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Expected Earthquake Losses to Buildings in Istanbul and Implications for the Performance of the Turkish Catastrophe Insurance Pool

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Abstract

The city of Istanbul will likely experience substantial direct and indirect losses as a result of a future large earthquake. This paper reports on the expected building losses in the city in terms of probable maximum and average annualized losses and discussed the results from the perspective of the compulsory earthquake insurance scheme operational in the country.

Introduction

As it is well known transfer of risk via insurance and other financial schemes is one of the basic tenets of earthquake risk mitigation. The other two tenets are "do not increase the existing risk" and "decrease the existing risk". In terms of national economy, the insurance system is an essential element for the economic recovery of businesses and of families.

As a consequence of the 1999 earthquakes the insurance sector in Turkey felt the need to change their paradigm. Turkish government established the National Earthquake Insurance Program. Reinsurance companies responded by reducing their risks by increasing the rates or by leaving the market. The insurance companies realized the need for the regular assessment of the risks associated with their portfolio in order to shape their future market strategies. In addition, given the high earthquake hazard, the need for identification of technical issues that merit consideration for underwriting new policies that would consider the particulars of regional earthquake hazard and physical vulnerabilities was quickly realized.

The main concern of this paper is to elaborate on the likely performance of the Turkish Catastrophe Insurance Pool in the event of a large-earthquake near the city of Istanbul, with a very high annual probability of occurrence of about 2%. Istanbul houses about one-eighth of the total population and one-half of the industrial potential of Turkey. There are about eight hundred thousand buildings in the city and the penetration of the compulsory earthquake insurance is about 30 % as of 2006.

Insurance System in Turkey Applicable to Earthquake Peril

There is a two-level earthquake insurance system in Turkey. On level one is the national compulsory earthquake insurance scheme, abbreviated as TCIP, that addresses only structural losses. TCIP covers property up to 50,000 USD value. On level two is the private homeowner's earthquake insurance that covers structural, non-structural and business interruption losses. To buy homeowner's earthquake insurance one first has to be covered by the national earthquake insurance system. The homeowner's insurance covers risks in excess of the TCIP limit. The premiums of both systems are fixed by the government. All companies in the market regardless of their size can sell catastrophe insurance.

Turkish Catastrophe Insurance Pool (TCIP)

The government-sponsored Turkish Catastrophic Insurance Pool (TCIP) is created through a World Bank project with the essential aim of transferring the government's financial burden of replacing earthquake-damaged housing to international reinsurance and capital markets. Coverage is limited to residential buildings and the commercial units located in residential buildings. Only losses due to earthquake, and fire, explosion and landslide following earthquake are covered. The scheme excludes business interruption losses, loss of market, loss of use and all similar indirect losses, damages to the contents, human losses and injuries; and liabilities. It does not cover governmental buildings, buildings in rural areas, buildings for only commercial and industrial use, and post-1999 buildings without a legal construction permit. The insured value of a property is calculated by multiplying the net area of a home by pre-determined monetary square-meter values. The annual premium, categorized on the basis of earthquake zones and type of structure, is about US$95 for a reinforced concrete building in the most hazardous zone (Zone 1) with 2% deductible. TCIP is operational since January 2001. Reinsurance is placed for about US$800 million. If the claims exceed the TCIP's resources, the payment will be pro-rated. Applicable premium rates of the compulsory earthquake insurance scheme in Turkey are given in Table 1 (after Milli Re, 2000).

In Turkey there are about four million buildings in metropolitan municipal areas; about 800.000 buildings in Istanbul. As of May 2006 about 2.5 million compulsory earthquake insurance policies sold Turkey-wide, whereas the total number of households is about 13 million. The penetration nationwide is about 19%. In the Marmara region, where the total number of households is about 4 million, the penetration is about 28%. The penetration in Istanbul is 30% (Garanti Insurance, 2006).

Multiple ownership housing is very common in Turkey. From the point of view of the insured with TCIP policies and the owners that do not have insurance living in the same building this will likely hinder the claim payment-repair-reconstruction period.

Table 1. Premium rates of the compulsory earthquake insurance scheme, categorization based on earthquake zones and construction type

Construction Type	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
A. Steel and Reinforced Concrete	2.20‰	1.55‰	0.83‰	0.55‰	0.44‰
B. Masonry	3.85‰	2.75‰	1.43‰	0.60‰	0.50‰
C. Other	5.50‰	3.53‰	1.76‰	0.78‰	0.58‰

Expected Building Losses in Istanbul in the Event of a M+7 Earthquake

The size of Istanbul as the economic, industrial and financial hub of Turkey and the high concentration of population (about 12 million people) and of buildings (about 800.000), coupled with the increased earthquake expectancies in the city necessitates the evaluation of the probable maximum building losses and their interpretation from the perspective of the performance of the TCIP.

In the following we describe the basic ingredients used for the estimation of earthquake building damages in Istanbul, as well as describe the elements involved for the transition from damage information to financial losses, expressed in this paper as probable maximum losses (PML) and average annualized losses (AAL).

The basic ingredients for loss estimation are probabilistic and deterministic regional site- dependent earthquake hazard, regional building inventory (and/or portfolio), building vulnerabilities associated with typical construction systems in Turkey and estimations of building replacement costs for different damage levels. A state-of-the-art time dependent earthquake hazard model that portrays the increased earthquake expectancies in Istanbul is used. Intensity and spectral displacement based vulnerability relationships are incorporated in the analysis. In particular we look at the uncertainty in the loss estimations that arise from the vulnerability relationships, and at the effect of the implemented repair cost ratios.

Earthquake hazard. State-of-the-art time-dependent probabilistic and deterministic methods have been utilized in parallel for the assessment of the earthquake hazard. Compilation and interpretation of seismotectonic features, propagation path characteristics, topographical, geological and geotechnical data, and the identification of the proper attenuation and site response analysis models constitute important ingredients of earthquake hazard assessment. The selected attenuation relationships provide MSK intensities, peak ground accelerations (PGA) and spectral accelerations (SA) at specific frequencies and damping ratios, for given earthquake magnitude, distance, fault mechanism and local geology. Region specific intensity attenuation relationships developed on the basis of Anatolian earthquakes are considered for the assessment of earthquake intensity based seismic hazard. For the site-specific modification of intensities, intensity change degrees empirically correlated with the geological ground conditions are used. Average horizontal spectral amplification factors stipulated in NEHRP recommendations are used to obtain site-modified earthquake hazard. Earthquake hazard data are aggregated in 0.005 x 0.005 degree geo-cells. The same geo-cells are also used for aggregation of the site classes and of the building inventory. The detailed treatment of the earthquake hazard in the Marmara region is given in Erdik et al (2004).

Building inventory. Basic information needed for the cell based earthquake vulnerability assessment studies is the type of structure (classified as reinforced concrete frame, masonry, reinforced concrete shear wall), number of stories (classified as low rise (1-4 stories), mid rise (5-8 stories), high-rise (8 and more stories)) and construction date (classified as pre-1979, post-1980). The seismic design codes evolved particularly after 1975 in Turkey. For our classification criteria the year 1980, is assumed as an approximate date of wider adoption and implementation of the seismic design in the country. The cell-based building inventory in Istanbul categorized with respect to criteria described above. Details of the studies carried out on the Istanbul building stock can be found in Erdik et al (2003).

Earthquake vulnerabilities of buildings. Both intensity-based (observed) and spectral-displacement based (predicted) vulnerability relationships were used in the analyses. We also included the variability associated with the vulnerability functions in the results, which is due to a variety of reasons such as difficulties associated with knowing the exact character of ground motion, estimating the extent to which the structure will be excited by and respond to the ground shaking, the construction material properties, character and condition of individual structural elements and their interaction etc.

The existing intensity-based vulnerability curves for the general building types in Turkey have been reevaluated and revised on the basis of available empirical data, compilations from post earthquake damage reports and engineering interpretations. The modified vulnerability curves for mid-rise (5-8 stories) reinforced concrete frame type buildings have been obtained and extended to low-rise (1–4 stories) and high-rise (9≥ stories) R/C frame type buildings. Details on this analysis and corresponding vulnerability curves can be found in Durukal et al (2006).

In addition to intensity-based vulnerability curves, analytically derived spectral displacement based vulnerabilities are also used in the loss estimation. The vulnerability relationships have been adopted from Erdik et al (2003).

Replacement cost ratios. The ratio of the cost of repair of damage to the cost of reconstruction is expressed as the Replacement Cost Ratio (or Repair-Cost Ratio). The replacement-cost ratios are given for each damage level. When multiplied with the corresponding percent damages in an area (or in a geo-cell) found from the combined analysis of earthquake hazard and building vulnerabilities, they yield the loss ratio in that zone. The significant differences among the estimations of replacement cost values adopted for different damage levels, initiated a study, where the insurance experts were asked to give their estimations of damage levels and corresponding replacement cost ratios for eighteen cases of damage. Their responses were analyzed to yield following replacement-cost ratios which were eventually adopted in the loss estimations: 10%, 20%, 40%, 90 % and 100% for D1, D2, D3, D4 and D5 respectively. The damage levels from D1 to D5 are defined in European Macroseismic Scale – EMS'98 (http://www.gfz-potsdam.de/pb5/pb53/projekt/ems/). The details of this survey and the results of statistical analyses carried out can be found in Durukal et al (2006).

Probable maximum losses and associated uncertainty. Probable maximum losses are found as a combination of ingredients described above. The uncertainty in loss figures arising from the variability in the reported replacement cost ratios are incorporated by their standard deviations. The extent of the data do not allow for a proper statistical treatment of vulnerability relationships. In the absence of this information the corresponding variation is assumed to take place within a zone roughly halfway between two adjacent vulnerability curves.

Cell-based distribution of probable maximum losses in Istanbul using spectral displacement based and intensity based vulnerabilities is presented in Figure 1 for the Mw 7.5 scenario earthquake. Estimated probable maximum building losses for the Istanbul building stock are given in Table 2 after Durukal et al (2006).

Table 2. Probable maximum building losses in Istanbul

Intensity Approach			
Scenario Earthquake (Mw 7.5)	SD-1 Loss Ratio	Median Loss Ratio	SD+1 Loss Ratio
Mean vulnerability, mean damage ratio	0,09	0,14	0,23
Max vulnerability, max damage ratio	0,17	0,26	0,36
Min vulnerability, min damage ratio	0,04	0,07	0,12
Spectral Displacement Approach			
	SD-1 Loss Ratio	Median Loss Ratio	SD+1 Loss Ratio
Scenario Earthquake (Mw 7.5)	0,16	0,28	0,38
72 Yrs Return Period	0,15	0,25	0,35
100 Yrs Return Period	0,17	0,30	0,40
224 Yrs Return Period	0,23	0,37	0,49
475 Yrs Return Period	0,27	0,43	0,55
2475 Yrs Return Period	0,38	0,57	0,68

Probabilistic maximum building loss curves associated with the Istanbul building inventory are shown in Figure 2 along with deterministic earthquake losses (Durukal et al 2006). The presented curves represent estimations found using spectral-based vulnerability curves only, since the probabilistic earthquake hazard is given in ground motion parameters PGA and SA's. The current functional form of intensity attenuation relationships for Turkey does not allow the assessment of probabilistic earthquake hazard using renewal type recurrence models because of software limitations.

The probable maximum loss (PML) ratios (the ratio of probable maximum loss to the building replacement value) are estimated as 14% (4-36 %) in the occurrence of a scenario event (i.e. deterministic approach) using the intensity-based vulnerabilities and as 28% (16–38 %) using the spectral-displacement based vulnerabilities. Using the probabilistic approach we estimate the 475-year return-period PML ratio as 43%. It should be noted however that, although the PML associated with 475 year return period is used as a standard by the insurance sector, it may not be rational to use it in the case of Istanbul, where the occurrence of an earthquake is quasi-deterministic with studies giving it a chance of 65% (Parsons et al 2000) and a revised 41±14% (Parsons, 2004) in the next 30 years. In probabilistic terms this corresponds to an event with a return period of 72-100 years. The 72 and 100-year probabilistic PML ratios found are 25% and 30% respectively. There exist about 2,500,000 housing units in Istanbul. At an average structural value of ($70m^2$ * USD 200 per m2) of $14,000 per housing unit, the total structural value would be about $35 billion. As such the PML for 72-100 year return period (or for deterministic scenario earthquake) will be around $9-11 billion.

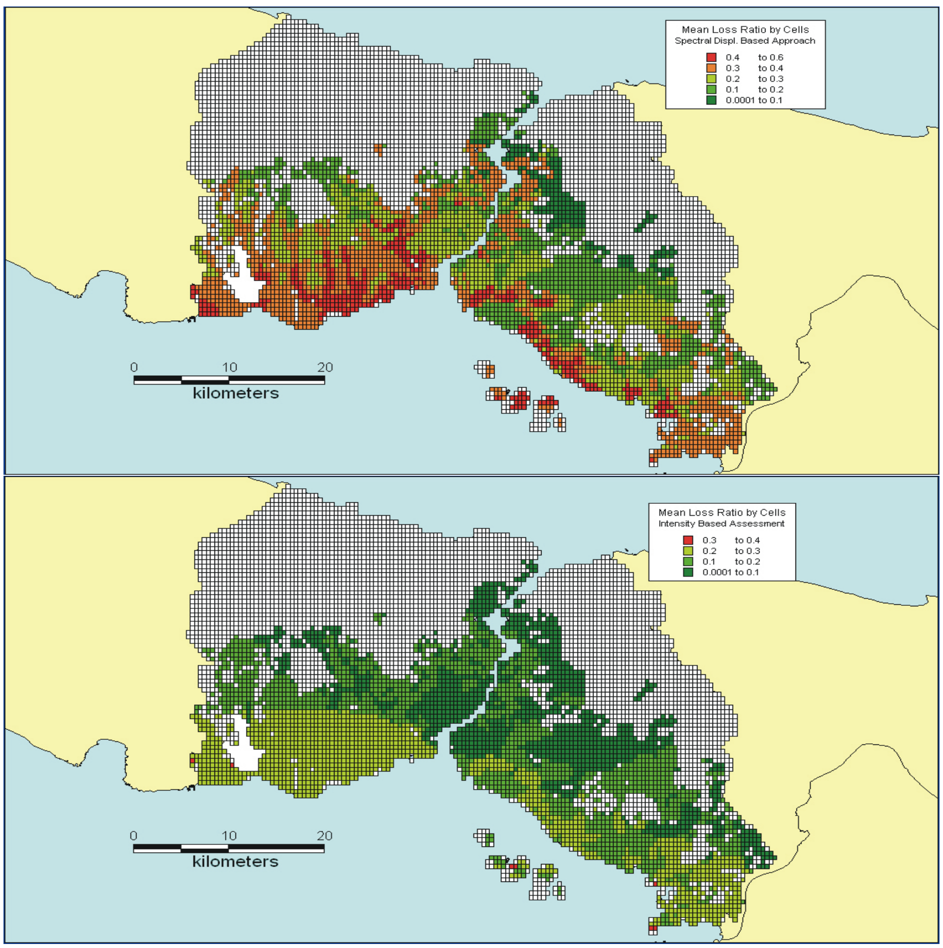

Figure 1. Cell-based distribution of probable maximum losses in Istanbul using spectral displacement based (top) and intensity based (bottom) vulnerabilities for the Mw 7.5 scenario earthquake

Average annualized losses (AAL) and associated uncertainty. Average annualized losses (AAL) are found from the area that fall under the loss curves. This figure is used as the basis to determine the insurance premium rates. The average annualized loss (AAL) associated with the Istanbul building stock is estimated as 4.7‰. It may vary between 3.1‰ and 6.2‰ representing SD-1 and SD+1 replacement cost estimations. The comparatively higher AAL of Istanbul is the result of two important agents: the very high expectations for a significant earthquake (up to 40-65% in 30 years for a M7+ earthquake on Main Marmara Fault, Parsons et al (2000) and Parsons (2004)) and the existence of a building stock with poor earthquake performance. These two factors also serve to increase the PML ratios over those so-called industry accepted figures of about 15%. As a comparison in California, the state average of AAL is 0.18%, county AAL's change between 0.05% and 0.26%.

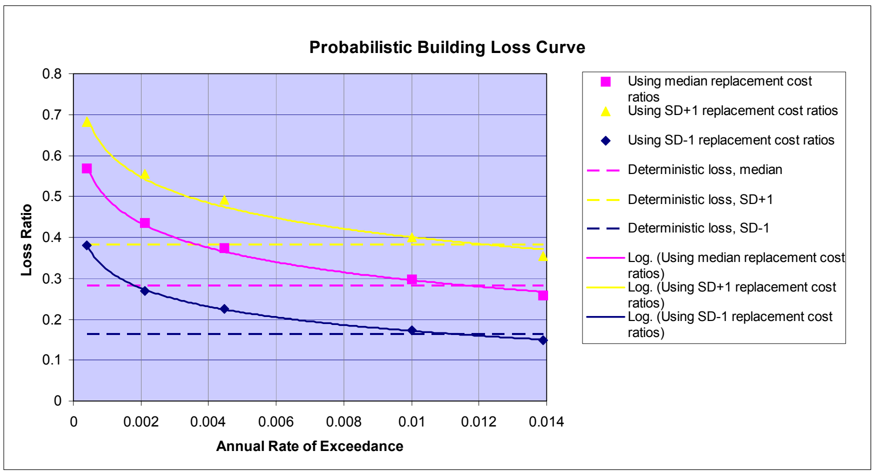

Figure 2. Probabilistic building loss curves for Istanbul shown along with deterministic earthquake losses.

For reinforced concrete structures which constitute the majority of the building stock in Istanbul, the compulsory earthquake insurance premiums in Zones I – III defining the hazard conditions in Istanbul based on national earthquake hazard map, vary between 2.2‰ and 0.83‰. If assumed that the average premium for Istanbul would be 1.5‰, there is a very significant difference between this value and 4.7‰ found from loss estimations.

Implications for the Likely Performance of the Compulsory Earthquake Insurance System

These results raise concern about the performance of the TCIP in the event of a M+7 earthquake near Istanbul. So far the operational experience of the TCIP is limited to small size earthquakes in small cities. Information gathered from Garanti Sigorta (current TCIP Operator) indicates that as of 2005 a total of about 7500 claims were processed at a total cost of about $10 million. The largest number of claims (about 1700) originated from the M5.6 earthquake in Izmir-Urla on 10.04.2003. These claims were paid without much dispute and in a very short time. Although this sets an excellent precedent it would be difficult to have the same performance in a large earthquake causing extensive damages in a large city. Even though the amount accumulated in the TCIP would be sufficient in covering such losses, the logistical and operational problems that would be expected in processing and adjusting the claims can easily exceed the current capacity of the system thereby causing delays and complaints. For a major earthquake near Istanbul the funds in the pool (including the reinsurance coverage) will very likely fall short of meeting the incurring losses. Erdik et al. (2003) predicts $11 billion for the total building (structural) damage. Note that the same value is also reached on the basis of PML calculations given in this paper. Assuming 30% insurance penetration the total claims faced by the TCIP will be around $3.3 billion or about three times the current capacity of payment. This will force the system to prorate the claims, meaning that the insured in Istanbul will only be able to recover their losses partially. It should be noted that the 2nd level private insurance is made over and above the TCIP coverage, assuming that the compulsory insurance losses will be fully covered by the TCIP. In case of such a pro-rating the missing portion has to be unjustly absorbed by the home owner.

On the basis of earthquake loss scenario assessments Erdik et al. (2003) predicts that about 40% of the buildings will experience damage ranging from moderate to collapse. This would amount to about 1,000,000 housing units. If the earthquake insurance penetration rates are sustained at about 30%, the number of claims to be processed after a sizeable earthquake will be huge (around 300,000, just for medium and higher damage levels). Noting the fact that the experts will be also earthquake victims, there will be a shortage of experts and resources to handle the claims and the whole claim processing scheme will fail causing long delays\ complaints and numerous court cases between the TCIP operator and the insured. Such cases will likely take years to complete. Moreover, for those who have private earthquake insurance, the companies will wait for the compulsory insurance to finalize claim processing before processing their own part. For the cases to be handled by courts, the private companies will also wait until the case is settled to handle their part.

Conclusions

Studies indicate that the national compulsory earthquake insurance pool in Turkey will face difficulties in covering incurring building losses in Istanbul and possibly in İzmir as well, in the occurrance of a large earthqıake, although it will likely perform well in medium size events and in events hitting medium size towns. Improvements to the system and/or other financial models and schemes may need to be developed to improve the current system.

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