Computers and Concrete, *Vol. 26, No. 3* (*2020*) *203-211*
DOI: https://doi.org/10.12989/cac.2020.26.3.203

Seismic risk investigation for reinforced concrete buildings in Antalya, Turkey

Engin Kepenek*[1], Kasim A. Korkmaz[2] and Ziya Gencel[1]

[1]*Department of Urban Planning, College of Architecture, Akdeniz University, Antalya, Turkey*
[2]*School of Visual and Built Environments, Eastern Michigan University, Ypsilanti Michigan, USA*

(*Received January 30, 2020, Revised June 10, 2020, Accepted July 10, 2020*)

Abstract. Turkey is located in one of the most seismically active regions of in Europe. The majority of the population living in big cities are at high seismic risk due to insufficient structural resistance of the existing buildings. Such a seismic risk brings the need for a comprehensive seismic evaluation based on the risk analysis in Turkey. Determining the seismic resistance level of existing building stock against the earthquakes is the first step to reduce the damages in a possible earthquake. Recently in January 2020, the Elazig earthquake brought the importance of the issue again in the public. However, the excessive amount of building stock, labor, and resource problems made the implementation phase almost impossible and revealed the necessity to carry out alternative studies on this issue. This study aims for a detailed investigation of residential buildings in Antalya, Turkey. The approach proposed here can be considered an improved state of building survey methods previously identified in Turkey's Design Code. Antalya, Turkey's fifth most populous city, with a population over 2.5 Million, was investigated as divided into sub-regions to understand the vulnerability, and a threshold value found for the study area. In this study, 26,610 reinforced concrete buildings between 1 to 7 stories in Antalya were examined by using the rapid visual assessment method. A specific threshold value for the city of Antalya was determined with the second level examination and statistical methods carried out in the determined sub-region. With the micro zonation process, regions below the threshold value are defined as the priority areas that need to be examined in detail. The developed methodology can be easily calibrated for application in other cities and can be used to determine new threshold values for those cities.

Keywords: reinforced buildings; risk parameters; loss estimation; seismic hazard; seismic vulnerability; rapid assessment

1. Introduction

Over 90% of Turkish lands, laid over on the Mediterranean-Alpine-Himalayan zone, are at risk of earthquakes. This zone is considered one of the most active earthquake zones in the World. In addition, 98% of Turkey's population lives in a seismic zone. Referring to Turkey's recent history, the 1992 Erzincan, the 1995 Dinar, the 1998 Adana, the 1999 Marmara, the 2000 Duzce and the 2020 Elazig earthquakes are some of the samples cases that motivated this study. These earthquakes caused a huge loss of life and property. Aochi and Ulrich (2015) reported in their study that a devastating earthquake is expected to occur in the North Anatolian Fault length exceeding 1,000 km in Turkey. It is important to question the earthquake resistance of existing buildings and then proceed to the strengthening or re-construction phase of the buildings in order to prevent loss of life from earthquakes.

The dominant building types in Turkey are mostly the Reinforced Concrete (RC) buildings, followed by unreinforced and confined masonry buildings (Dabbeek and Silva 2020). At the same time, when RC buildings collapse, the loss of lives is higher compared to masonry buildings (Coburn and Spence 2002). To determine the collapse risk of the RC buildings, first it is necessary to know the properties of the soil and the material parameters of the building, and it should be modeled in a computer by nonlinear analysis. However, detailed experimental and analytical work in cities with thousands of buildings is very difficult and complex in terms of time, labor, and financial aspects. The multitude and structural conditions of existing RC building stock in Turkey makes the detection of buildings at risk more and more difficult. The next stage after determining the buildings that are at risk will be taking emergency measures in these buildings, if necessary to strengthen or demolish and minimize the loss of lives from a possible earthquake.

In the big cities of Turkey, such as Antalya, where the number of residential buildings is quite high, the performance of buildings against earthquakes should be examined and evaluated with rapid, economical, and reliable methods. Many rapid assessment methods have been developed that provide these conditions in the world. The first study of the rapid assessment method was based on the column-wall index developed using data obtained after the Tokachi-Oki earthquake in 1968 (Shiga *et al*. 1968). In the study that was conducted by Nanda *et al.* (2019), studies on rapid assessment methods were conducted in a comprehensive manner. In Turkey, since the Erzincan Earthquake in 1992, various rapid assessment methods that attempt to determine the risk of collapse have been investigated (Tezcan *et al*. 1996, Hassan and Sozen 1997, Gulkan and Sozen 1999, Pay 2001, Boduroglu *et al.*

*Corresponding author
E-mail: enginkepenek@akdeniz.edu.tr

ISSN: 1598-8198 (Print), 1598-818X (Online)

Fig. 1 Typical RC buildings in Antalya, Turkey


Fig. 2 Typical damages in R/C buildings after 1999 Marmara earthquakes in Turkey

2004, Yakut 2004, Yakut *et al.* 2005, Yakut *et al.* 2006, Sonmezer *et al.* 2018). These methods differ from each other based on the parameters and formulas they evaluate. Finally, the rapid assessment method set out in 2012 in Turkey has taken place with the Urban Transformation.

In the present study, a new model has been developed to find the threshold value based on the rapid assessment method. The principle of the study is based on a simple rule as locations should be evaluated with the local threshold value with rapid assessment methods. Although a rapid visual assessment method has been used in Turkey, the use of this method is possible by developing a model for threshold value determination.

2. Residential buildings in Turkey

The metropolitan cities in Turkey such as Istanbul and Izmir are under high seismic risk. The populations in these cities have constantly increased over the last decades due to migration from less developed regions of the country. During this population increase, most of the buildings that are typically low to mid rise RC buildings with infill walls, were generally not designed according to the current design code, which was the1975 version of the Turkish Design Code (TDC 1975). Also, the supervision in the construction phase of these buildings was not adequate (Erberik and Cullu 2006). Therefore, the majority of the building stock is generally composed of low quality buildings (Erberik 2008). Examples of typical RC residential buildings in Antalya, Turkey are represented in Fig. 1. Such building types are ubiquitous in Turkey and Antalya (Korkmaz *et al*. 2010).

Many existing buildings in Antalya and all over the country are subjected to ground motions as has been empirically proven during the recent earthquakes in various locations in Turkey (Ozcebe *et al*. 2004). The large number of casualties due to heavy damage or collapse of this kind of buildings demonstrates the vulnerability of such RC buildings during strong earthquakes. It is highly probable that such devastating earthquakes will occur in the future. To avoid damage and losses when earthquakes occur in the future, the determination and assessment of the seismic vulnerability of these buildings is quite imperative.

3. Recent earthquakes in Turkey

In August and November 1999, two major earthquakes hit the northwestern region of Turkey and resulted in a loss of more than 50,000-property and 20,000-lives. Typical building damages following the 1999 Marmara earthquakes are presented in Fig. 2 (Korkmaz *et al.* 2010). After this countrywide catastrophic experience, researchers focused on existing buildings and carried out various projects. In addition, over the last two decades disaster mitigation programs have gone through a paradigm shift. As a conclusion of the research that was conducted, most of the existing buildings were tagged as suspicious in terms of the structural behavior satisfaction level for future earthquakes. After the 1999 Marmara earthquakes, Turkey has experienced other major earthquakes in 2003 in Bingol and two recent devastating earthquakes in the east part of the country. These include the March 2010 Elazig and the October 2011 Van earthquakes. The results were similar to the 1999 Marmara earthquakes. Structural damage due to the infill walls were typical during these earthquakes (Murty *et al*. 2006).

In the Elazig earthquake (M_w=6.1) on March 8, 2010, 42 people lost their lives and 137 people were injured. The earthquake caused major structural damage in residential and school buildings. A significant percentage of the

Fig. 3 Typical damages in 2011 Van earthquakes in Turkey

Fig. 4 Typical damages in 2020 Elazig earthquakes in Turkey

building stock in the region is low-story masonry buildings constructed with walls, with low quality mortar. The damage that occurred in infill walls is similar to those observed in previous earthquakes. In the October 23, 2011 Van earthquake (M_w=7.2), the disaster was devastating as seen in Fig. 3. The buildings responded insufficiently during the experienced earthquake, even the earthquake was not at a level of a design earthquake defined in Turkish Design Code. After the main earthquake occurred in November 9, 2011, the Van Edremit earthquake (M_w=5.6) happened as a following earthquake. In this earthquake, more than 2000 buildings collapsed, and more than 4000 buildings were severely damaged. More than 600 people lost their lives and more than 4000 people were injured. The southeast part of Turkey has experienced a strong earthquake in Elazig (M_w=6.7) very recently on Jan 24, 2020. It was the second biggest earthquake in this region after the 2010 earthquake. This earthquake caused significant damage and led to the loss of lives. More than 300 buildings collapsed and 7,500 buildings were damaged. In Fig. 4, the damage that occurred in the region can be seen.

4. Methodology and results

The methodology used in this study is an improved rapid assessment methodology, which is similar to the one, used in the Istanbul Earthquake Master Plan studies and has been implemented by the Urban Transformation in 2012 in Turkey. The observations that took place after the experienced earthquakes in Turkey and some other countries have revealed that the main factors that cause the damage in RC buildings include irregularities in the buildings including soft stories, weak stories in architectural and structural systems, improper reinforcement detailing and using non-standard construction material (Yakut 2004). Factors such as soft and weak stories, heavy cantilever beams, short columns and low quality of labor cause the damage and the collapse in the buildings. During the Duzce earthquake in 1999, one of the most devastating earthquake in Turkey, similar damages were observed in buildings with basic architectural and structural system defects in similar soil conditions (SERU 2012, IEMP 2003). To minimize the structural damage caused by these factors during an earthquake, it is appropriate to use the rapid assessment methods based on detecting these factors. The proposed methodology consists of four phases as follow and seen in Fig. 5.

1. Determination of the vulnerability level of buildings by the rapid evaluation methodology

2. Re-arrangement of the parameters that cause the vulnerability

3. Implementation of more detailed examination to the neighborhood which has the closest performance score value to the average performance score value

4. Statistical analysis of the data obtained in the first and third stages finally determining threshold value

In the study, 26,610 buildings were examined by the research team. These buildings were selected within a region with similar soil and topographic conditions. The characteristics of the examined buildings are in the typical structural features of the multi-story concrete residential buildings. RC residential buildings are common all over the country. Structural systems are ubiquitous for many buildings in different cities (Yakut 2004, Korkmaz *et al.* 2010). In addition, the selected RC building types that constitute the focus of the study are 84% of all building stock. This is very important for the Antalya area in the historical process and the administrative factors.

4.1 Rapid assessment methodology

One of the most important stages of the regional earthquake risk assessment studies in the built environment

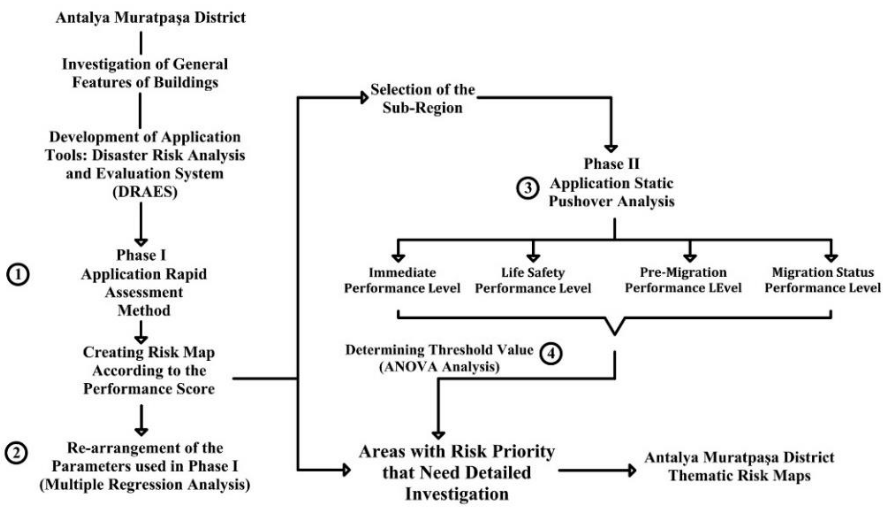

Fig. 5 The overall process of the applied method

is the rapid assessment methods used in determining the structural risk. The common point and the main aim of the rapid assessment methods is to determine the priority areas for detailed investigations within a city, thus providing time, labor, and cost savings. The rapid assessment methods used in structural risk classification aim to determine whether the buildings need a detailed examination with simple observations and measurements in a short period of time. The method is a preliminary examination approach that does not lead to a durable or weak result for buildings. Rapid assessment methods ignore risk factors that are not visible but that affect earthquake performance, as they are examinations made from outside observations. The method used shows that buildings have a performance score with the help of 11 parameters that together with the type of structural system and the soil has the possibility of damaging the buildings. The buildings are ranked according to the performance score they have received and evaluated comparatively within themselves. It is concluded that a building with a high performance score may be safer than a building with a low performance score. However, since no threshold value is specified in the method, it is difficult to comment on the results. Buildings are not classified as risky or risk-free in the method. They are examined comparatively according to each other. The rapid assessment methodology used in this study was developed to determine the factors that increase the probability of damage in RC buildings.

Fig. 6 Representative existing buildings in Antalya, Turkey

4.1.1 Performance score calculation

The method is performed by observing a number of factors that may cause damage and evaluating them with the help of determined coefficients and a mathematical function. The factors and their coefficients that may cause damage were determined by statistically examining of the thousands of buildings that were damaged by the Duzce earthquake in Turkey in the year 1999 (Sucuoglu *et al.* 2015). The parameters required for the application of the method are as follow.

1. Number of stories (1 to 7),
2. Quality of appearance (“good”, “medium” and “bad”)
3. Soft/weak story (yes/no),
4. Vertical irregularity (with and without),
5. The presence of Heavy weight (with / without),
6. Plan irregularity (with/without),
7. The presence of short column (with/without),
8. Adjacent buildings with neighboring buildings (with/without),
9. Slope status (based on with or without),
10. Earthquake zone and soil properties,
11. The type of structural system of the building as RC frame and shear walls.

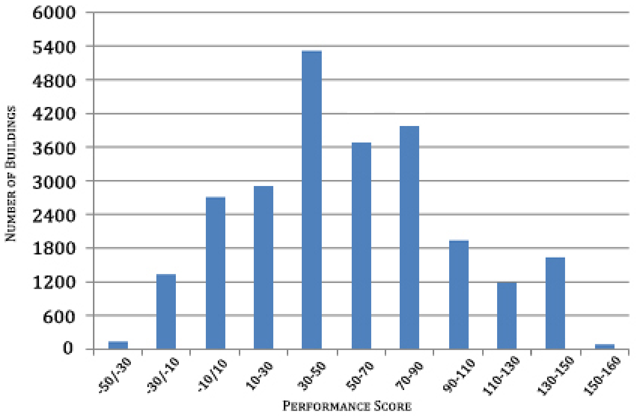

Fig. 7 Distribution of performance scores of the buildings examined

In the proposed methodology, buildings were given a base point (BP) according to the soil conditions (SC), positive parameter points according to the type of the structural system of the building (SS), and negative points according to the other parameters (O_i) and coefficients (C_i) of those parameters. The value function used is given in Eq. (1).

$$BP = SC + \sum_{i=1}^{n} O_i * C_i + SS \quad (1)$$

Typical irregularities considered in the study existing in the buildings in Antalya, Turkey are given in Fig. 6. In the Muratpasa district of Antalya that was selected as the study area, 26,610 buildings were examined with the help of the developed procedure to determine the irregularities in the architectural and structural systems of the buildings. The study was carried out by a team formed of Civil Engineers and City Planners with the help of the adapted version of DRAES software developed for this study (Kepenek and Gencel 2017). A numerical distribution of Performance Scores of the Buildings Examined is given in Fig. 7. Fig. 8 shows the spatial distribution of the buildings according to their performance scores.

4.1.2 Reassessment of parameters

The relationships between parameters were explained by regression analysis. In the regression analysis, performance scores obtained by examining buildings were taken as dependent variables and parameters collected during the field study to find performance scores were taken as independent variables. Afterwards, the parameters were rearranged according to the model description levels. As shown in Table 1, when the effect levels between the parameters were examined, it was found that the factor that most affected the performance score, the value whose R^2 value was closest to 1, was the "number of stories". In the generated model, the description rate of the "number of stories" is 66%. However, the following point should be taken into account as well; although the first reason affecting the performance score in the research is the number of stories, the interaction between the number of stories and the soil properties is the most important factor determining the destructive effect of the earthquake (Scarfone *et al*. 2020).

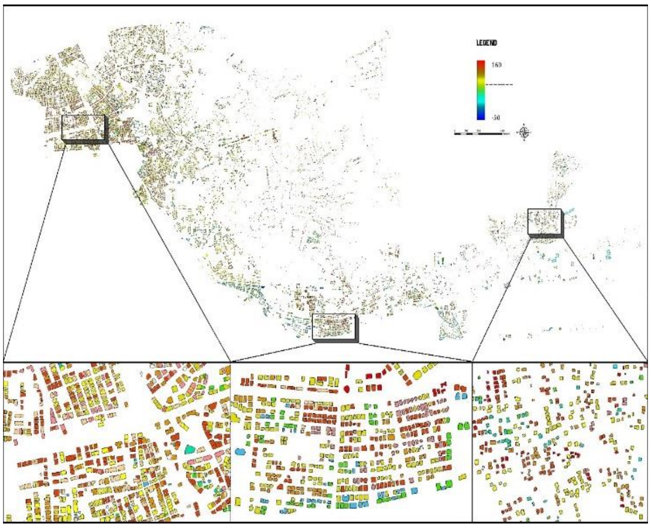

Fig. 8 Spatial distribution of the buildings examined according to performance scores

Table 1 Number of story-performance score relationship model summary

Model	*R*	*R* Square	Adjusted *R* Square	Std. Estimated Error
1	0.81	0.66	0.66	24.55

Table 2 Coefficients of relationship between number of stories and performance score

Model	Non-Standard Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Err	Beta		
Constant	174.481	0.937		186.146	0.000
Number of Stories	-25.420	0.193	-0.814	-131.747	0.000

Table 2 represents the "F" test showing the significance of the model and the sig. value, which indicates the significance level of the F value. The sig. stands for the significance value indicating the amount of error that can occur in a comparison to decide whether there is a statistically significant difference (Kalayci 2010). Evidence of statistically significant difference increases as the sig. value decreases. The model described with sig 0.000a is a significant model with less than 5% error. As given in Table 2, one unit change in the number of stores in the buildings in the study area causes a change in performance score of twenty-five units when other variables remain constant.

According to the model created for the study area, "vertical irregularity" is the parameter that affects the least performance score. Asymmetrical or irregular vertical carrier elements such as columns and shear walls change the center of mass in a plan significantly. In such cases, seismic forces acting on the buildings increase (TDC, 2007). The irregularities are either soft story, weak story, unparalleled vertical elements of the structural system or discontinuities in vertical elements. In the study, in addition to the soft story and weak story irregularities, the unparalleled vertical elements in the building or discontinuity are considered as vertical irregularities. The

Table 3 Vertical irregularity and performance score relationship model summary

Model	R	R Square	Adjusted R Square	Std. Estimated Err
1	0.059[a]	0.004	0.003	42.159

Table 4 Relationship between vertical irregularity and performance score coefficients

Model	Non-Standard Coefficients		Standardized Coefficients	t	Sig.
	β	Std. Err	Beta		
Constan	56.314	0.455		123.816	0.000
VI	-14.387	2.574	-0.059	-5.590	0.000

Table 5 All parameters and performance score relation model summary

Model	R	R Square	Adjusted R Square	Std. Estimated Err
1	0.977	0.954	0.954	9.036

Table 6 Relation of all parameters and performance score coefficients

Model	Non-Standard Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Err	Beta		
Constant	241.119	0.730		330.080	0.000
Number of Stories	-23.088	0.080	-0.739	-287.773	0.000
Ground Slope	-9.230	0.946	-0.023	-9.753	0.000
Building Visual Quality	-21.118	0.205	-0.252	-103.260	0.000
Plan Irregularity	-7.352	0.204	-0.085	-35.972	0.000
Vertical Irregularity	-11.672	0.554	-0.048	-21.067	0.000
Short Column	-2.397	0.313	-0.018	-7.652	0.000
Weak Soft Stories	-28.183	0.210	-0.334	-134.164	0.000
Heavy Duty	-27.355	0.224	-0.289	-122.165	0.000
Adjacent Building Story Level	- 4.106	0.404	-0.026	-10.166	0.000

description for the rate of the "vertical irregularity" is 0.4% as given in Table 3. The effect level of parameters for "vertical irregularity" is low since it is the most difficult parameter to determine among irregularities detected by external observation, which is also specified by users during fieldwork. The "Vertical irregularity" was determined to be about 0.7% of the buildings in the examined area. The model created for the "vertical irregularity" parameter is a significant model with a value of sig. 0.000 which is the same as the "number of stories" parameter model given in Table 4.

When the parameters used in the calculation of the performance score are examined together, the created model gives a high percentage of 95% overall meaningful results as given in Table 5. When the relationship between the "t" values of all variables is examined, the "Weak-Soft Story" parameter makes the most effect on performance score in one unit change. With the value of -28, "Soft and weak story" parameters are the most influential factors among the negative parameters in the Muratpasa district as given in

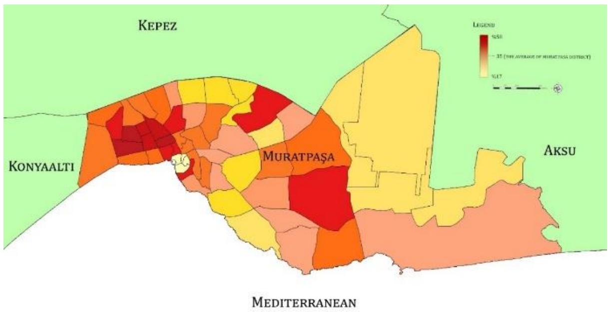

Fig. 9 Graphical distribution of average performance scores in neighborhood

Table 7 Significance level of the model established

	Sum of Squares	df	Mean Squares	F	Sig.
Between Groups	20,893.266	3	6,964.422	6.527	0.001
Within Groups	69,357.169	65	1,067.033	-	-
Total	90,250.435	68	-	-	-

Table 6. With this examination, it will be possible to reduce the number of parameters for the study area by examining the effect of each of the parameters separately and all together to the performance score.

4.2 Determination of threshold value

The analysis of variance (ANOVA) is used to calculate the significance of the difference between three and more independent averages in a normally distributed series. ANOVA compares the arithmetic means of three or more groups cumulatively. The basic condition for "ANOVA" can be explained with the averages of the main masses to be examined with the same variance. If the variances are homogeneous, all assumptions are fully met with whole mass. Therefore, the area to be examined in more details is selected as the neighborhood in which the average performance score is closest to the average performance score of the main mass. The selected neighborhood is determined to be closest to the average performance score of the study area, which is 48 with an average of 43 performance points. Graphical distribution of neighborhoods according to average performance scores is given in Fig. 9.

In Fig. 9, the performance score distributions of the examined buildings are given in graphical presentation. As seen in the Fig. 9, the distribution gives the symmetrical distribution. Table 7 shows the result of the homogeneity of the variance test, which is the basic assumption of a one-way ANOVA analysis. Hence, the variances are homogeneous (0.001) because the sig. value is less than 0.05 per the basic assumption made in the analysis. As a result of the study, it is observed that the found values for the variance in the analysis are significant.

The buildings examined were classified into four subgroups which include immediate use performance level, life safety performance level, pre-collapse performance level, and collapse performance level. In Table 8, the numbers, averages, standard deviations, and standard error

Table 8 The relationship between performance levels and performance scores

	N	Average	Std. Deviation	Std. Error
Immediate Use Performance Level	4	61.00	29.69	21.00
Life Safety Performance Level	44	61.13	31.91	6.80
Pre-Migration Performance Level.	74	25.62	32.98	5.42
Migration Status Performance Level	16	20.62	33.64	11.89
Total	138	37.39	36.43	4.38

Table 9 Performance scores acceptance range highest and lowest values

	95% Confidence Interval for Averages		Least	Most
	Lowest Value	Highest Value		
Immediate Use Performance Level.	err	err	40.00	82.00
Life Safety Performance Level.	**46.98**	75.28	10.00	105.00
Pre-Migration Performance Level	14.62	36.61	-18.00	90.00
Migration Status Performance Level	-7.49	48.74	-15.00	60.00
Total	28.63	46.14	-18.00	105.00

margins of the buildings are examined by static pushover analysis, which is the 2nd stage examination method. The first and second stage survey results of 138 buildings were compared in Table 8. Accordingly, four buildings were determined as immediate use performance level, 44 buildings were at life safety performance level, 74 buildings were at pre-collapse performance level, and 16 buildings were at collapse performance level. The average performance score of the buildings with immediate use performance level is 61. The average of the buildings with life safety performance level is 61.13. The average performance score of buildings with pre-collapse and collapse performance level is 25.62 and 20.62 respectively. Hence, it is found that, there is a consistent relationship between the average performance scores and the performance levels in the model.

Table 9 represents the highest and lowest values of the performance scores of buildings within the 95% confidence interval and the highest and lowest performance scores in the performance levels of the entire data set. Accordingly, the lowest value defined in the confidence interval, which provides the life safety performance level, can be accepted as “46.98” threshold value for use in the whole study area. Fig. 10 shows Micro zoning according to this threshold value.

As seen in Fig. 10, micro zoning is defined based on the threshold value “46.98” which is determined for the selected region. According to the data obtained, it is possible to make a sub zoning study in the Muratpasa district. In addition, 10,482 out of 26,610 buildings were defined as under the threshold, and were identified as buildings in need of detailed examination.

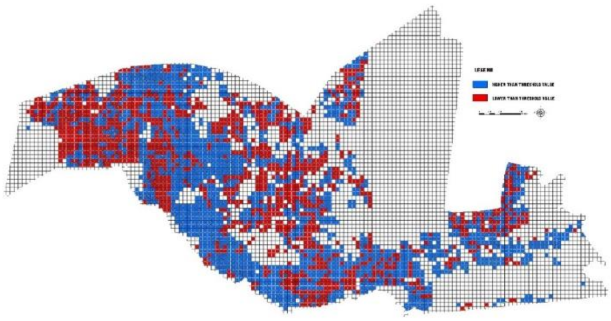

Fig. 10 Micro zoning according to determined threshold value in selected region

5. Discussion

A threshold value is required to determine the risk levels of the buildings. As the threshold value increases, the numbers of risky buildings decrease and the urban transformation process takes a more protective approach. As the threshold value increases, the number of buildings and other costs to be examined in details decreases, but the risk ratio increases. Yakut *et al*. (2012) revealed the relationship between the expected performance score and the predicted performance score. Research achieved 71% accuracy in high risk buildings and 75% accuracy in low risk buildings with the rapid assessment method. Mansouri *et al*. (2010) conducted a similar study. They classified buildings according to the performance score he determined and achieved 70% accuracy at high- medium risk level and 72% at low risk level. In both studies, rapid evaluation methods gave accurate results with their boundaries. Therefore, it can be concluded that the rapid evaluation values are reliable when the threshold value is correctly decided and clearly seen and when the importance of field surveys carried out on buildings is dependable.

The threshold values determined in this study were found to be the result of a more detailed analysis in a sub-region with the arithmetic mean closest to the main mass. For the sake of time and cost, rapid assessment methods will be beneficial. Applying the threshold values in the sub-regions first, then in the district and e the province will give more accurate results as well. Additionally, rearranging, grouping, or subtracting less effective parameters in the sub-regions from the functions used in the method will also save time and cost. Soil properties, settlement patterns, building materials and their properties and many features such as construction techniques differ from each other in almost every province in Turkey. Sonmez et. al. (2018) in their study in the Kirikkale province in Turkey through street survey based on rapid assessment conclude that rather than the number of storeyss, heavy overflow and short column presence are more effective variables for a possible damage of buildings. This situation shows that different parameters in different regions and even in the same country increase the vulnerability of the cities against earthquakes. Therefore, it is not possible to use a defined threshold value in every province. Such problems can be solved by choosing different threshold values for each city.

Some studies that determine the regional risk level were prepared in many countries including Turkey. Urban vulnerabilities were tried to be determined with the help of the Analytical Hierarchical Process and TOPSIS analysis methods by using similar parameters. The presence of short column, soft storey, adjacent buildings with neighbor buildings, age of building, and recessed balcony are some of the parameters in the study conducted by Kumlu and Tudes (2019) at the urban level. However, Danumah *et al*. (2016) and Papaioannou *et al*. (2015) stated that only using the Analytic Hierarchical Process as a. multicriteria decision-making technique may fail due to the fact that value judgments will change according to experts. Therefore, additional methods in which possible risk values of regions can be determined more accurately with the help of threshold values should be integrated into such studies. Hence, variations in personal judgments can be minimized.

4. Conclusion and recommendations

Turkey is located in one of the most seismically active regions. Most of the big cities in Turkey are at high risk. Natural disasters may cause more destruction in developing countries such as Turkey. The results are much worse when compared to the destruction that happens in more developed countries (Parker 2006). Therefore, in order to do more effective disaster management in Turkey, disaster management principles and practices should be developed according to local studies. Global protections may not be effective as in other places. The levels of detailing in different analysis methods give different results. None of the results can specify whether the buildings are risky or not. The decision can only be made once detailed investigations are carried out. In the present study, the first level of investigation has been carried out and the second stage is introduced. In the second stage, the buildings are divided into four different groups and there is no classification in the rapid assessment methodology used in the first stage. The buildings are ranked according to the performance score they got, and they were evaluated comparatively. It is concluded that a building with a high-performance score may be safer than a building with a low performance score. Since the method is a comparative evaluation and does not specify any threshold values, it is difficult to comment on the results. In Turkey, it is becoming difficult to apply such method to determine the regional risk due to the building typologies in urban areas.

This study presents a report that was developed to use in local administrations and managers in Antalya to reduce earthquake risk damage by means of site-specific application tools using enacted examination methods in Turkey. From 26,610 buildings 138 were selected which were evaluated by the rapid assessment method and were examined by detailed investigation. Thus, a threshold value was determined to be used for 26,610 buildings and throughout the whole city. Determined threshold value is based on the detailed examination of buildings and the relationship between building parameters and high probability of damage. When the accuracy of previous studies is considered, the presented seismic risk prioritization study is thought to be a reliable procedure if detailed and accurate data is used. The study can be used as a basis for the initiation of detailed seismic risk mitigation planning by disaster risk mitigation decision makers.

In addition to the classification of the buildings that may be damaged after the earthquake with the method presented in the study, intervention plans can be prepared to contribute to the disaster management system against the earthquake hazards that may occur in the near future. Today, there are damage maps that can be prepared using satellite images (Syifa *et al*. 2014). However, these maps are not so reliable and accurate for a quick estimation (Maqsood and Schwarz 2011, Feng *et al.* 2013). Therefore, the interventions that will be carried out using prepared risk maps and damage maps using satellite images will be more accurate and reliable. Building-specific estimation is more accurate and reliable than the satellite imagery methods if it is used for an area since it is based on the properties of a specific buildings (Ranjbar *et al.* 2016). The recommended method in this study can also be used in other developing countries with the local building data.

Acknowledgments

The research described in this paper was financially supported by the Suleyman Demirel University Scientific Research Projects Coordination Unit, Project number: 3482-D2-13.

References

Aochi, H. and Ulrich, T. (2015), “A probable earthquake scenario near Istanbul determined from dynamic simulations”, *Bull. Seismol. Soc. Am.*, **105**(3), 1468-1475. https://doi.org/10.1785/0120140283.

Boduroğlu, H., Özdemir, P., İlki, A., Şirin, S., Demir, C. and Baysan, F. (2004), “Towards a modified rapid screening method for existing medium rise R/C buildings in Turkey”, *Proceedings of 13th World Conference on Earthquake Engineering*, Vancouver, Canada, August.

Coburn, A. and Spence, R. (2002), *Earthquake Protection*, John Wiley & Sons, West Sussex, England.

Dabbeek, J. and Silva, V. (2020), “Modeling the residential building stock in the Middle East for multi-hazard risk assessment”, *Nat. Hazard.*, **100**, 781-810. https://doi.org/10.1007/s11069-019-03842-7.

Danumah, J.H., Odai, S.N., Saley, B.M., Szarzynski, J., Thiel, M., Kwaku, A., Kouame, F.K. and Akpa, L.Y. (2016), “Flood risk assessment and mapping in Abidjan district using multi-criteria analysis (AHP) model and geoinformation techniques, (cote d’ivoire)”, *Geoenvironmental Disasters*, **3**, 10. https://doi.org/10.1186/s40677-016-0044-y.

Feng, T., Hong, Z., Wu, H., Fu, Q., Wang, C., Jiang, C. and Tong, X. (2013), “Estimation of earthquake casualties using high-resolution remote sensing: a case study of Dujiangyan city in the May 2008 Wenchuan earthquake”, *Nat. Hazard.*, **69**, 1577-1595. https://doi.org/10.1007/s11069-013-0764-1.

Gülkan, P. and Sözen, M.A. (1999), “Procedure for determining seismic vulnerability of building structures”, *ACI Struct. J.*, **96**(3), 336-342.

Hassan, A.F. and Sözen, M.A. (1997), “Seismic vulnerability assessment of low-rise buildings in regions with infrequent earthquakes", *ACI Struct. J.*, **94**(1), 31-39.

IEMP (2003), Istanbul Earthquake Master Plan Report, Istanbul Metropolitan Municipality, Istanbul, Turkey.

Kalaycı, S. (2010), *SPSS Applications for Statistical Problems in Multi Degree Cases,* Ankara, Turkey. (in Turkish)

Kepenek, E. (2016), "A structural risk classification model proposal for urban transformation", Ph.D. Dissertation, Suleyman Demirel University, Isparta, Turkey.

Kepenek, E. and Gençel, Z. (2017), "A tool for comperative disaster risk analysIs and evaluation in urban areas (DRAES)", *Proceedings of Al Azhar's 14th International Conference on: Engineering, Architecture & Technology*, Cairo, Egypt, December.

Korkmaz, K.A., Irfanoglu, A. and Kayhan, A.H. (2010), "Seismic risk assessment of buildings in Izmir, Turkey", *Nat. Hazard.*, **54**(1), 97-119. https://doi.org/10.1007/s11069-009-9455-3.

Kumlu, K.B.Y. and Tudes, S. (2019), "Determination of earthquake-risky areas in Yalova city center (Marmara region, Turkey) using GIS-based multicriteria decision-making techniques (analytical hierarchy process and technique for order preference by similarity to ideal solution)", *Nat. Hazard.*, **96**, 999-1018. https://doi.org/10.1046/j.1365-246x.2000.00137.x.

Mansouri, B., Ashtiany, M.G., Hosseini, K.A., Nourju, R. and Mousavi, M. (2010), "Building seismic loss model for Tehran", *Earthq. Spectra*, **26**(1), 153-168. https://doi.org/10.1193/1.3280377.

Maqsood, S.T. and Schwarz, J. (2011), "Estimation of human casualties from earthquakes in Pakistan", *Seismol. Res. Lett.*, **82**(1), 32-41. https://doi.org/10.1785/gssrl.82.1.32.

Murty, C.V.R., Brzev, S., Faison, H., Comartin, C.D. and Irfanoglu, A. (2006), "At risk: The seismic performance of reinforced concrete frame buildings with masonry infill walls", Earthquake Engineering Research Institute, WHE-2006-03, 70.

Nanda, R.P., Paul, N.K. and Chanu, N.M. (2019), "Seismic loss estimation tool as rapid survey for prioritizing buildings for disaster preparedness: case study to hospital buildings", *Nat. Hazard.*, **95**, 769-781. https://doi.org/10.1007/s11069-018-3518-2.

Papaioannou, G., Vasiliades, L. and Loukas, A. (2015), "Multi-criteria analysis framework for potential flood prone areas mapping", *Water Res. Manage.*, **29**(2), 399-418. https://doi.org/10.1007/s11269-014-0817-6.

Parker, R.S. (2006), *Hazards of Nature, Risks to Development: An IEG Evaluation of World Bank Assistance for Natural Disasters*, World Bank, Washington, DC, USA.

Pay, A.C. (2001), "New methodology for the seismic vulnerability assessment of existing buildings in Turkey", Master Thesis, Middle East Technical University, Ankara, Turkey.

Ranjbar, H.R., Dehghani, H., Ardalan, A.R.A. and Seradjian, M.R. (2016), "A GIS-based approach for earthquake loss estimation based on the immediate extraction of damaged buildings", *Geomat. Nat. Hazard. Risk*, **8**(2), 772-791. https://doi.org/10.1080/19475705.2016.1265013.

Scarfone, R., Morigi, M. and Conti, R. (2020), "Assessment of dynamic soil-structure interaction effects for tall buildings: A 3D numerical approach", *Soil Dyn. Earthq. Eng.*, **128**, 105864. https://doi.org/10.1016/j.soildyn.2019.105864.

SERU (2012), "Structural engineering research unit archives", Middle East Technical University Civil Engineering Department, Ankara, Turkey.

Shiga, T., Shibata, A. and Takahashi, T. (1968), "Earthquake damage and wall index of reinforced concrete buildings", *Proceedings of 12th Tohuku District Symposium*, Architectural Institute of Japan, Sendai, Japan, November.

Sindel, Z., Akbaş, R. and Tezcan, S.S. (1996), "Drift control and damage in tall buildings", *Eng. Struct.*, **18**(12), 957-966. https://doi.org/10.1016/0141-0296(95)00215-4.

Sonmezer, Y.B., Bas, S. and Akbas, S.O. (2018), "Seismic risk estimation of kırıkkale province through street survey based rapid assessment method (SSRA)", *Earthq. Struct.*, **14**(6), 615-626. https://doi.org/10.12989/eas.2018.14.6.615.

Sucuoglu, H., Yakut, A., Ozmen, A. and Kubin J. (2015), "Seismic risk prioritization and retrofit cost evaluation of code-deficient RC public buildings in Turkey", *Earthq. Spectra*, **31**(1), 601-614.

Syifa, M., Kadavi, P.R. and Lee, C.W. (2019), "An artificial intelligence application for post-earthquake damage mapping in Palu, central Sulawesi, Indonesia", *Sensor.*, **19**(3), 542. https://doi.org/10.3390/s19030542.

Turkish Design Code (2007), Regulation on Structures to be Made in Earthquake Zones, Ministry of Public Works and Settlement, Ankara, Turkey.

Yakut, A. (2004), "Preliminary seismic performance assessment procedure for existing RC buildings", *Eng. Struct.*, **26**(10), 1447-1461. https://doi.org/10.1016/j.engstruct.2004.05.011.

Yakut, A., Gülkan, P., Bakır, B.S. and Yılmaz, M.T. (2005), "Re-examination of damage distribution in Adapazarı: Structural considerations", *Eng. Struct.*, **27**(7), 990-1001. https://doi.org/10.1016/j.engstruct.2005.02.001.

Yakut, A., Özcebe, G. and Yücemen, M.S. (2006), "Seismic vulnerability assessment using regional empirical data", *Earthq. Eng. Struct. Dyn.*, **35**(10), 1187-1202. https://doi.org/10.1002/eqe.572.

Yakut, A., Sucuoğlu, H. and Akkar, S. (2012), "Seismic risk prioritization of residential buildings in İstanbul", *Earthq. Eng. Struct. Dyn.*, **41**(11), 1533-1547. https://doi.org/10.1002/eqe.2215.

CC