DEVELOPING AN EARTHQUAKE LOSS ESTIMATION TOOL – HAZTURK - FOR TURKEY

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Keywords

HAZTURK, MAEviz, Consequence Based Risk Management, Earthquake, Loss Estimation

Abstract

The increasing interest in computer-based seismic risk and loss assessment systems imposes new research requirements on the earthquake engineering community. Such systems are being used for the important purposes of disaster response planning and formulating risk reduction policies. Their accuracy and reliability are therefore fundamental to the success of these mitigation measures. The ingredients of seismic loss assessment are hazard (exposure), vulnerability or fragility (sensitivity), inventory (value) and integrated visualization (losses). This paper describes the components of seismic loss assessment developed, implemented and assembled for the city of Istanbul.

To reach the maximum reliability on the loss assessment results the input data should also have the maximum quality, since the results of the loss assessment based on the inputs. To get the most reliable results from the software for a new region, the best available data are required. The best available data for the city of Istanbul is the data of the Zeytinburnu District. This selection provides the best results for the loss estimation of the buildings with respect to the accuracy of the building attributes.

Before starting the loss assessment process for the region first, the previous works or studies were reviewed. The main topics for those previous studies are determined as hazard, fragility and inventory. For the hazard part available attenuation relations for Turkey, are investigated and compared based on the available earthquake scenarios for the city of Istanbul. At the fragility part, a new method named as parametrized fragility method (PFM) which is proposed by (Jeong and Elnashai, 2006), is used for deriving the fragility relationships for Istanbul buildings. At the inventory part, data for the study area Zeytinburnu -a district of Istanbul- are collected, processed and refined.

Introduction

Increasing possibility of the Istanbul Earthquake also increase the needs of a seismic loss assessment for the city of Istanbul. This project aims to accomplish a seismic loss assessment for the buildings of the Istanbul. Leading seismic loss assessment software around the world are only capable of use for the country that they were developed for. To be able to use this kind of software for another country with different administrative units, different ground motions, different vulnerabilities, and different inventories requires a huge effort, and the results may not be as good as needed. The deficiencies are based on the different geographic systems and datum used in different countries. These differences lead to big errors of distance, area, and angle calculations. For example, if we take into consideration the attenuation relationships to calculate the accelerations on the study area, the inputs are the magnitude of the expected earthquake, the soil types, and the shortest distance from source to the site. The error on the distance cause enormous errors on acceleration values at the site, which causes big differences on loss estimation and mitigation process. The use of HAZTURK software for Istanbul case includes the use of Turkish datum, administrative units, regional attenuations and strong motions.

Thesis

The approach for the study is CRM also known as Consequence Based Risk Management, which is developed by the Mid-America Earthquake (MAE) Center. "CRM paradigm provides a philosophical as well as a practical framework for the assessment of the dynamic inter-disciplinary relationship between causes, effects and effectmitigation, response and recovery features of major event or disaster management, and links seamlessly with new Major Incident Management (MIM) approaches being developed and applied in other fields. Social Sciences and Information Technology are also major components of the CRM Framework, as well as the Engineering Engines. These three components define the hazard and the consequences as seen in Figure 2. In Figure 1, the 'Consequences' are all effects of earthquakes (or indeed any other form of natural or manmade hazard - incidents) on society, including engineering, social and economic impact. 'Consequence-Mitigation' refers to all measures of reducing the consequences of hazard events. The latter includes conventional measures of retrofitting of engineered systems, as well as network hardening, social impact reduction measures and land-use management alternatives. The MAE Center approach couples 'Decision-Making' and 'Visualization' so as to provide the decision- and policy-maker with a vivid environment for informed decisions. This approach provides an exceptionally effective framework for loss assessment in the service of mitigation, response and recovery. It is also suitable for planning research, education and outreach in a systematic and transparent fashion." (UIUC MAEC, 2006)

Figure 1

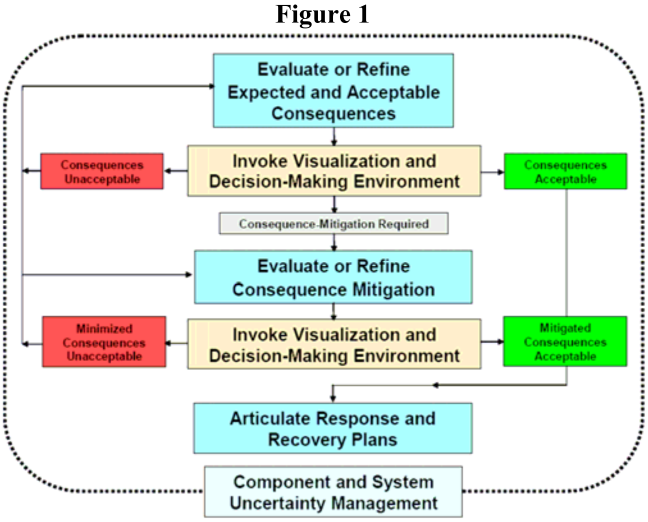
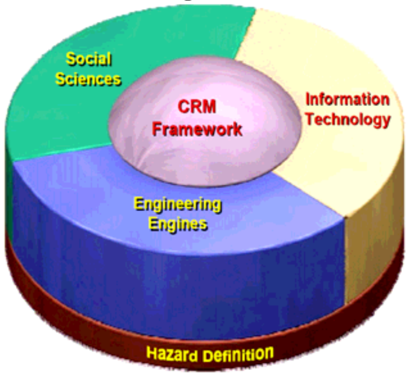


Figure 2



Based on the CRM approach the seismic loss assessment study is divided into three parts. Based on these parts the outline of the study will be explained except the fragility part.

Hazard

The loss estimation depends on the acceleration of the ground motion with respect to magnitude, distance, soil conditions and topography. There are two type of approaches for the attenuation relations for Turkey. The first one is to adopt the attenuation relations of the Northwest America because of the similarity on the faultlines of the San Andreas and North Anatolia. The second one is to create new attenuation relations for Turkey by using only Turkish strong motion records or both strong motion records around the world and Turkey. There are six attenuation relations given in Table 1 which can be used for the loss estimation process of Istanbul.

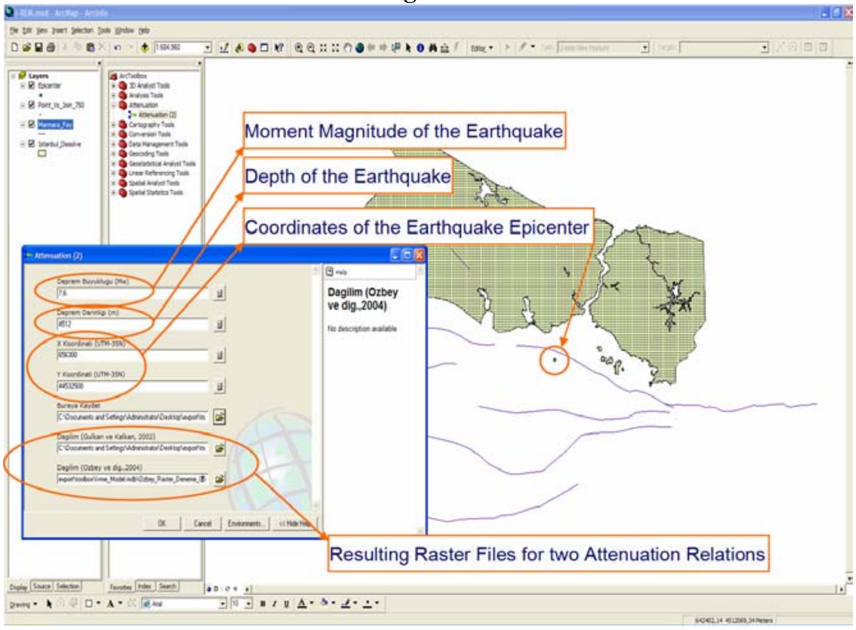
Table 1

Attenuation Model	Ground Motion Parameter	Distance Type	Site Conditions
Kalkan & Gülkan (2004)	PGA & PSA	Horizontal Dist. To Rupture	Rock, Soil, Soft Soil
Özbey et al., (2004)	PGA & SA	Horizontal Dist. To Rupture	Hard Rock, Rock, Dense Soil, Stiff Soil
Ulusay et al., (2004)	PGA	Dist. To Epicenter	Rock, Soil, Soft Soil
Boore et al., (1997)	PGA & SA	Horizontal Dist. To Rupture	$V_{S,30}$
Fukushima et al., (2003)	PGA & SA	Site to Fault Plane Dist.	Rock, Soil
Sadigh et al., (1997)	PGA & SA	Horizontal Dist. To Rupture	Rock, Deep Soil

The attenuation relations which are used within the first approach are, (Boore et al., 1997), (Sadigh et al., 1997), (Fukushima et al., 2003). These models, excluding the Fukushima et al., 2003, which were derived both using both North American, Japanese, Turkish and Western Eurasian records, are derived by using the North American strong motion records, including some other records around the world and Turkey. The second approach is used by; (Kalkan and Gülkan, 2004), (Özbey et al., 2004), (Ulusay et al., 2004), is mainly using the Turkish strong motion records. But, because of the lack of enough data, those models include the records around the world.

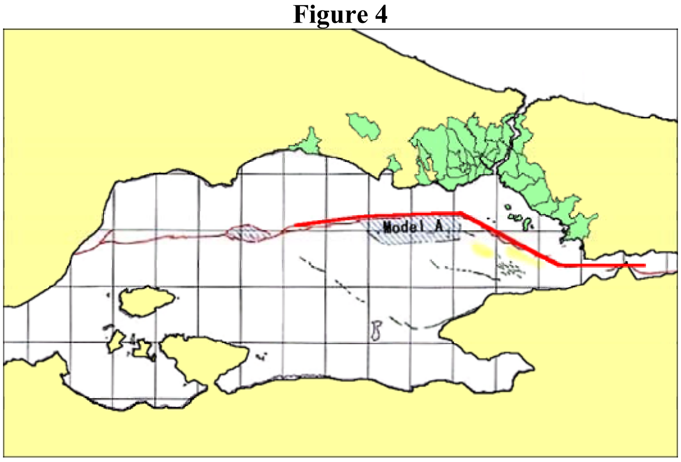
A deterministic approach is followed in selection of the attenuation relations. The most possible earthquake scenario is applied to all attenuation relations using the ArcGIS 9.1 Geographic Information System software. A model created by (Unen, 2006) is used to evaluate and compare the candidate attenuation relations. The model was built to generate the acceleration values for Istanbul based on the (Kalkan and Gulkan, 2002) and (Ozbey et al., 2004) attenuation relations for each point in every 750 meters. See Figure 3. The model is edited and improved to include different distances and different soil types, which are used to derive the accelerations.

Figure 3



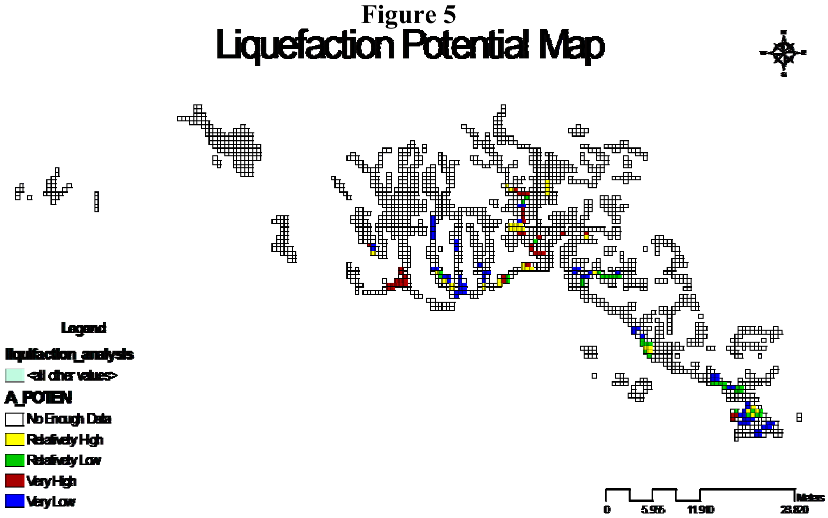
There are four different earthquake scenarios for the expected earthquake in Istanbul, which were constituted by the JICA study team and published in 2002 as a report (JICA, 2002). The most possible one is named as Model A. "Model A is break on the eastern section of the fault line. This section is about 120 km long from west of 1999 Izmit earthquake fault to Silivri" as shown in the Figure 4. This model is the most probable model of these four scenario earthquakes because the seismic activity is progressing to the west. The moment magnitude (Mw) is assumed 7.5" (JICA, 2002).

Figure 4



Another hazard parameter for earthquake is the liquefaction. "Excessive hydrostatic pore water pressure during earthquakes leads to the loss of stiffness and strength of soils. They behave, therefore, as viscous fluids rather than as solids. Liquefaction takes place generally in loose saturated sand deposits. Its effects on structures are devastating. The liquefied material initiates lateral-spread slides or leads to loss of bearing capacity under foundations. This depends on the depth and thickness of the liquefied zone and local topography. Excessive pore water pressures cause sand boils on the ground." (Elnashai and Di Sarno, 2007) Liquefaction susceptibility is also taken into account for the study. However, the data for liquefaction is not enough for the whole city of Istanbul as it can be seen in Figure 5, the white cells indicate the areas with no data available.

Figure 5



The effect of the topography on ground motions in earthquakes is also considered in the study. The city of Istanbul has many hills (see Figure 6) and this may amplify the ground motions during the earthquake. As it can be seen from the previous earthquakes, hills and mountains amplificate the ground motion drastically (Table 2). However, the effect of the pure topography couldn't represented good enough. The studies on the effect of topography generally underestimates the amplification at the top of the mountains and hills (Geli L., et al., 1988). There are also no design codes availables except the Eurocode-8 Part-5, which take into consideration the effect of the topography (Paolucci R., 2002). That is why, the (Eurocode 8, 1994) and (Paolucci R., 2002) are taken into account for this study.

Figure 6

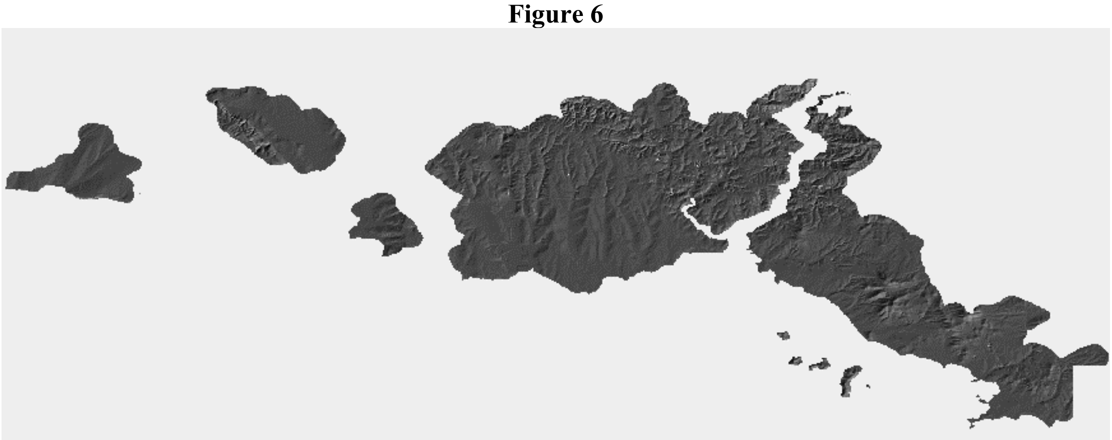


Table 2 (Paolucci, 2002)

Earthquake	Date	Type of Observation
Lambesc (France)	1909	Macroseismic
Friuli (Italy)	1976	Macroseismic
Irpinia (Italy)	1980	Macroseismic
Chile	1985	Macroseismic/Instrumental
Northridge (California)	1994	Instrumental
Umbria-Marche (Italy)	1997	Macroseismic/Instrumental
Egion (Greece)	1995	Macroseismic

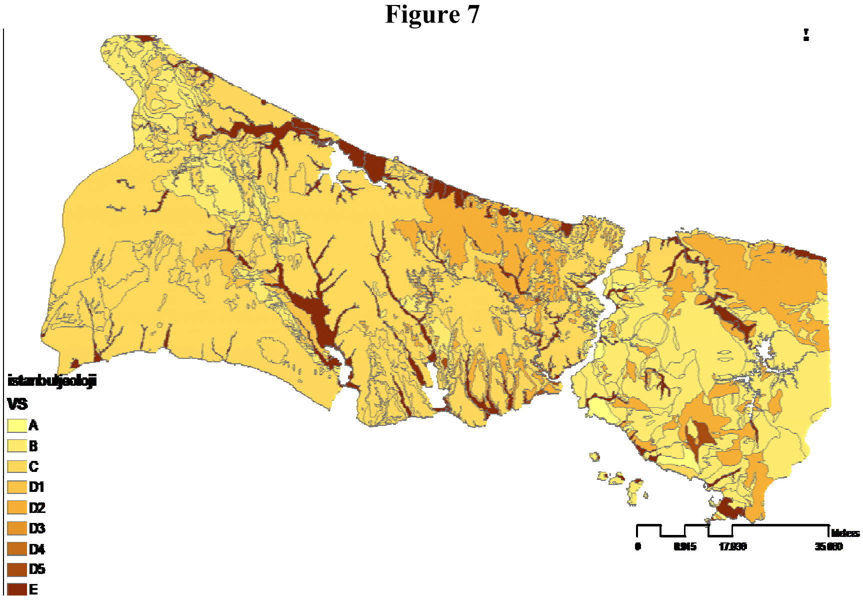
Athens (Greece)	1999	Macroseismic

Most of the attenuation relations uses NEHRP ground classifications (Table 3), which is based on the shear wave velocity values of the site. For this study the NEHRP site classes were used to create a ground classification map of Istanbul in Figure 7. The ground classification map is used for creation of the acceleration maps of Istanbul for the candidate attenuation relationships.

Table 3

Site Class	Average S Wave Velocity Over Upper 30m
A	>1500m/sec
B – B0	760 - 1500m/sec
C – C0	360 - 760m/sec
D – D0	180 - 360m/sec
D1	300 - 360m/sec
D2	250 - 300m/sec
D3	220 - 250m/sec
D4	200 - 220m/sec
D5	180 - 200m/sec
E	<180m/sec

Figure 7



With respect to those attenuation relations mentioned above at the hazard section, the hazard maps of peak ground acceleration, spectral acceleration at a number of key periods were created. All the attenuation relations were run for a M_W=7.5 earthquake with a 10 km depth, and the PGA values were compared for each earthquake.

<u>Inventory</u>
The building data for Zeytinburnu District is being used for the study. The data is derived from the Istanbul Metropolitan Municipality. The attributes are important for the loss assessment process of the buildings. The attributes of the building data must include the features listed in Table 4. The more the attribute we have about the study area inventory, the more accuracy we get on the assessment.

The data classification and format is another big issue in the process. A unique set of records must be ingested as the inputs and a unique set of data must be the outputs. According to this approach the data classification and format for the study and the software is generated and given in Table 5.

Table 4

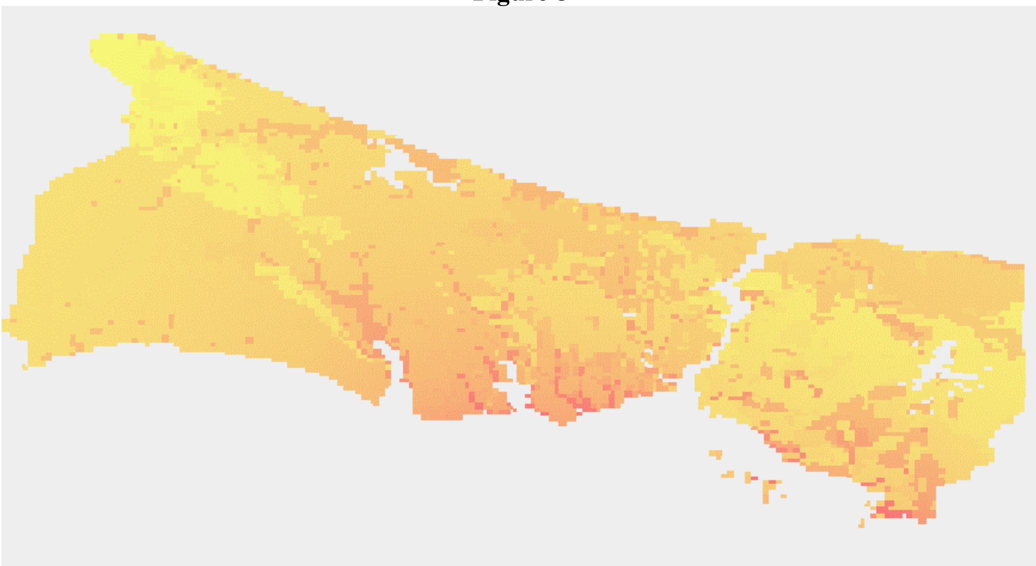
Data Model for Building Inventory										
ID	Structure Type	Number of Storeys	Construction Year	Occupation Type	Essential Facility	Dwelling Number	Square Meter (m2)	Building Value	Content Value	Address
Data Model for Geology Inventory										
ID	Geology	Area	Perimeter							
Data Model for Ground Classification										
ID	Soil Type	Area	Perimeter							
Data Model for Boundary Inventory										
City Boundary										
ID	City_ID	District_ID								
Distrcit Boundary										
ID	City_ID	District_ID	Sub-district_ID							
Sub-distrcit Boundary										
ID	City_ID	District_ID	Sub-district_ID							
Data Model for Attenuation Relations										
Coefficient Table for the Attenuation relations										

Table 5

Dataset	Data Format	Extension	Data Type	Coordinate System	Datum
Hazard	ASCII Raster	*.asc, *.txt	ASCII	GCS*	WGS84
Building	ArcGIS Shape file	*.shp	Nokta	GCS*	WGS84
Geology	ArcGIS Shape file	*.shp	Poligon	GCS*	WGS84
Topography	ASCII Raster	*.asc, *.txt	ASCII	GCS*	WGS84
Boundary	ArcGIS Shape file	*.shp	Poligon	GCS*	WGS84
Attenuation	Tablo	*.csv	Tablo	GCS*	WGS84
Others	ArcGIS Shape file	*.shp	Çizgi, Nokta, Poligon	GCS*	WGS84
Mapping	XML	*.xml	XML	GCS*	WGS84

The tool will have the ability to generate the acceleration values for the study are, based on the characteristics of the regarding attenuation relation. This creates the need for ground classification, geology, topography inventory as an input. The resulting dataset gives the acceleration map in raster format as seen in Figure 8.

Figure 8



Sources of Information

JICA's study on Istanbul (JICA, 2002) is reviewed and the useful data and models are taken into consideration for the study. Four different models were found in the JICA report, which are developed according to the breaks on the fault line at the Sea of Marmara. Those scenarios were named as Model A to Model D. It is also indicated in the JICA study report that the most possible scenario is the Model A. That is why, the model A taken into account as the scenario, while the attenuation relationships were compared.
There are other previously generated models reviewed for loss estimation, which are carried out by two different research teams, named as, Kandilli Observatory and Earthquake Research Institute (KOERI, 2002), and the Earthquake Master Plan for Istanbul prepared by the Bogazici University, Istanbul Technical University, Middle East Technical University and Yıldız Technical University (IMM, 2003), which used the JICA study data and KOERI software.

Findings and Discussion

All the attenuation relations were run for a M_W=7.5 earthquake with a 10.0 km depth, and the PGA values were compared for each relationship. The results are given in the Table 6.

Table 6

Attenuation Model	**Site Categories (m/s)**				**Acceleration Values**			
	Soft Soil	**Soil**	**Rock**		PGA_{min}	PGA_{max}	PGA_{mean}	σ
Kalkan & Gülkan (2002)	V_S=200	V_S=400	V_S=700		0.073	0.542	0.168	0.060
Kalkan & Gülkan (2004)	V_S=200	V_S=400	V_S=700		0.474	1.725	0.823	0.184
Ulusay et al., (2004)	V_S=200	V_S=400	V_S=700		0.079	0.632	0.262	0.092
	Stiff Soil	**Dense Soil & Soft Rock**	**Rock**	**Hard Rock**				
Özbey et al., (2004)	$180 \le V_S \le 360$	$360 < V_S \le 760$	$760 < V_S < 1500$	$V_S \ge 1500$	0.051	1.843	0.196	0.168
	Class C	Class B	Class A					
Boore et al., (1997)	$180 \le V_{S,30} \le 360$	$360 < V_{S,30} \le 750$	$V_{S,30} > 750$		0.059	0.681	0.148	0.076
for Geometric Mean					0.053	0. 599	0.132	0.068
	Rock							
Sadigh et al., (1997)	$V_S \le 750$				0.048	0.639	0.177	0.099

Fukushima et al., (2003)	**Soft Soil**	**Medium Soil**	**Hard Soil**	**Rock**	1.863	2.636	2.245	0.158

Next Generation Attenuation Models from the Pacific Earthquake Engineering Research Center, are also going to be applied for the loss assessment tool. The developing tool will give the option to choose the attenuation relation to the user. The ongoing work is on the fragility generation for the Turkish building inventory. The fragilities will be derived by using the Parametrized Fragility Method. Idealized systems are analytically subjected to suites of ground motion representing a particular scenario that the loss assessment is to be carried out for. Once stiffness, strength, and ductility are known, analytically-based probabilistic fragility relationships are derived without further simulation. This method is proposed by (Jeong and Elnashai, 2006).

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Biography

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He is a geodesy and photogrammetry engineer and has his Master of Science degree on 2003 from ITU Science and Technology Institute on database systems on disaster management. He is a PhD candidate since 2004. He is a research assistant in Istanbul Technical University, Civil Engineering Faculty, Surveying Technique Division, since 2001, and visiting scholar in MAE-Center at University of Illinois at Urbana-Champaign since 2006.

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