EARTHQUAKE LOSS ASSESSMENT FEATURES OF HAZTURK

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Abstract

As the possibility of the Great Istanbul Earthquake increases, the needs for the earthquake loss assessment software specialized for Turkey has also augmented. There was no single system or software, which can be used to mitigate the risks and minimize the damage after the disaster. Several big projects were conducted for the loss assessment of the great Istanbul earthquake. However, those studies gave one-time results and as the new researches done and discoveries found, the analysis should be rerun and the results of those studies should be updated. On the other hand, this kind of projects requires long time and research to simulate the new approximations if there is no software to give those new inputs. Creating brand new loss assessment software or converting an existing one for a country, has its own difficulties. The leading seismic loss assessment software around the world has been specialized for the countries that they were developed for. These customizations restrain the users to use the software for another country's earthquake loss assessment. The main obstacles for the use of the loss assessment software for another country can be considered as; the difference in administrative units, difference in the seismic source parameters, difference in the vulnerabilities of the inventories, and the difference in the datum and coordinate systems used in different countries. These obstacles for using the current loss assessment systems for Turkey especially for Istanbul lead us to customize the MAEviz seismic loss assessment system for Istanbul. This paper summarizes the features of the seismic loss assessment system developed for Turkey with respect to the obstacles mentioned above.

Introduction

The possibility of the Istanbul Earthquake is increasing day by day since, the 1999 earthquakes. However, Turkey didn't have an all in one software system that demonstrates the earthquake hazard map for different defined scenarios and simulates the structural, economic and social damages to structures and community. This study explains the features of the HAZTURK earthquake loss assessment software.

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Theory and Method

The need for a loss assessment system for the city of Istanbul arises after the 1999 Kocaeli and Düzce earthquakes. There were several studies conducted since 1999. However, all of them were valid for only the period that they were accomplished and those studies were not able to be rerun for the updated datasets, models, and scenarios. These deficiencies lead us to create an all in one system that can be used from the beginning to the end of the disaster management cycle. The base of the HAZTURK software is chosen from Mid-America Earthquake (MAE) Center software MAEviz. The reason for this selection is that, the software is open source software and can be modified easily for the use outside the United States of America. Most of the famous loss assessment software are strictly dependent on the datum of the country that they were developed for and the format of the datasets which are going to be used within the analyses should fit the format of the owner country. For example, a system built in the United States for emergency management provides good generalized results at the region level, but it was not designed to provide specific results for points of interest where each point takes into consideration the inventory item type, its fragility and geologic location.

HAZTURK follows the Consequence-based Risk Management methodology using a visually-based, menu-driven system to generate damage estimates from scientific and engineering principles and data, test multiple mitigation strategies, and support modeling efforts to estimate higher level impacts of earthquake hazards, such as impacts on transportation networks, social, or economic systems. It enables policy-makers and decision-makers to ultimately develop risk reduction strategies and implement mitigation actions.

For any science related project where the field is in constant flux, the biggest challenge is to design a platform that is flexible and extensible enough to meet current and future demands of the domain. Many of the design decisions for HAZTURK were directly influenced by this requirement so that HAZTURK would be an earthquake loss assessment platform that the community could easily contribute to and expand upon. The result is a software platform that contains the very latest in earthquake engineering domain, provided by the Istanbul Technical University, Surveying Technique Division and MAE Center Research Teams with the gaps being filled by published literature and the HAZUS Technical manual. In addition, some features have been added from small projects seeking to solve specific problems.

The HAZTURK system consists of four main concepts; hazard (exposure), vulnerability or fragility (sensitivity), inventory (value) and integrated visualization (losses). Hazard is described as an input ground motion parameter or a spectral response value. Vulnerability or fragility is given as a conditional probability of an asset (inventory unit) reaches or exceeds a damage threshold. Inventory data describe the location and characteristics of the assets of interest to the decision-maker seeking the loss assessment results. Integration and visualization is an essential framework to use hazard, fragility and inventory to evaluate physical and economical impact, given the loss functions that translate damage into loss of value. The order of the analyses performed in the system is also important. There are three main phases of the loss assessment system named as;

- Initial Scenario Definition
- Preliminary Analyses
- Mitigation Planning

and the main flow diagram of the system can be seen in Figure 1.

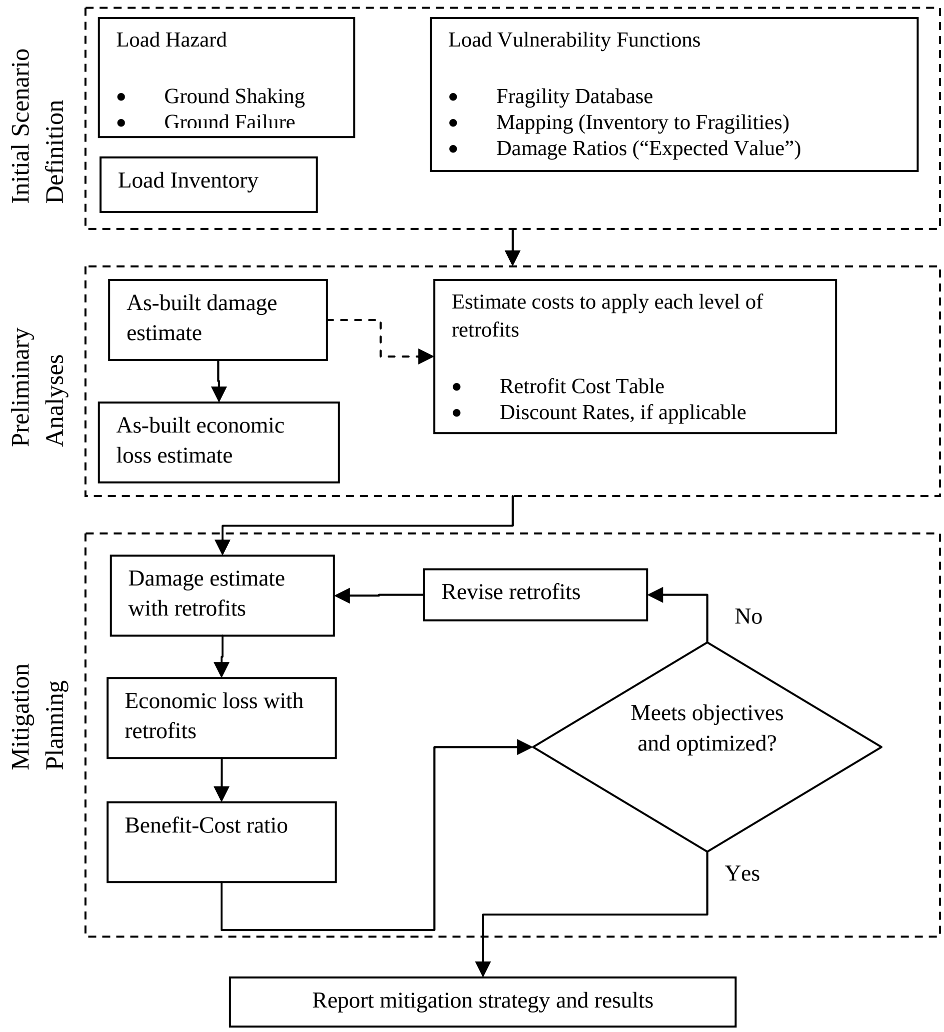

Figure 1 HAZTURK loss assessment system overview (HAZTURK and MAEviz, 2007)

Seismic loss assessment studies require inter disciplinary work and need efforts from various disciplines. The studies without an integrated system cannot be edited or redone easily and every modification and repetition could cost almost a new project cost. Analyses in HAZTURK can generate data for the results of the various calculations. For example, generating a deterministic earthquake map based on a magnitude and epicenter would be considered one type of analysis. The other type is to load pre-generated hazard map. Basic investigations for loss assessment studies are the hazard analyses. Mainly, hazard analyses include liquefaction and scenario earthquake evaluations. The main analyses included in HAZTURK software are;

- Scenario Earthquake Analyses
- Building Liquefaction Analysis
- Structural Damage Analyses
- Non-structural and Content Damage Analysis
- Economic Loss Analyses
- Retrofit Cost Estimation Analyses
- Repair Cost Analyses
- Cost Benefit Analyses
- Fiscal Impact Analyses
- Network Based Seismic Retrofitting
- Multi Attribute Utility Analysis

- Business Content Loss
- Business Interruption Loss
- Business Inventory Loss
- Household and Population Dislocation
- Short Term Shelter Needs
- GIS Analyses

Initial Scenario Definition

The concept of hazard is included and the effect of the earthquake is defined in this phase. The end user defines the scenario based on the fault type, moment magnitude, epicenter, geology and topography of the study region. Only limitation is the limitations of the attenuation relation chosen by the end user. The user can select one or a set of attenuation relations and give weights for each attenuation relation in a set. By this way the user can match the mechanism of the study region with the available attenuation relations given in Table 1. This phase includes the building liquefaction analysis, scenario earthquake analysis. The Next Generation Attenuation (NGA) Models which were generated by the Pacific Earthquake Engineering Research (PEER) Center are also included within the system. The liquefaction potential index analysis computes the damage from ground failure using the HAZUS Methodology found in the HAZUS Technical Manual.

Table 1 Available Attenuation Relations for Istanbul

Attenuation Relation	Parameter
Kalkan and Gülkan, (2004)	PGA, PSA
Özbey *et al.*, (2004)	PGA, Sa
Ulusay *et al.*, (2004)	PGA
Boore *et al.*, (1997)	PGA, Sa
Sadigh *et al.*, (1997)	PGA, Sa
Spudich *et al.*, (1999)	PGA, Sa
Boore and Atkinson, (2007)	PGA, PGV, Sa
Chiou and Youngs, (2007)	PGA, Sa
Campbell and Bozorgnia, (2007)	PGA, PGV, PGD, Sa

Another new feature of the HAZTURK is the ability to ingest the topography of the study region into hazard map creation. Previous earthquakes show that the hills and mountains amplify the ground motion significantly. On the other hand, the effect of the pure topography couldn't be represented good enough. The studies on the effect of topography generally underestimate the amplification at the top of the mountains and hills (Geli L., et al., 1988). The definitions and the rules for the effect of the topography on strong ground motions in Eurocode-8 Part 5 (Eurocode 8, 1994) are used in the HAZTURK to simulate the effects. To take the effect of the topography into account the slope map of the region is required. The capability to convert the Digital Elevation Model (DEM) of the region to a raster slope map is also added into the system within the GIS analyses. Both raster and shape file formats can be used in the earthquake scenario analysis to create the hazard map.

Preliminary Analyses

Earthquake damage on the structures is estimated within this phase. Damage to buildings, bridges, lifelines like buried pipelines of gas, water and sewage systems, electricity networks and substations can be estimated based on the scenario created by the user. The other class of analyses is the estimation of the economic losses based on the structural damages and the estimation of the retrofit costs for the structures before the earthquake occurs. The sensitivity concept includes the development of the fragility functions for the structures.

To evaluate the effect of ground shaking or ground displacements on the assets in the earthquake-prone area, fragility relationships were required. These are conditional probability functions that relate the severity of shaking to the probability of reaching or exceeding different levels of damage. All existing fragility relationships for Turkish building type construction, bridges, and utility networks are reviewed and compared to identify suitable candidates that are implemented in the HAZTURK software. Fragilities developed through recent research at Turkish universities and the American Lifelines Alliance are assessed.

Moreover, the extensive surveys undertaken by the Istanbul Technical University and MAE Center team are used to develop uniform fragilities using a novel approach developed by Jeong and Elnashai (2006), referred to as Parameterized Fragilities.

These new relationships provided uniform reliability of the assessment results hence the relative risk of damage to all types of buildings, such as reinforced concrete, steel, masonry and wood, carries the same reliability, thus increasing the overall reliability of the loss assessment. The same approach is employed for bridge structures to support the assessment of transportation networks.

The Parameterized Fragilities are generated by using the Parameterized Fragility Method (PFM). This method uses the idealized systems which are analytically subjected to suites of ground motion representing a particular scenario for which a loss assessment is to be carried out. A closed-form solution for a generalized single-degree-of-freedom system is employed to construct a response database of coefficients describing commonly used lognormal fragility relationships. Then, the response data is stored in a manner that allows its extraction at a later stage for any system for which the stiffness, strength, and ductility are known. In other words, once the latter three fundamental response quantities are known, analytically-based probabilistic fragility relationships are derived without further simulation. This approach is ideally suited to regional loss assessment since it provides completely consistent and uniformly reliable damage assessment.

The fragility relationships for buildings in this study are specific to Turkey, not standard relationships that are used globally in some other software packages. The fragility relationships are integrated with cost functions with the mapping XML files so that the most probable damage state is translated to economic losses that can then be aggregated for any size geographical region.

Preliminary analyses provide retrofit cost estimations other then the structural damage analyses. The retrofit cost estimation analysis approximates the cost of the various retrofits, based on the current building code. The available codes are pre code, low code, moderate code and high code. If a building is built to low code, then the pre code column would have the value 0. The building codes inside the system for evaluating the damage and the retrofits are given in Table 2.

Table 2 Building Code Levels Used in Turkey

Building Code	Year	Code Level
Italian Structural Code	1940	Pre code
Earthquake Regions Interim Structural Code	1944	Pre code
Turkey Earthquake Regions Structural Code	1949	Pre code
Structural Code for Buildings in the Earthquake Zones	1953	Pre code
Structural Code for Buildings in the Disaster Zones	1962	Pre code
Structural Code for Buildings in the Disaster Zones	1968	Pre code

Structural Code for Buildings in the Disaster Zones	1975	Low code
Structural Code for Buildings in the Disaster Zones	1997	Moderate code
Structural Code for Buildings in the Earthquake Zones	2006	High code

Building economic loss analysis computes the direct economic loss for buildings based using the results of previously executed analyses for structural (and nonstructural, optionally) damage. The algorithm of this analysis calculates direct economic loss in terms of repair and replacement of building stock and contents. The damage analyses already contain the expected damage ratios for each component (Karaman et al., 2008).

<u>Mitigation Planning</u>

The third phase of the system is for decision making for mitigation and response steps. The initialization of the mitigation planning phase starts with the damage and economic loss analyses for the retrofitted structures. Continuing these analyses the comparison between the damages of the non-retrofitted and retrofitted structures are done by running the cost benefit and multi attribute utility analyses. Cost benefit analysis takes two structures datasets containing economic loss or decision support datasets before and after retrofitting. Users can generate as-built damage for a structure's dataset and the associated economic loss and then repeat those analyses for a retrofitted set of buildings. These analyses help to decide if retrofitting the structures are logical or not and help to find out the ratio of injuries or mortalities. For the mitigation of the social losses the business -content, -interruption, -inventory losses, household and population dislocation, and short term shelter needs analyses are included inside the HAZTURK.

To help the authorities on easy and rapid decision making, reporting of the loss assessment analyses are as important as the analyses itself. HAZTURK creates both the detailed and summary reports for the basic analyses and provides to export them in several different formats from portable document format (pdf) to html. Figure 2 represents a sample report from HAZTURK building damage analysis.

Results

As a result of this study an all in one earthquake loss assessment system HAZTURK is created for Turkey, especially for Istanbul. Figure 3 represents the main framework of the HAZTURK software.

The main advantage of HAZTURK is, it can be used for any region or country and the analyses are not in region level. For example, the user can run all the analyses for a specific point of interest like a building and can get the results only for that point. Moreover, the results can be converted to the region level using the GIS analyses provided inside the HAZTURK. Thus, the results can be compared with the actual or other studies results. The results of the analyses for building damage in Istanbul are compared with several previous studies and the comparison results are given in Table 3. The results of the HAZTURK loss assessment software are within the range of the other studies results. However, the data used in this study is relatively up to date with respect to previous studies.

Building Damage Summary (v4)

Scenario: paper scenario zeytinburnu

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Location: ZEYTINBURNU District, Istanbul City

Using data:
Ozbey04 Building Damage
Kalkan04 Building Damage
Boore97 Building Damage
Boore 97 Building Damage Zeytinburnu
Boore97 7.7 Building Damage
BA06 7.7 Building Damage
Region of Interest
02 sec Sa Istanbul Building Fragility Mapping
Zeytinburnu Egim Haritasi
Turkey Soil Types
Istanbul Building Fragilities
Zeytinburnu Bina Verisi
Ozbey 04 Sa020 0.2 Sa
BA 06 Sa020 0.2 Sa
Kalkan Gulkan 04 Sa020 0.2 Sa
Boore 97 Sa020 0.2 Sa
Boore 97 7.7 Sa020 0.2 Sa
BA 2006 7.7 Sa020 0.2 Sa
Turkey Soil Geology
Building Damage Ratios v1.1

		Probability of Damage			Likelihood of Damage State				
Structure Type	# Buildings	Imm. Occup.	Life Safety	Collapse Prevention	Insignific	Moderate	Heavy	Complete	Mean Dmg
C1	7355	81.74 %	38.19 %	10.41 %	18.26 %	43.54 %	27.78 %	10.41 %	31.49 %

Figure 2 Sample HAZTURK Building Damage Summary Report

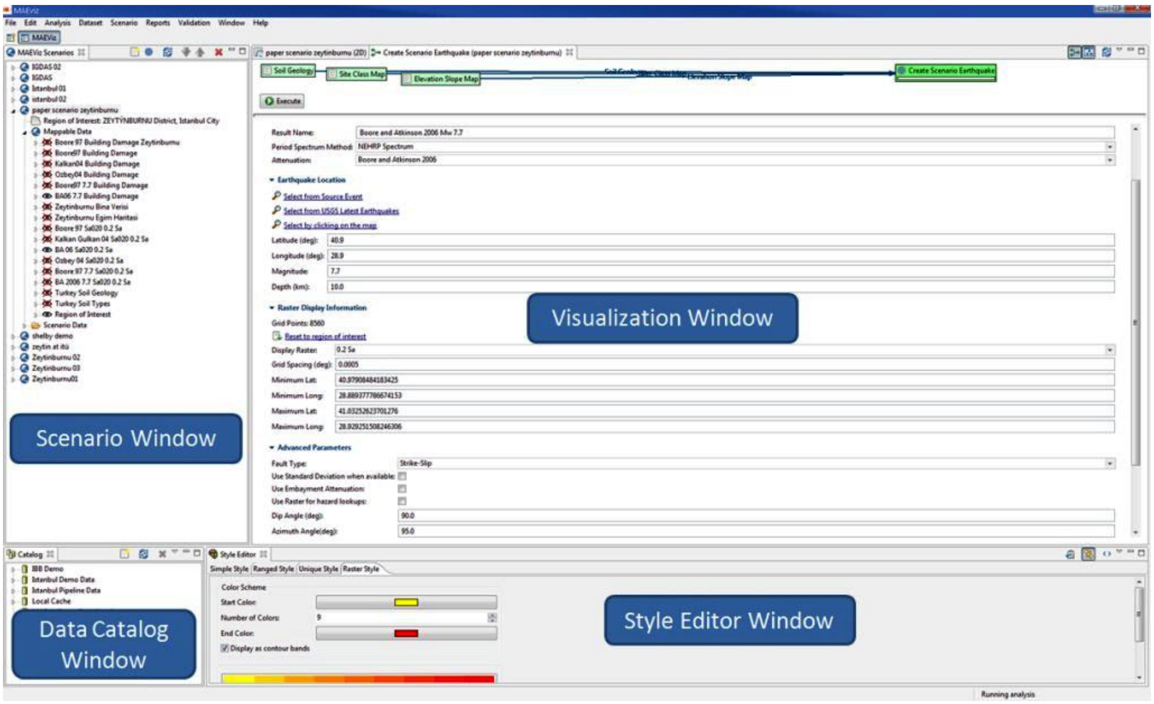

Figure 3 Main Framework of HAZTURK

The building dataset derived from the Istanbul Metropolitan Municipality contains records for 17,037 buildings. It has the attributes for the number of stories, structure type, occupancy type(s), and number of residences, offices, industrial businesses, and name of the building. For buildings, the metadata required to describe the inventory are location (latitude and longitude), material, height, structural system, age, design code level, and type of input expected at the site. The building attributes missing from the set of records are updated from

several sources. One of those sources is the Directorate of the Public Works of Zeytinburnu. The data collected from the Directorate are the building licenses of the structures, which includes 9,607 licensed buildings. This data has the information about the construction year, license year, and the addresses for the buildings. In order to obtain the missing attributes of the building inventory field work was carried out. The main principle of this field work was to perform the procedures of the Federal Emergency Management Agency's *FEMA-154 Rapid Visual Screening of the Buildings for Potential Seismic Hazards Handbook* (FEMA-154, 2002). After the field work, ages of 15,857 buildings, essential facilities, unit prices per meter squared, areas, location in World Geodetic System 1984 Geographical Coordinate System (WGS-84), number of stories, number of empty and occupied residences, offices, and industrial facilities were collected. It is also observed that 503 buildings were demolished and 267 new buildings were constructed within the study region. As a result of these updates, a total number of 16,801 buildings were collected for the Zeytinburnu District. The update process for the building inventory required six months.
It is also important to check whether the results of the analyses are logic or not. Table 3 compares the summary results of HAZTURK and the previous studies. According to Table 3 it can be seen that the results of the analyses are very close although, they have different methodologies. It can also be understood from that the new methodology developed by the HAZTURK has the ability to make logical assessments for the earthquake hazard.

Table 3 Comparison of Several Loss Assessment Studies with HAZTURK

HAZTURK Mw 7.5	**Insignificant**	**Moderate**	**Heavy**	**Complete**	**Mean Damage**
Boore and Atkinson (2006)	43.78	35.60	16.40	4.22	18.55
JICA (2002) Mw 7.5	**H+M+P**	**H+M**	**Heavily**	*H: Heavily*	*M: Moderately*
Boore *et al.*, (1997)	61.2	34.0	16.6	*P: Partly*	
KOERI (2002) Mw 7.5		**Moderately**	**Extensive**	**Complete**	
Spectral Displacement Based		26.5	9.1	4.7	
Intensity Based			**Heavy**	**Damage Beyond Repair**	
			10.43	5.5	
Yakut *et al.*, (2006)	**Low Risk**	**Moderate Risk**	**High Risk**		
	10	21	69		
EDMI (2003)			**Heavily Damaged Building Ratio**		
			13.22		

Discussion

The accuracy of the loss assessment software depends on the data quality and the data accuracy. The earthquake loss assessment process results are only the estimations regarding to the scientific studies. However, they cannot be taken into account as the real determination. The features in HAZTURK continue to grow as new research is completed in the community.
HAZTURK uses large amounts of memory. Memory consumed is based on the size of the datasets used. The size of a dataset also makes a large difference in the speed. The speed of rendering and of analysis computation is heavily dependant on the dataset size. To partially alleviate this issue, users can disable automatic rendering, which will help with speed-related performance issues.
HAZTURK provides new capabilities and understanding about seismic events, the interdependencies of our man-made systems and how to best mitigate and respond to a situation. HAZTURK has been customized to meet the needs of the researchers, practitioners and decision-makers in Istanbul, Turkey. It provides a common place where they can work in a common model to develop risk reduction strategies and understand mitigation responses based on the latest science in an effort to avoid catastrophic results and benefit society.

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