol{Y}$; t_i is the component of a target output vector $\boldsymbol{T}$; p is the number of output neurons; and P is the number of training patterns. The least square error method is used to optimise the network weights. The gradient descent method, along with the chain rule of derivatives, is employed to modify the network weights [20]:

$$\Delta v_{ij}(n) = -\delta \frac{\partial E}{\partial v_{ij}} + \alpha \Delta v_{ij}(n-1) \tag{5}$$

where $\Delta v_{ij}(n)$ and $\Delta v_{ij}(n-1)$ = the weight increments between node i and j during the n-th and (n-1)-th pass or epoch; δ = the learning rate; and α = the momentum factor. The details of ANNs can be obtained from [22].

Input neurons stand for "*physical density*", "*distance to the centre*", and "*land value*". Output neuron stands for "*earthquake damage*". 18 out of 26 data sets were used for training the model. Tab. II shows the training and testing data sets. To determine the number of neurons in the hidden layer, the trial-and-error procedure was used. The learning of the ANNs was accomplished by the back-propagation algorithm (learning rate, $\delta = 0.04$ and momentum factor, $\alpha = 0.08$). Before starting the training process, a random value of 0.2 for the connection weights in between input-hidden layers and 0.4 for the weights in between inner-output layers were assigned. A value of -1.0 was the entry for the bias neurons. Assigning different initial values resulted in no change in the results.

When trained ANN is applied to the testing data sets, $R^2 = 0.76$, F-value = 12.06 with significance value of 0.0001 for 0.01 error margin level are obtained.

6. Discussion of Results

Tab. III presents the predictions of observed data by the models for the testing (verification) stage. The related AE (absolute error) values are also presented in Tab. III. As seen, although ANN model slightly outperforms the others, all are fairly capable of estimating the damage. Fig. 6 shows the comparison results with goodness of fit lines. Aside from few observations, all models produced fairly satisfactory results.

Although the R^2 values are almost the same for each model, ANN predictions fall mostly on the goodness of fit line, according to scatter diagrams in Fig. 6. Out of 8, only 3 predictions are off the line (see Fig. 6a). This number is 7 for the linear model (see Fig. 6b) and 5 for the log-linear model (see Fig. 6c). Furthermore, when one converts the values to the actual ones in the case of log-linear model, one could then see that this model produces large errors, especially in the case of the last observation (see the bar graph in Fig. 6c). It is a fact that ANN outperforms linear models in solving non linear problems. This fact however could have been more significantly supported in the predictions results in this study if there had been more number of observations, by which ANN could have done better generalization.

Tab. IV provides further statistics for the performance of the models. All models on the average produced 35% prediction error that is considered acceptable. The data in Tab. IV allows the interpretation of the significance of the variables in the studied models. Based on the two regression model results, it is observed that

Test data observed	ANN Predicted	**MAE** of ANN	**Lin-regres. Predicted**	**MAE of Lin. reg**	**Log-lin. observed** (converted)	**Log-lin. Predicted**	**MAE of Log-lin**
2.8	2.56	0.24	8.36	5.56	0.45	0.58	0.13
7.1	7.68	0.58	5.75	1.35	0.85	0.76	0.09
8.3	9.6	1.3	12.65	4.35	0.92	1.29	0.37
19	15.86	3.14	23.89	4.89	1.28	1.48	0.21
10	22.67	12.67	15.70	5.70	1.00	1.24	0.24
30.6	21.93	8.67	23.91	6.69	1.48	1.06	0.42
25.5	22.6	2.9	20.32	5.18	1.41	1.39	0.02
14.3	22.79	8.49	23.97	9.67	1.15	2.72	1.56

Tab. III *Comparison of ANN and the regression models.*

	Model Reliability					**Rent** (X_1)			**Distance** ($\boldsymbol{X_2}$)			**Density** ($\boldsymbol{X_3}$)		
	MAE	MARE	R^2	F-test	signif.	S.E.[a]	Coeff.	t-stat.	S.E.[a]	Coeff.	t-stat.	S.E.[a]	Coeff	t-stat
MLR	5.42	0.344	0.74	13.07	0.0002	0.011	–0.009	0.86	0.015	–0.056	–3.79	0.08	0.265	3.34
Log-MLR	0.38	0.381	0.78	17.03	0.00006	0.44	–0.783	–1.76	0.35	–2.002	–5.67	1.23	1.968	1.6
ANN	4.75	0.343	0.76	12.06	0.0001	–	–	–	–	–	–	–	–	–

[a] Standard error values for each variable

Tab. IV *Comparison of the summary model results.*

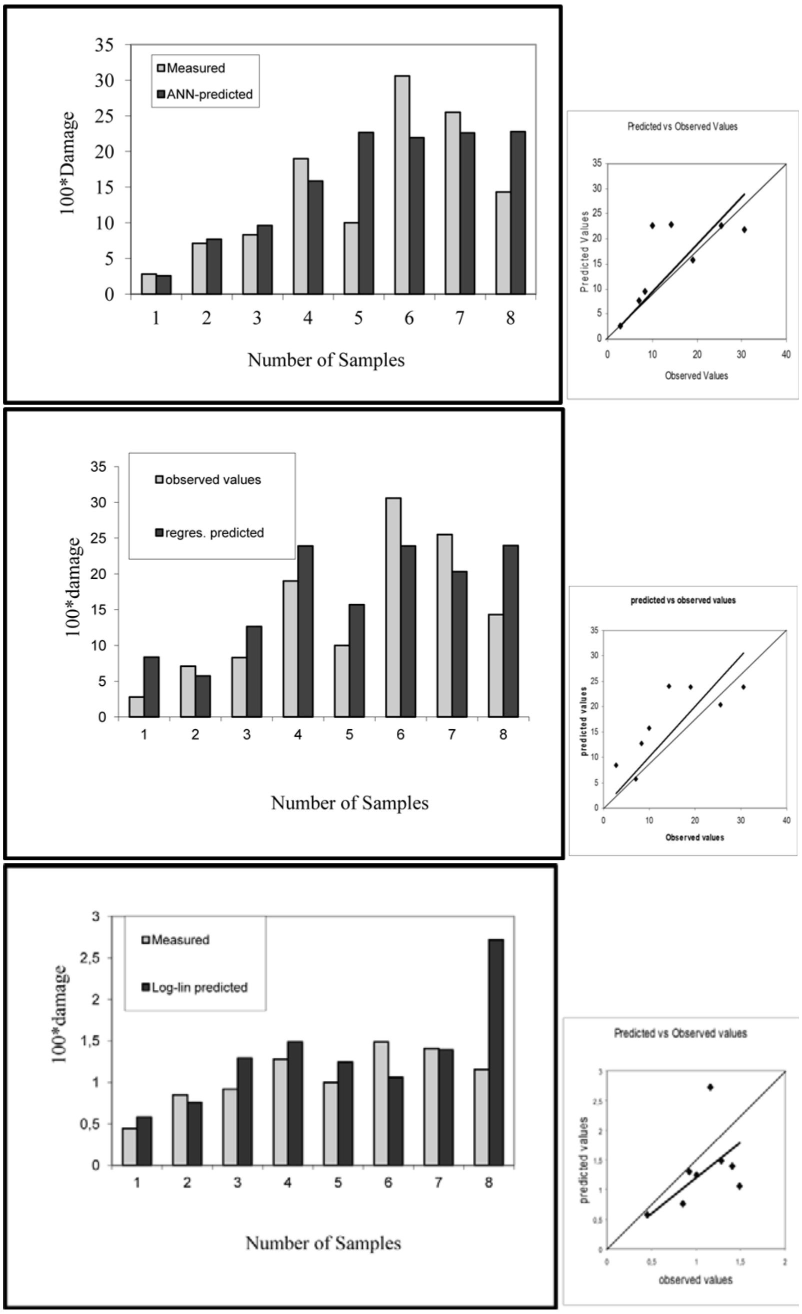

Fig. 6 *The comparison of observed and predicted results for all models and their scatter diagrams.*

when land value increases, the damage rate decreases, which is contradictory to the argument that rent in general is positively related to the damage

Model results support the fact that the damage density actually follows urban density, as verified by other studies. Unlike the distance and density variables land value, as it is discussed later, in fact does not seem a very effective variable due to its low *t-statistic* values of 0.86 and 1.76 for the linear and log-linear regression models, respectively.

According to Tab. IV, the distance to city centre variable has a negative direction, which means that the damage risk decreases with settling away from the city centre The physical density variable has a positive direction clearly meaning that the more density the more damage risk.

All variables prove to be significant in such modeling studies especially when considering the role of urban parameters in escalating or mitigating the risks in urban planning. Furthermore, modeling such urban parameters with earthquake consequences may serve planning as a decision support tool. For example, one can know possible impacts of dense settlements when proposed on risk areas; he/she can either refrain from such land use proposals or propose them with the least care required. This fact points to the importance of the rent-based parameters, and the urban planning parameters at large.

As pointed out in the Introduction section, some authorities (planning, architecture, or other) proclaimed that "rampant rent-seeking urges" are responsible for the severities and the damages when an earthquake happens in a developing country. Accordingly; they usually blamed the increased land values due to the artificially "created" rents However, this study has shown that only one part of rent would be responsible, which is density, and not the 'land value' which is actually in negative correlation with the damage output. That is; in a low income society, most probably low value of the land attracts more people, and more floors into the property. On the other hand, if the society were to be rich, then the rent of the land would let low density settlements (villa, or single-family houses) there, drawing less people into the disaster-prone area. Thus, such an objective method based on objective models as provided here can disprove such groundless ready-made arguments even if they come from the experienced experts in their areas. Contrary to the false utterance that the problem is "rent-seeking urges", (which may only slightly be true), only the increased density which is not rightfully done, or not controlled by the local authorities is the real problem (parameter).

Rent, after all, is not one entity that can be culpable of hazard but has components which may have diverse impacts on causality. In urban design projects (at macro or micro scales), possible impacts of many rent-related parameters which form the basics of urban planning should be re-evaluated within this refreshed view. This study focused on a few rent parameters due to limited resources. The subject, however, requires a more scrutinized effort to explore further unknown relationships.

7. Conclusions

This study attempted to seek the effectiveness of rent in general, and of rent variables in specific detail on the earthquake damage. It furthermore investigated whether the robustness of the chosen variables can be cross-verified by various model approaches.

The study found that while land value rather contributes to the resistance against earthquake hazard, the other components of urban rent, the density and distance to the city centre have negative effects. This is the common result of all three model findings, which also provides firm verification of the significance of the chosen variables.

The linear regression models, like ANN model, efficiently explain the relationship for the case area and the chosen data values. However, the results might be peculiar to the selected case area and to the conditions (type of the earthquake severity, the size of the city, sample size, etc.). A more scrutinised effort to conduct similar studies is required, employing other modelling approaches.

For the time being, these findings should not be generalised. Geographical differences may add to variation in results that may be gathered at different locations of the world.

What is inferred from the results is that urban rent parameters, frequently used in city planning, would be the major policy areas that can reduce the severity of damages, provided that adequate consideration is devoted to city planning long before a big earthquake hits.

The study also nullifies the assumption that site characteristics and planning decisions are not critical in escalating or avoiding such damages. Thus, the study restores the importance of planning decisions to the centre of the issue of determining preventive measures in the earthquake hazard estimation process.

A more precise definition of rent and selecting appropriate data play significant role in arriving at conclusions. City planners and land developers should also be aware of land value, rent, and density factors along with other complimentary determinants such as geological features, the material and the methods in creating the living environments. Also, rent types as absolute, monopoly and differential may require other devoted studies in the future.

Acknowledgment

We appreciate very much the help of the Greater City Municipality of Adapazari and the staff there for providing data without which this study could not be performed.

References

[1] AKINCITURK N. The effects of 17 August 1999 Marmara Earthquake on structures. *Yapi Dünyasi.* 2006, 120, pp. 11-21.

[2] ANSAL A. Depremlerde yerel zemin tabakalarının davranışları. In: *Depreme Güvenlikli Konut Sempozyumu,* Turkey. Ankara: MESA publ., 1999, pp. 49-56.

[3] BAHRAINY H. Urban planning and design in a seismic-prone region. *J. of Urban Planning and Development.* 1998, 124(4), pp. 140-160, doi: 10.1061/(ASCE)0733-9488(1998)124:4(148).

[4] BALAMIR M. Urban planning and seismic risk management. In: *Second Annual IIASA-DPRI Meeting Integrated Disaster Risk Management: Megacity Vulnerability and Resilience,* Laxenburg, Austria. 2002, pp. 24-25.

[5] BROOKSHIRE D.S., SCHULZE W.D. *Methods Development for Valuing Hazards Information.* Laramie: University of Wyoming, 1980. United States Geological Survey (*USGS*) Research Report.

[6] CHATTOPADHYAY S., JHAJHARIA D., CHATTOPADHYAY G. Univariate modeling of monthly maximum temperature time series over northeast India: neural network versus Yule-Walker equation based approach. *Meteorological Applications.* 2011, 18(1), pp. 70-82, doi: 10.1002/met.211.

[7] CHATTOPADHYAY S., JHAJHARIA D., CHATTOPADHYAY G. Trend estimation and univariate forecast of the sunspot numbers: Development and comparision of ARMA, ARIMA and autoregressive neural network models. *Computes Rendus Geoscience.* 2011, 343(7), pp. 433-442. doi: 10.1016/j.crte.2011.07.008

[8] CUI Y.S. A study of sample size with neural network. In: *Proceeding of the Third International Conference on Machine Learning and Cybernetics,* Shanghai, China. IEEE, 2004, pp. 3444-3448, doi: 10.1109/ICMLC.2004.1380382.

[9] ERDIK M. Earthquake risk assessment for Istanbul Metropolitan Area. *Earthquake Engineering and Engineering Vibration.* 2003, 2(1), pp. 1-23, doi: 10.1007/BF02857534.

[10] ERDIK M., AYDINOGLU N. Earthquake risk to buildings in Istanbul and a proposal towards its mitigation. In: *Second Annual IIASA-DPRI Meeting Integrated Disaster Risk Management: Megacity Vulnerability and Resilience*, Laxenburg, Austria. 2002, pp.: 1-16.

[11] ERTURK H. *Rant Kuramlarıve Kent TopraklarıSorunları: Kent Ekonomisi.* Ankara: Ekin Kitabevi, 1995.

[12] ISKENDEROGLU A. Istanbul ili sismik mikro bölgelendirme dahil afet önleme/azaltma temel planı(JICA Projesi). In: *Kentlerin Depreme Hazirlanmasi ve Istanbul Gercegi Sempozyumu,* Istanbul, Turkey. Mimarlar Odasi Press, 2002, pp.: 11-17.

[13] JACKSON D.D., KAGAN Y.Y. Testable earthquake forecasts for 1999. *Seismological Research Letters.* 1999, 70(4), pp. 393-403, doi: 10.1785/gssrl.70.4.393.

[14] KIRBAS H., ERMEZ S. Comparative investigation of the earthquake risk analysis methods. In: *International Conference on Earthquake Hazard and Risk in the Mediterranean Region,* Near East University Press, Northern Cyprus. 1999, pp.: 605-612.

[15] MILETI D.S. Disasters by design: A reassessment of natural hazards in the United States. In: T. INOGUCHI, ed. *Cities and the Environment.* Tokyo: The United Nations University Press, 1999, pp. 161-184.

[16] REDUCING DISASTER RISK (RDR). *A challenge for development: A global report.* UNDP Bureau for Crisis Prevention and Recovery. New York, 2004. Research Report.

[17] RHOADES D.A., EVISON F.F. Test of the EEPAS forecasting model on the Japan earthquake catalogue. *Pure Applied Geophysics.* 2005, 162(6-7), pp. 1271-1290, doi: 10.1007/s00024-004-2669-0.

[18] SENGEZER B. *13 Mart 1992 Erzincan Depremi, Hasar Analizi ve Türkiye'de Deprem Sorunu.* Yıldız Teknik Üniversitesi, Istanbul, 1999. Research Report YTÜ.MF.YK-99.0496.

[19] SENGEZER B., KOC E. A critical analysis of earthquakes and urban planning in Turkey. *Disasters.* 2005, 29(2), pp. 171-194, doi: 10.1111/j.0361-3666.2005.00279.x

[20] TAYFUR G., et al. Case study: Finite element method and artificial neural network models for flow through Jeziorsko earthfill dam in Poland. *Journal of Hydraulic Engineering.* 2005, 131(6), pp. 431-440, doi: 10.1061/(ASCE)0733-9429(2005)131:6(431).

[21] TAYFUR G., MORAMARCO T., SINGH V.P. Predicting and forecasting flow discharge at sites receiving significant lateral inflow. *Hydrological Processes.* 2007, 21(14), pp. 1848-1859, doi: 10.1002/hyp.6320.

[22] TAYFUR G. *Soft Computing in Water Resources Engineering.* UK, Southampton: WIT Press, 2012.

[23] WAMSLER C. Managing urban risk: Perceptions of housing and planning as a tool for reducing disaster risk [online]. *Global Built Environment Review.* 2005, 4(2), pp. 11-28 [viewed 2014-12-09]. Available from: http://works.bepress.com/christine_wamsler/3.