UPDATE OF POSSIBLE EARTHQUAKE LOSS ESTIMATES IN ISTANBUL PROVINCE PROJECT

EXECUTIVE SUMMARY

NOVEMBER, 2009

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Introduction

This study, which can be a basis for "hazard-related land use management and urban planning" within the boundaries of Istanbul Metropolitan Municipality and to determine the potential risks of different areas against earthquakes; Within the scope of Anatolian Side Microregulation Project, IMM– OYO – B.U. KANDİLLİ OBSERVATORY was prepared in cooperation.

In the aftermath of the losses caused by two major earthquakes on 17 August and 12 November 1999, the need to prepare comprehensive earthquake response plans based on detailed earthquake hazard analyses has emerged as a fact accepted by local government, government agencies, non-governmental organizations and academic circles, and in this context, IMM and JICA prepared within the scope of The Disaster Prevention/Mitigation Basic Plan Study including Seismic Microregulation in Istanbul Province was reanalyzed with the current data within the scope of stage II Anatolian Side Microregulation Project completed at the end of 2009 and the results were updated.

This current earthquake loss assessment study, based on information obtained from the Istanbul earthquake hazard assessment and Microzonation studies commissioned by the Istanbul Metropolitan Municipality (IMM), is aimed to enable the use of more accurate and up-to-date information in urban disaster planning and urban earthquake structural improvement and transformation initiatives in the determination of priority areas.

In summary, the purpose of the study; It is the realization of a building damage, loss of life and direct economic loss estimate based on the updated building and infrastructure inventory, ground information and earthquake ground movement models of the province of Istanbul. All kinds of data available in Istanbul Metropolitan Municipality and all relevant official institutions and especially CBS-based data were used primarily in the compilation of information, data and maps that constitute inputs to the project studies; is integrated into the GIS system and software developed within the scope of the project.

All kinds of data, inputs and outputs related to the project are prepared based on land cells (grid) with dimensions of 0.005x0.005 degrees.

Scope of The Study

This study, which was carried out with the aim of updating urban earthquake loss determinations, includes the following stages;

1. Probabilistic and Deterministic Earthquake Ground Movement Determination
2. Ground Magnification Analysis
3. Ground Problems (Liquefaction and landslide)
4. Structural inventory detection and typing
5. Development of structural fragility and socio-economic damage relations
6. Determination of error limits in fragility and damageability relationships
7. Determination of building damage and related error limits
8. Determination of injury and loss of life and related error limits
9. Determination of financial losses and related error limits due to structural damage
10. Determination of the number of households in urgent need of housing and the relevant error limits
11. Determination of closed road rates (in terms of emergency assistance and recovery effectiveness)
12. Determination of fire-hazardous material leakage-explosion probabilities
13. Estimate of losses in industrial facilities
14. Estimate of infrastructure damage
15. Estimate of direct economic losses

Ground-dependent deterministic earthquake ground movements corresponding to a 50% probability of exceeding each cell (grid) in 50 years were assigned to each cell (grid) in order to determine the losses, and the losses specified in the above articles were determined by error limits.

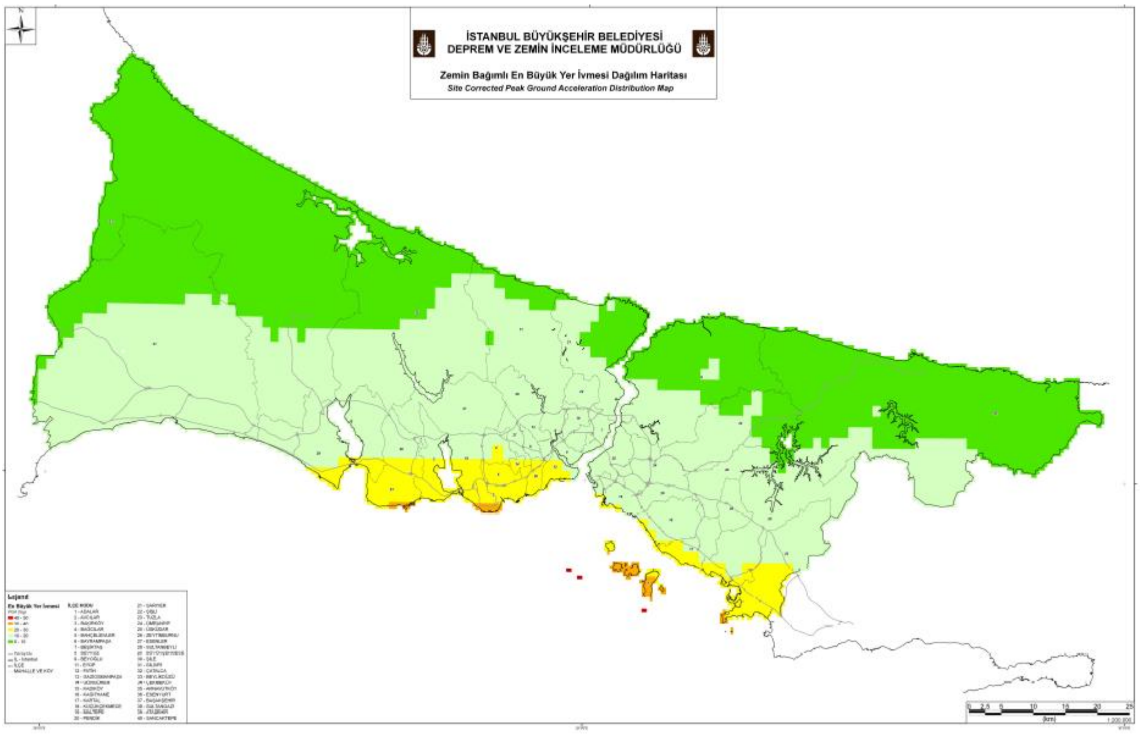

Figure 1. Ground dependent largest ground movement (PGA) distribution map

The scope of the workspace is shown **in** Figure 2. ELER software developed within the scope of EU-FP6 NERIES project in the study of earthquake losses (Erdik et al., 2009; Erdik et al., 2009; Sheshetyan et al., 2009; Sheshetyan et al., 2009; Hancilar et al., 2009; Hancilar et al., 2009; Demircioglu et al., 2009) was used in accordance with the project purpose.

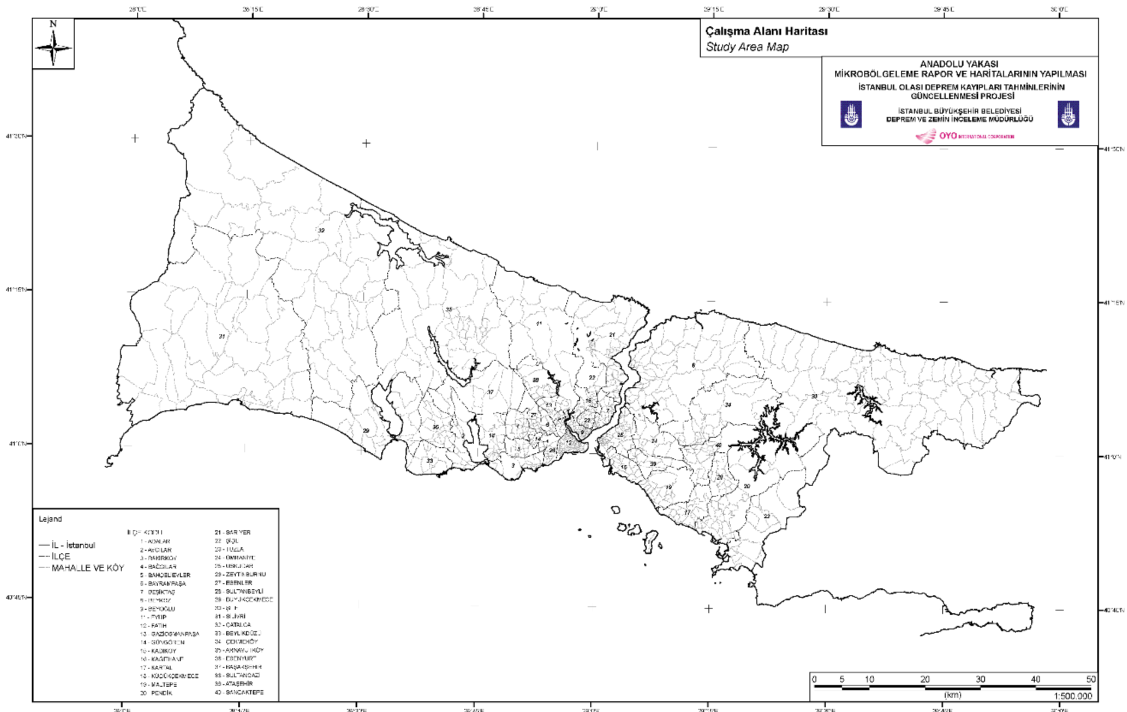

Figure 2. Workspace map

Ground Shake Analysis

Previous studies for this purpose in the determination of earthquake ground movement for risk assessment of Istanbul Province (JICA - IMM, 2002; Bu – ARC, 2002) similarly used the deterministic method due to the scenario earthquake. This deterministic scenario was obtained by de-aggregation of the probabilistic earthquake hazard, which corresponds to a 50% probability of earthquake overrun in 50 years (Erdik et al., 2008). Modal parameters corresponding to the probability of exceeding 50% in 50 years as a result of earthquake hazard separation were obtained as Mw=7.25 and =0 on unbroken segments of the Marmara Fault. =0 corresponds to the median value of the ground movement. However, it was appropriate to take Mw=7.5 ,taking into account previous earthquake risk assessment studies and emergency assistance, rescue, health care and settlement planning. In the analysis based on the deterministic scenario earthquake, both ground movements and estimated losses are median values. In other words, there is a 50% chance that the results will be below these estimates and above 50%.

Tectonic and Seismic Structure

Earthquakes large enough to have a devastating effect in Istanbul are expected to be caused by the active fault system in the Marmara Sea. Two important models have been developed in relation to this active fault system. As a result of the study carried out by Le Pichon et al., (2000, 2003), the North Anatolian Fault is defined as a right lateral pulsed fault that extends across the north of the Marmara Sea (Figure 3). Armijo et al. (2002, 2005), on the other hand, shows a complex structure with normal faulting in the Cinarcik pit with Ganos and Izmit lateral pulses, including the check-separate system (Figure 4).

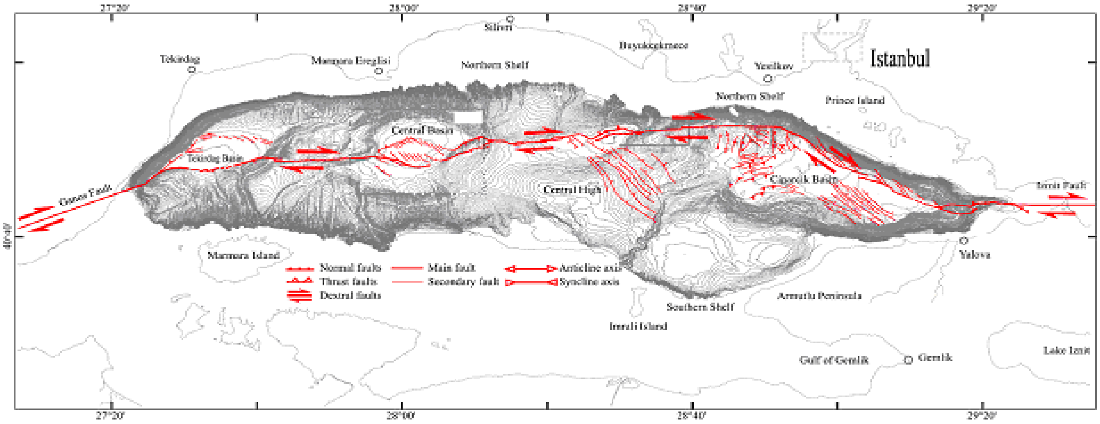

Figure 3. Tectonic structure of the Marmara Sea according to Le Pichon et al. 2003 model

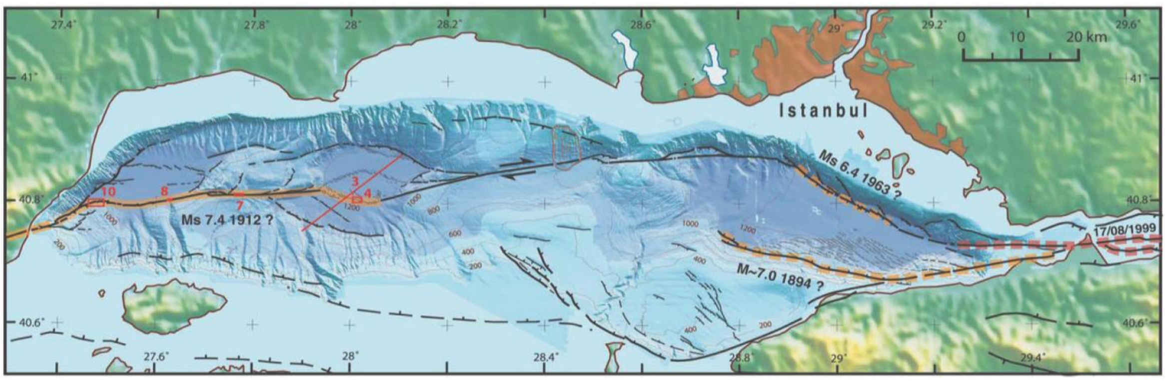

Figure 4. Armijo et al., tectonic structure of the Marmara Sea according to 2005 model

Istanbul has been subjected to many devastating earthquakes throughout its history (Ambraseys and Finkel, 1991). Between the 4th and 19th centuries, 32 earthquakes affected Istanbul. This corresponds to a moderate earthquake every 50 years on average. Approximately every 300 years, Istanbul is subjected to very strong earthquakes. The estimated sources of important historical earthquakes affecting the Marmara region based on macro-seismic data are shown in Figure 5. Earthquake activity in the 20th century of the Marmara Region is on the same shape.

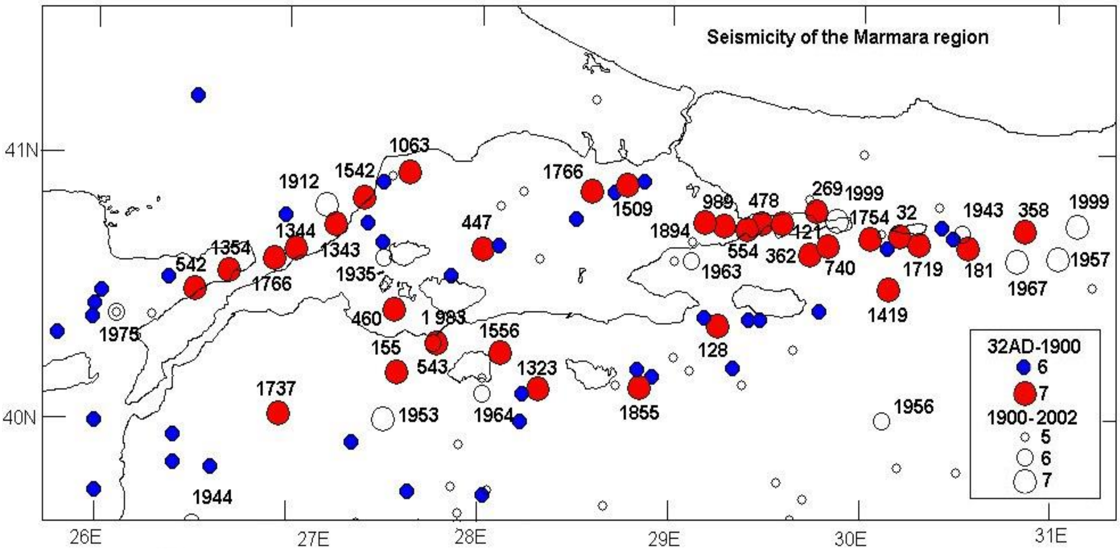

Figure 5. Estimated sources of historical earthquakes based on macrosysmic data and 20 centuries seismicity of the region (historical earthquakes: Ambraseys and Finkel, 1991).

Earthquakes large enough to have a devastating effect in Istanbul are expected to be caused by the active fault system in the Marmara Sea. In the light of the current sismo-tectonic information, two different resource regions created for the Marmara region are presented in Figure 6 (Erdik et al., 2004, OYO-IBB, 2007).

Parsons and others (2004) also gave approximately 35– 70% (average 50%) the probability of an earthquake of M≥7 or greater in the next 30 years.

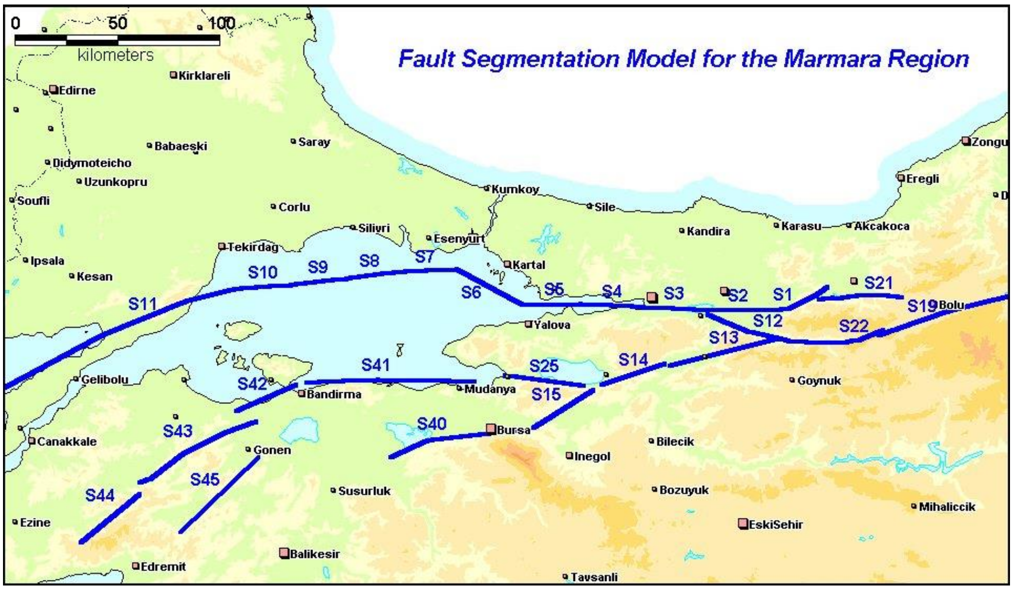

Figure 6. Resource region created for Marmara region (IBB - OYO 2007)

Scenario Earthquake

The scenario to be used to determine the earthquake hazard for the province of Istanbul is in the segments of the Main Marmara Fault (figure 6; Segments 5, 6, 7 and 8) Mw=7.5 magnitude is accepted. (Figure 7) The same sismo-tectonic structure was envisaged in the JICA – IBB (2002) study and the "A" Model scenario earthquake was used as equivalent to the BU – ARC (2002) study. This deterministic scenario provides a relaption of ground movement (Figure 1), which corresponds to a

50% probability of earthquake overruns in 50 years (based on earthquake hazard separation studies) (Erdik et al., 2008).

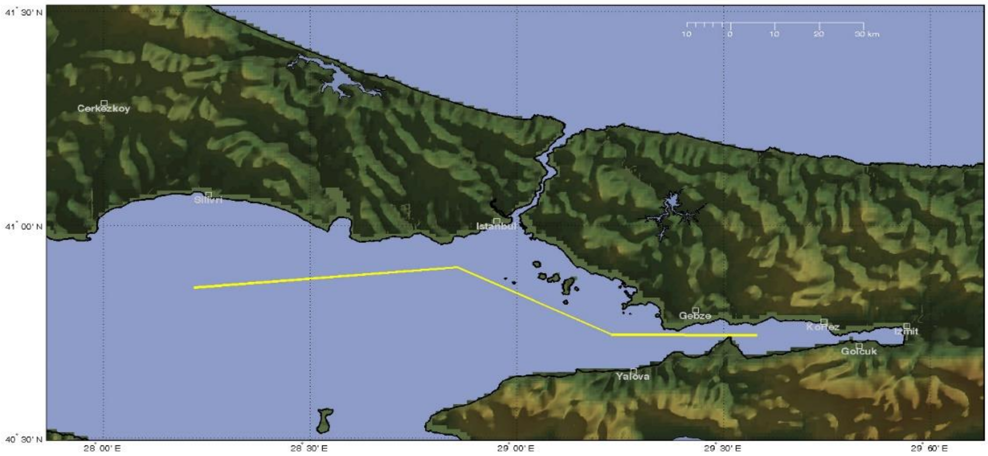

Figure 7. Scenario earthquake used in the study (Erdik, M., 2009)

Ground Modeling Studies

In order to estimate the earthquake movement on the ground surface, an average S-wave rate (Vs30, 30 meter) was detected at depth from the ground surface in grid cells of *0.005* degrees covering the entire Istanbul area (Figure 8).

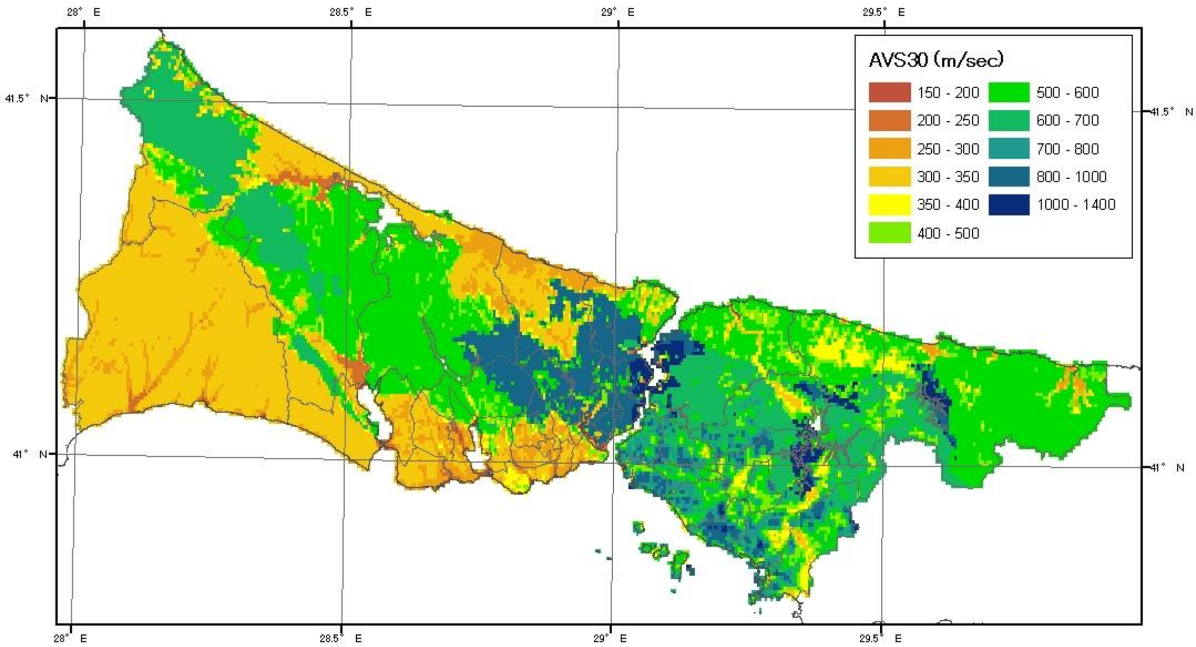

Figure 8. *Vs30* distribution

Analysis Method

After the urban data collection, compilation and production process is completed; building damage and loss of life analysis was carried out. Violence-based (macro-seismic) and/or analytical methods can be used to estimate building damages and loss of life in urban areas in a possible earthquake. In addition, the population distribution associated with the building inventory was obtained. Subsequently, the building damage and loss of life estimation methods present in the literature were examined and methods suitable for the building structure of Istanbul province and damageability relations were selected.

Damageability is defined as the degree of loss that occurs in the event of a projected hazard, in a risk element or risk element group. The damageability functions (damageability curves) of an at-risk element represent the likelihood that the response of this element to earthquake movement exceeds different performance limit states, depending on physical and socio-economic conditions.

Damage to population, structures, infrastructure systems and socio-economic structure are the main factors affecting the loss and earthquake risk in urban areas.

There are two main approaches to producing damageability relationships. The first approach is the so-called macro-seismic method, based on damage data obtained from past earthquake observations. The second approach is an analytical method based on comparing earthquake demand with the capacities obtained from simplified models of structures.

In this study, a "spectral capacity-based damage estimation method" developed using modern methods was applied within the framework of the HAZUS project (1999) carried out in recent years in USA for the estimation of building damages by analytical methods. Within the scope of this method, one "Capacity Spectrum" is defined for each building class and "Earthquake Demand Spectrum" obtained from the acceleration spectrum defined for the location of the building, based on the possible nonlinear behavior of building carrier systems under the effects of earthquakes. By mathematically intersecting the "Capacity Spectrum" and "Earthquake Demand Spectrum" curves, the spectral displacement value, which defies the carrying capacity of the building and is called "performance point", is determined.

In this study, the loss of can and injury to the macro-seismic method were examined, but in this study, the method used to establish a direct relationship between building damage and death and injuries was used in HAZUS99 and HAZUS-MH. As structural damage is minimal, injuries are mostly caused by unstructured damage, and as structural damage is severe, there is a possibility of numerous deaths. However, since the statistical information about deaths and injuries in earthquakes does not include the issues of what type of buildings and what kind of damage the deaths caused, it should be noted that the injury rates used are approximate.

In the next step, urban damageability was evaluated. The results obtained are presented in the following sections.

In this study, ground dependent ground movements were used in all kinds of loss prediction analyses.

Results

The results of the study were presented through maps showing the distribution of building and infrastructure damages and casualties that are predicted to occur as a result of the scenario earthquake in Istanbul within the scope of Istanbul province. The resolution of these maps is 0.005 degrees, or about 400m x 600m in size, on a cell (grid) scale.

According to the deterministic approach, estimates for the province of Istanbul on the basis of both violence and spectral displacement;

- 2,500-10,000 Very Badly Damaged Buildings
- 13,000-34,000 Heavily Damaged Buildings

- 85,000-150,000 Medium Damaged Buildings
- 250,000-350,000 Lightly Damaged buildings
- 10,000-30,000 Casualties
- 20,000-60,000 Hospital Treatments
- 50,000-140,000 Minor Injuries
- ~ 530,000 Households in Urgent Need of Housing
- ~ Damage to 400 combustible explosive buildings
- ~ Drinking Water Line Damage at 450 Points
- ~ Waste Water Line Damage at 1,500 Points
- ~ Natural Gas Infrastructure Network Damage at 650 Points
- ~ 17,000 Gas Canister Damage
- ~ 26 Billion TL. Loss due to Structural Damage
- ~ 80 -100 Billion TL. Total Loss
- Loss of Life to 0.1%-0.2% of Istanbul's population
- Unusable buildings (very heavy, heavy, medium) are monoliths to 10%-15% of the structures.

In 2002, pacific consultants international and OYO corporation carried out a similar earthquake tearing model (Model A) in the Istanbul metropolitan area earthquake risk assessment, commonly known as the "JICA" squat, bringing the total number of heavily damaged buildings to 51,000 and the total number of heavily and moderately damaged buildings to 114,000. The number of casualties from these injuries was estimated at 73,000 and the number of seriously injured was estimated at 120,000. These scopes are above the estimates presented within the scope of the state-of-the-table study. This difference is mainly due to the fact that information and random uncertainties specific to earthquake risk studies can be better countered and reduced in parallel with current technological and scientific developments. In this study, ELER (EU 6.ÇP NERIES Project) software containing current technology and knowledge accumulation was used. Earthquake ground movement modeling, damageability relationships and risk modeling covered by the methodology on which this software is based are more advanced than those used in the "JICA" study.

For Istanbul, earthquake loss results should be perceived as an indicator of the losses that may occur rather than predetermining an earthquake damage.

The selected scenario earthquake corresponds to the "Worst Case Scenario". However, in the deterministic hazard analysis, the median value of minority relationships was used. Therefore, statistically, there is a 50% chance that hazard results are greater or smaller than the hazard values used in lost accounts.

While the losses associated with buildings are considered a reasonable indicator of the risk of earthquakes in the city; it is also important to remember that these estimates are not an absolute assessment of the total risk that will occur in earthquakes. The loss parameters used in the study indicate direct economic losses due to building inventory. The risk of earthquakes is determined by physical losses (fire, etc.) of earthquake and non-direct economic losses, as well as parameters is not covered in this study.

The element needed in the planning process to reduce the losses that will occur after the earthquake is the publication of the earthquake loss data obtained in this study in an understandable format in a way that will attract the public's attention, inform the technical personnel who are planning disasters and ensure the sensitivity of the decision makers at the highest level.

Priorities and optimal approaches for reducing the risk of earthquakes in Istanbul can only be determined by full knowledge of the losses due to earthquakes. The results of this study should be used in the development of strategies for reducing earthquake risk and in the planning of post-earthquake intervention studies.