# THE IMPACT OF EARTHQUAKES ON ECONOMIC DEVELOPMENT: CASE OF DENIZLI-TURKEY

**[1]ERDAL AKYOL, [2]SUAT TASDELEN, [3]NIHAT BATMAZ, [4]ALI AYDIN, [5]ALI KAYA, [6]EMIN BARLAS**

[1,2,3,4,5,]Pamukkale University, Denizli, Turkey, [6]Gaziosmanpasa University, Tokat, Turkey
E-mail: eakyol@pau.edu.tr, stasdelen@pau.edu.tr, nbatmaz@pau.edu.tr, aaydin@pau.edu.tr, alikaya@pau.edu.tr, emin.barlas@gop.edu.tr

**Abstract—** Natural disasters are a clear example of people living in conflict with the environment. Disasters cause human, social and environmental losses and, sometimes, even threaten geopolitical stability, as in many less developed countries. In order to reduce earthquake damages, it is crucial to estimate seismic performance of buildings in tectonically active areas. Structural system, date and quality of construction and geotechnical properties of soil are important parameters, which affect seismic behavior of the buildings. In this study, building inventory data collected by Turkish Statistical Institute are used to assess the damage states to buildings in Denizli City. Damage assessment for the buildings is made based on an earthquake of magnitude 6.4 on Pamukkale fault line. HAZUS methodology is adapted to reflect building stock in Turkey. Building damage, life loss and maximum ground acceleration maps, which will be used to prepare emergency plans and take safety measures, and effects on economy are discussed for Denizli.

**Index Terms—** Damage assessment, Denizli, earthquake, natural disaster, economic development.

## I. INTRODUCTION

Natural disasters have numerous impacts on national economies that can bear on the conduct of economic policy, on the sustainability of long-term development strategies, and on productive performance. These impacts are particularly relevant in the countries of Latin America and the Caribbean, which frequently experience natural disasters of various origin and intensity, with the sequel of human lives lost and grave economic and social impact [1].

The impact of natural disasters is increasing over time in parallel to the expansion of human activity. Furthermore, growing urbanization increases exposure and vulnerability of large numbers of people to natural hazards. The escalation of severe disaster events triggered by natural hazards is increasingly threatening both sustainable development and poverty-reduction initiatives.

During the past four decades, natural hazards such as earthquakes, droughts, floods, storms and tropical cyclones, wildland fires, and volcanic eruptions have caused major loss of human lives and livelihoods, the destruction of economic and social infrastructure, as well as environmental damages. There is a close correlation between the trends of increased demographic pressure especially in developing countries, and particularly in least developed countries, escalated environmental degradation, increased human vulnerability and the intensity of the impact of disasters.

Poverty and hazard vulnerability are integrally linked, thereby increasing both the risk and exposure to disasters. Sustainable and integrated management of natural resources will increase the resilience of communities to disasters by reversing current trends of environmental degradation.

## II. MACROECONOMIC IMPACTS OF NATURAL DISASTERS

In the event of a natural disaster, humanitarian, economic and ecological impacts and effects may occur as illustrated in Fig. 1 [1].

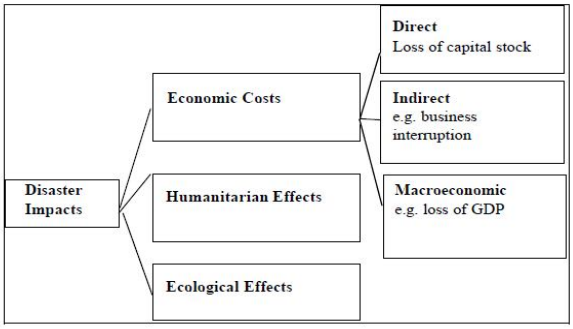



**Fig. 1 Natural disaster impacts [1].**

Humanitarian effects include loss of life, affected people and psychological post-disaster effects; ecological effects comprise the loss of arable land, forests and damage to ecosystems. Economic effects are usually grouped into three categories: direct, indirect, and macroeconomic (also called secondary) effects. These effects fall into stock and flow categories: Direct losses describe the physical impacts on infrastructure (transport, energy and water), buildings, machinery and agricultural assets. They are roughly equal to stock impacts. These can be caused by the disaster itself or by follow-on physical destruction (e.g. through fire). Indirect losses occur as a consequence of these direct stock losses and include

production and wage losses due to business interruption. The macroeconomic impacts comprise the aggregate impacts on economic variables like gross domestic product (GDP) and inflation due to the effects of disasters, as well as the reallocation of government resources for relief and reconstruction efforts. Because macroeconomic effects reflect indirect damage as well as relief and restoration efforts, these effects cannot simply be added up without causing duplication [1].

## III. BUILDING STOCK IN DENIZLI

In Denizli, 65% of the buildings have reinforced concrete (RC) structural system, 33% of the stock is masonry and the rest is constructed using other structural systems (Fig. 2). RC structures, which are 2/3 of the stock, are mostly constructed after 1970. On the other hand 1/3 of masonry structures are constructed before that (Fig. 3). It is because of fast urbanization due to industrial development after 70s, number of buildings increased rapidly. In this process, old buildings were not replaced. Instead, owners preferred to use old ones and they constructed new buildings in suburbanized areas. Therefore, non-circulation of building stock has caused poor city-planning.

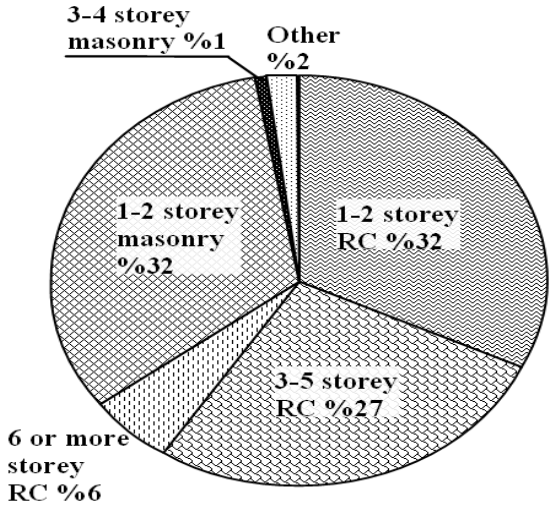
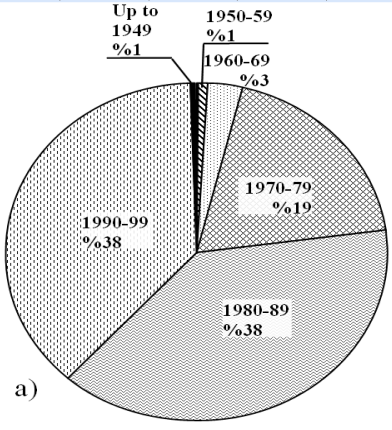



**Fig. 2: Distribution of buildings according to structural system**



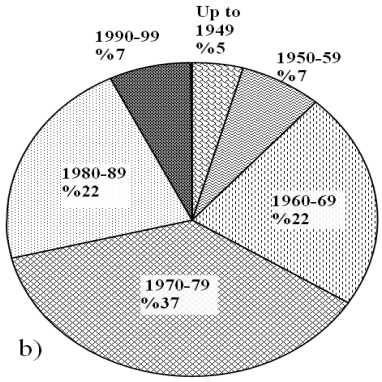




**Fig. 3 : Distribution of buildings according to date of construction; a) RC, b) Masonry**

Distribution of buildings according to their number of storeys is shown in Fig. 4. Almost all of the masonry buildings have 1 or 2 storeys. 1/6 of RC structures have 5 or more storeys, in which damage and losses increase with respect to ones having fewer storeys in Turkey. These multi-storey and old masonry buildings are in central parts of the city mostly. After grading, all buildings are qualified as good, fair or low. Distribution of buildings according to this qualification is shown in Fig. 5. Half of RC structures can be described as fair quality, where only a quarter is qualified as good. On the other hand, 69% of the masonry structures are good quality buildings as 75% of them have one storey.

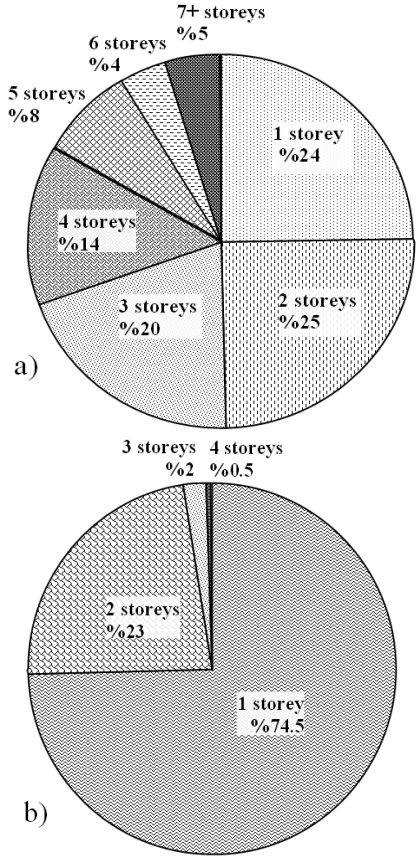



**Fig. 4 : Distribution of buildings according to number of storeys; a) RC, b) Masonry**

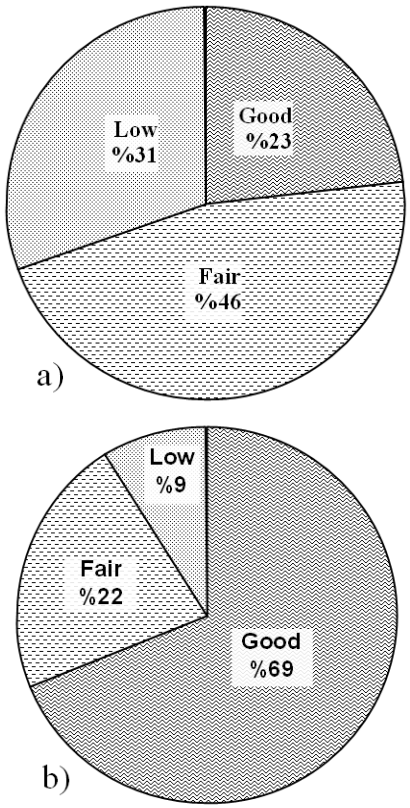



**Fig. 5 : Distribution of buildings according to quality; a) RC, b) Masonry**

## IV. DAMAGE AND LOSS ESTIMATION

Building capacity against lateral loads can be calculated by pushover analysis without nonlinear dynamic analysis. Capacity spectrum method (CSM) is another efficient tool that used to determine a building's displacement level (performance) for a given earthquake demand. Details can be found in reference [3]. There are many factors affecting building capacity. Capacity of a building is defined with its lateral load carrying capacity and ductility. However, these may change significantly with changes in material quality, lateral and longitudinal reinforcement ratios, structural system type, structural irregularities and some other factors.

The employed coefficients that define building capacity were modified to reflect building stock in Turkey. These parameters have been tailored from [4], [5]. Another factor affecting the performance of a building is the earthquake demand. Maximum expected earthquake around the area would have M= 6.4 considering the faults around the city. Peak ground acceleration maps of the city is taken from [6] and shown in Fig. 6. This map is prepared using attenuation relationship proposed by Reference [7]. Map shows peak accelerations arisen from Pamukkale fault line, which treats the city [8].

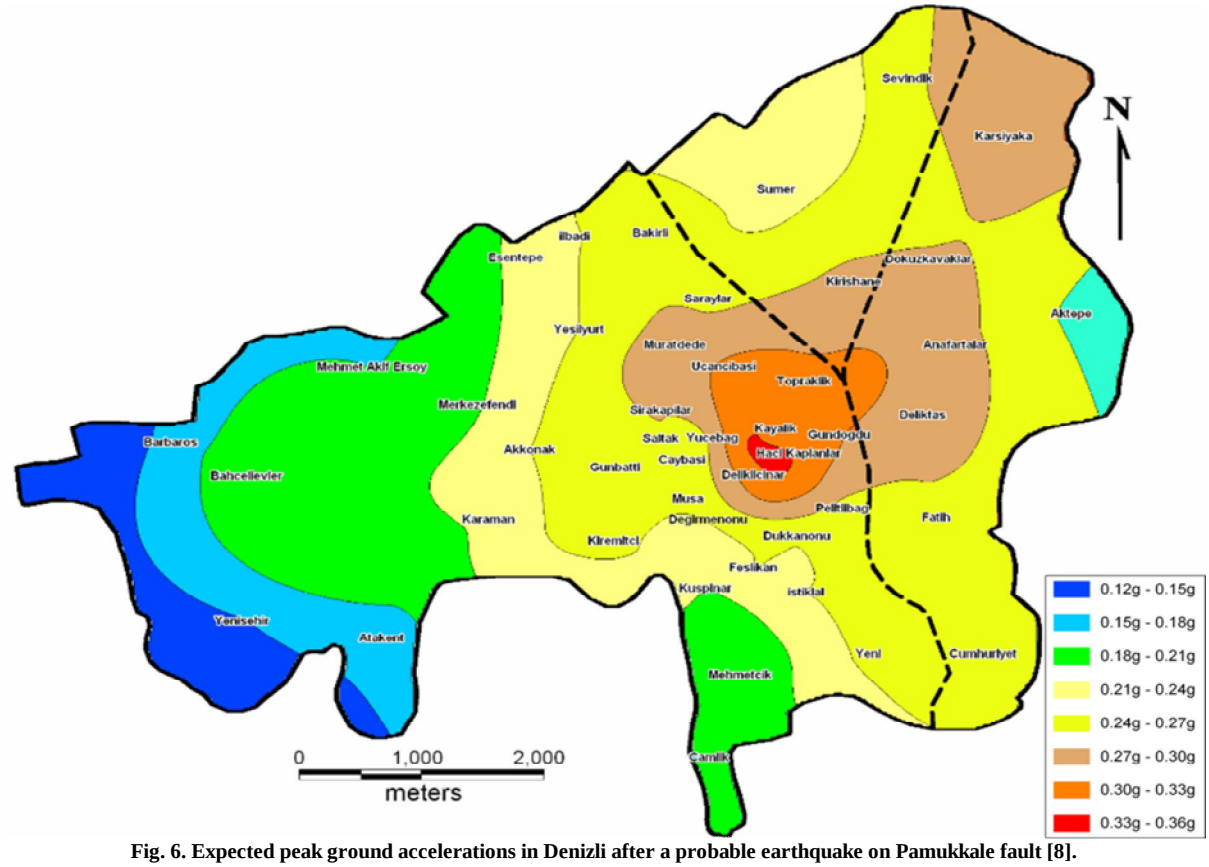


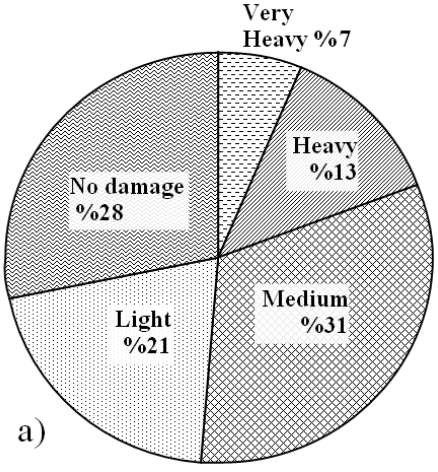

**Fig. 6. Expected peak ground accelerations in Denizli after a probable earthquake on Pamukkale fault [8].**

To determine seismic vulnerability of structures, CSM is utilized to calculate performance points of each structure. Concerning geographical location of buildings, different demand spectrums are used in the

calculation. In this study, building damages classified into 4 categories: light, moderate, heavy, very heavy. Buildings, not included in any one of these, are considered as non-damaged.

Varying ratios of very heavily damaged structures, depend upon structural system, are assumed as collapsed buildings. For RC structures, 20% of 1-2 storey, 15% of 3-5 storey, and 10% of higher very heavily damaged structures and 25% of very heavily damaged masonry structures are expected to collapse. Injury matrices given in [7] to estimate the number of injuries and deaths are adapted to the cases in Turkey. Average house costs (per 1 $m^2$) in each quarter are determined by field investigations to calculate economic losses. It is assumed that heavily or very heavily damaged buildings will lose all their value. On the other hand, buildings with moderate damage will lose 30% and those have light damage will lose 10% of its economic value [5].

It is estimated that 720 people will be dead after the scenario earthquake. 5050 of 42000 buildings will be heavily damaged and 1100 of them will totally collapse. After such an earthquake, 4400 people will need medical treatment in hospitals. Total economic losses are estimated to be around 1.76 billion dollars. In Fig. 7, damage distribution in RC and masonry structures is illustrated. Only 20% of RC structures will be damaged heavily or very heavily, whereas this ratio increases up to 42% for masonry structures. Ratios of serviceable flats after scenario earthquake are shown in Fig. 8. 74300 of flats in the city are in RC structures. Only 15800 flats are in masonry structures. After the earthquake, 17300 of them will be out of service. 38000 would be usable after a seismic retrofit and strengthening of the structures. In light of this data, 75000 people will be faced with sheltering problem. It is estimated that 1.6 billion dollar of all the economic losses would result from damages in RC structures. This estimation does not include industrial damages and work-day losses which are crucial for the industrialized city of Denizli.



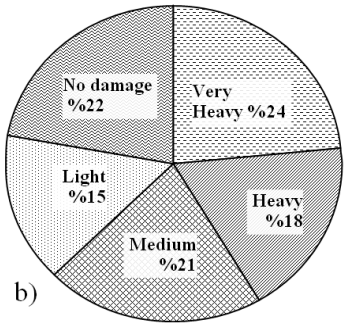




**Fig. 7 Damage distribution; a) RC, b) Masonry**

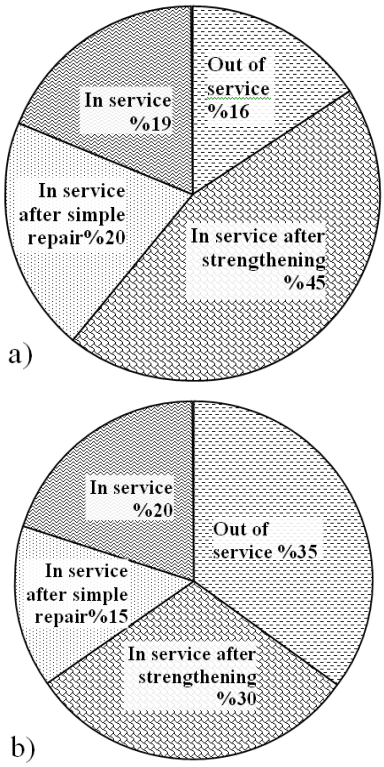



**Fig. 8 Serviceability of flats; a) RC, b) Masonry**

Estimated damages in the city are also mapped and Fig. 9 shows collapse ratio of buildings. Old and squatter parts of the city are the most critical regions. Deaths in 1 $km^2$ area are illustrated in Fig. 10. In Fig. 11, economical losses per capita are figured out. It is so similar to damage maps as they increase with the damage. Another major problem that will be faced with after the quake is the sheltering. The flats which cannot be used after the earthquake are given in Fig. 12.

## V. RESULTS

Denizli is located in highly active tectonic area. They cause a large number of catastrophic earthquakes both in historical and recent times. Although, current approaches in seismic vulnerability evaluation methods include three main stages: walk-down, preliminary and final evaluations which require abundant time, qualified workmanship and financial

sources in this study. Another stage that does not need giant sources has been employed before starting the stages for optimized planning. The data are evaluated to obtain each building's structural system, construction date and quality. The developed scenario includes both the structural information and geotechnical properties. Capacity spectrum for each building is calculated using the parameters adapted from HAZUS to reflect building stock in Turkey. The demand spectrums are shaped by attenuation relations. Then, using the CSM, performance of each building is calculated as spectral displacements, which is used to define seismic vulnerability of structures.

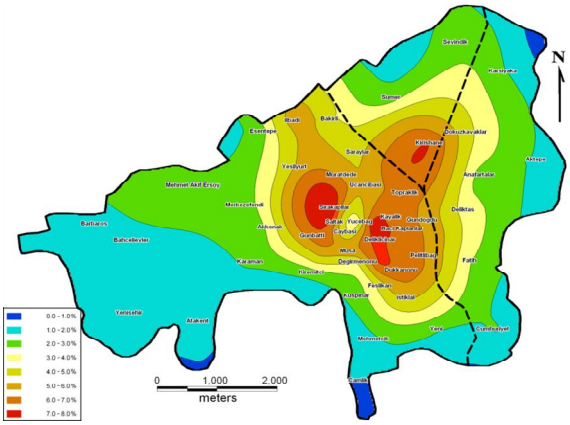



**Fig. 9 Ratio of collapsed buildings (%)**

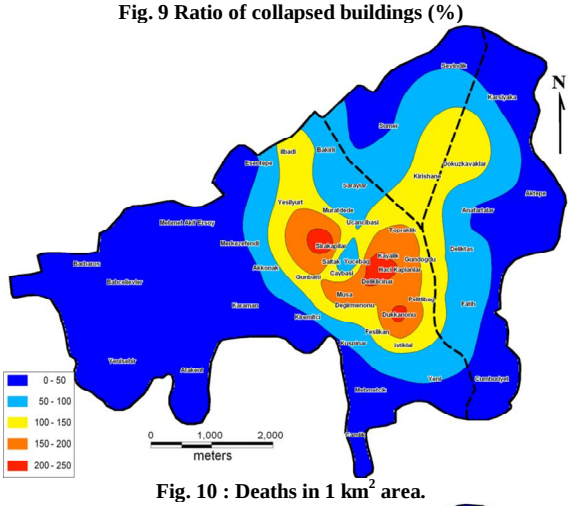



**Fig. 10 : Deaths in 1 km$^2$ area.**

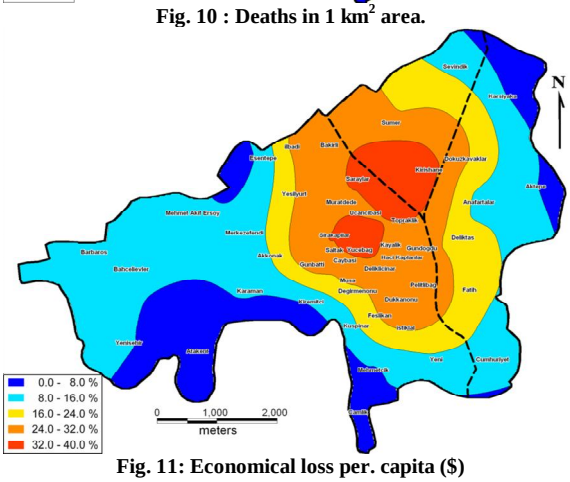



**Fig. 11: Economical loss per. capita ($)**

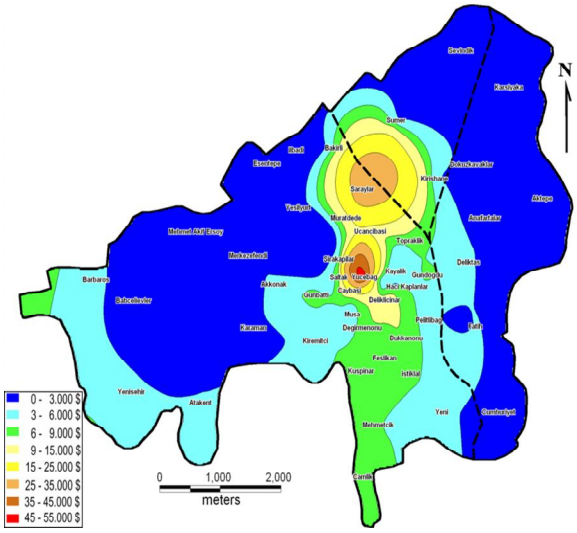



**Fig. 12: Economical loss per person**

Damages are observed mostly in old settlement and the squatters areas, in which masonry structures are the most popular ones. The study estimates that 720 people will be dead after the scenario earthquake. 5050 of 42000 buildings will be heavily damaged and 1100 of them will totally collapse. After such an earthquake, 4400 people will need medical treatment in hospitals and total economic losses will be around 1.76 billion dollars. After the earthquake, 17300 flats will be out of service while 38000 of them would be usable after seismic strengthening. In light of the obtained results, 75000 people will be faced with sheltering problem in Denizli.

The results clearly demonstrate that if the mitigation measures are not implemented, enormous economic damages are unavoidable when the highest possible earthquake hits Denizli. It also shows that a possible disaster in such scale is going to impact the economic development process in the city.

## REFERENCES

[1] R. C., Otero, and R. Z. Marti, "The Impacts of Natural Disasters on Developing Countries: Implications for the International Development and Disaster Community." In M. Munasinghe and C. Clarke, Eds., Disaster Prevention for Sustainable Development: Economic and Policy Issues. Report from the Yokohama World Conference on Natural Disaster Reduction. World Bank, Washington, D.C, 1995

[2] R. Mechler, "Natural Disaster Risk Management and Financing Disaster Losses in Developing Countries," Ph.D. Thesis. Karlsruhe, University of Karlsruhe, 2003.

[3] ATC, "Applied Technological Council, ATC-40 Seismic Evaluation and Retrofit of Concrete Buildings, Redwood City, California, USA, 1996.

[4] HAZUS, "Earthquake loss estimation methodology technical manual prepared by the National Institute of Building Sciences for Federal Emergency Management Agency (FEMA)," 1997.

[5] EDMPI, "Earthquake Disaster Master Plan for the city of Izmir," Report, www.koeri.boun.edu.tr, 2000.

[6] H. Kaplan, S. Yılmaz, E. Akyol, G. Sen, and N. Dayanir, "Preliminary Seismic Risk Assessment Based on Statistical Data," 2nd ASIA Conference on Earthquake Engineering (ACEE2006-IVA4) Manila, Philippines, 2006.

[7] D. M. Boore, B. J. Joyner, and T. E. Fumal, "Equations for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes: A Summary of Recent Work," Seismological Research Letters, 68, 128-151, 1997.

[8] H. Kaplan, S. Yilmaz, E. Akyol, G. Sen and N. Dayanir, "Preliminary seismic risk assessment of urban building stocks: A case study for Denizli-Turkey," Journal of Science and Technology (Beykent University), 1(1), 106-124, 2007.

★★★