Estimation of Seismic Damage in Antakya Region due to Background Seismic Activity

M. Semih Yücemen

Departments of Civil Engineering and Earthquake Studies and Earthquake Engineering Research Center, Middle East Technical University, Ankara, Turkey

e-mail: yucemen@metu.edu.tr

Ayşegül ASKAN

Departments of Civil Engineering and Earthquake Studies and Earthquake Engineering Research Center, Middle East Technical University, Ankara, Turkey

Elif Müge ÜN

Department of Civil Engineering, Middle East Technical University, Ankara, Turkey

Nazan YILMAZ

Earthquake Department, Disaster and Emergency Management Presidency, Ankara, Turkey

Objective

- To present a probabilistic model for the estimation of expected earthquake damage in terms of Expected Annual Damage Ratio (EADR).
- Illustrate the application of the model for the estimation of the potential seismic damage in Antakya Region based on background seismic activity.

- Assessment of EADR requires two types of study:
  - Seismic hazard analysis (**SHA**)
  - Estimation of potential seismic damage to structures (**DPM**)

- Due to existing **aleatory** and **epistemic** uncertainties, both studies should be carried out based on **probabilistic methods**.

Seismic Hazard Analysis due to Background Seismic Activity

In probabilistic seismic hazard analysis, the seismic activity that cannot be associated with the major seismic sources is generally called as "background seismic activity". Contribution of background seismic activity to seismic hazard is generally calculated by using two different models:

- Background area source with uniform seismicity
- Spatially smoothed seismicity model

- In the widely used classical probabilistic seismic hazard analysis (PSHA) method (Cornell,1968) background area sources are delineated and over these background area sources seismic characteristics are assumed to be spatially homogeneous.

- The main disadvantage of this method is the significant subjectivity in the delineation of seismic source zones, especially where the seismotectonic knowledge of the observed area is poor.

- Spatially smoothed seismicity model assumes that future earthquakes will occur in the vicinity of past earthquakes and eliminates this subjectivity. In this model, earthquakes that are not assigned to major seismic sources are assumed to be potential seismic sources and spatially distributed to cells of a grid.

- The algorithm developed by Frankel (1995) uses a Gaussian smoothing function with a correlation distance denoted by c in computing the seismic hazard.

Seismic Hazard Analyses for the Antakya Region

Seismic Data Base:

➢A rectangular region bounded by 34.4˚-38.4˚N latitudes and 34.0˚-38.4˚E longitudes is studied.

➢Events recorded, between the years 1900 to 2004 and magnitudes, $M_w \geq 4.5$ are considered.

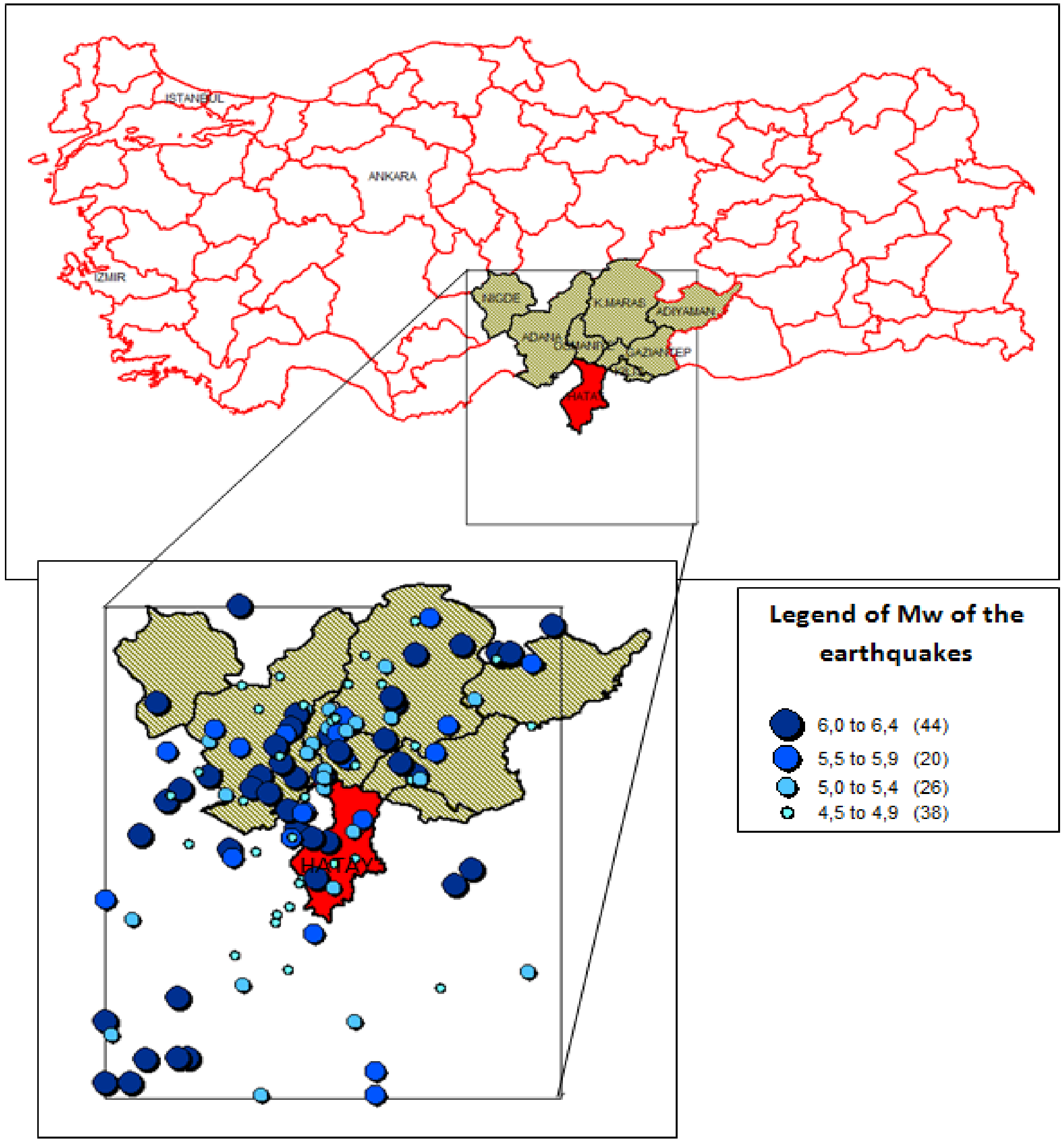
➢Due to the memoryless nature of the Poisson process, secondary events (i.e. foreshocks and aftershocks) are removed from the earthquake catalog (declustering).

- Slope of the exponential magnitude distribution, b, is computed as 0.73.

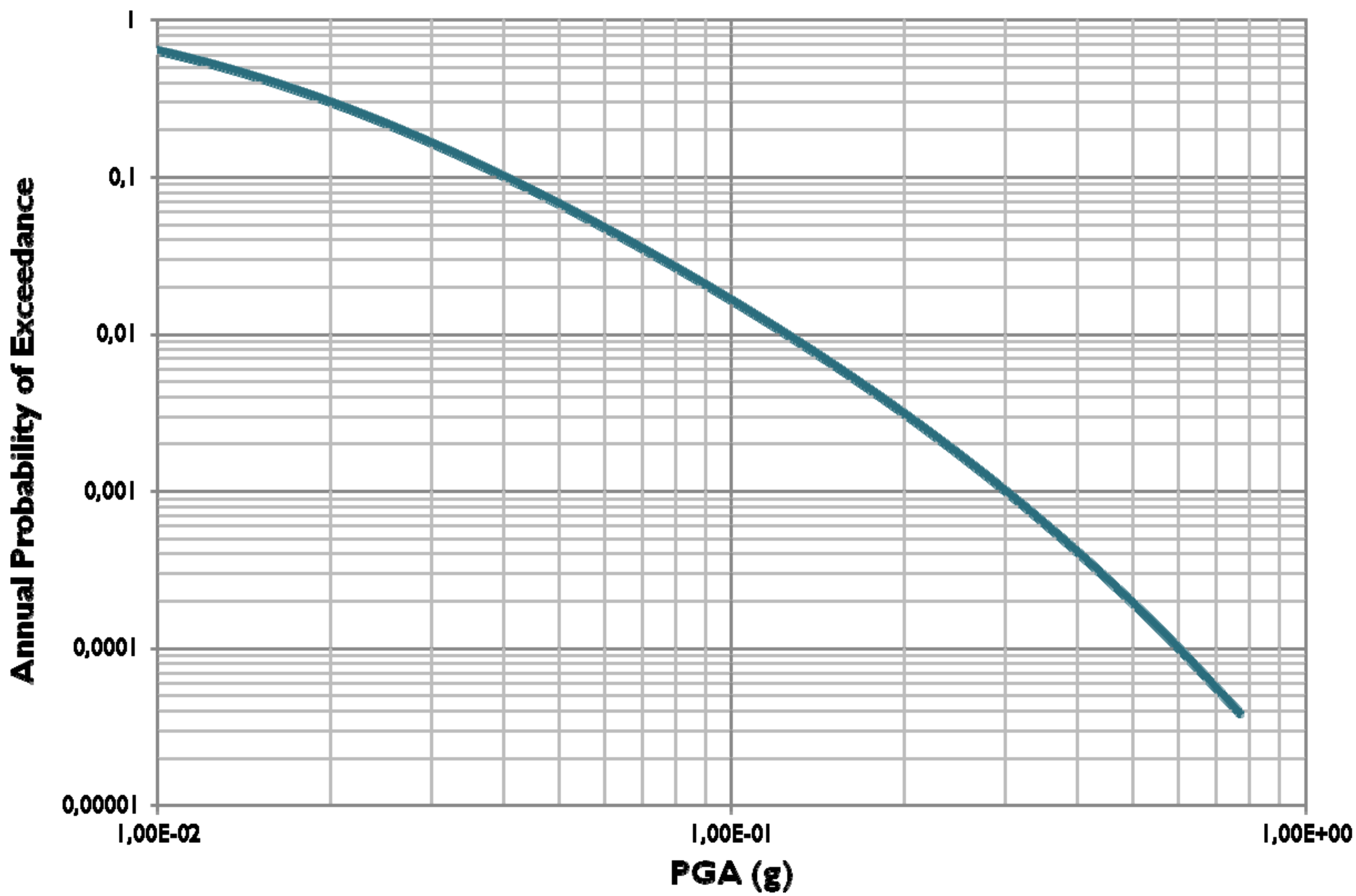
- The attenuation relationship proposed by Kalkan and Gülkan (2004) is used in the assessment of seismic hazard in terms of peak ground acceleration (PGA) which is taken as as the basic parameter.

- The correlation distance, c, is taken as 50 km.

Seismicity Map of the Antakya Region



Seismic Hazard Curve for the Antakya Region



Estimation of Potential Seismic Damage

- Due to the uncertainties involved, the damage that may occur during future earthquakes has to be treated in a probabilistic manner. For this purpose damage probability matrices (DPM) are used.

- A damage probability matrix (DPM) expresses what will happen to buildings, designed according to some particular set of requirements, during earthquakes of various intensities.

Damage Probability Matrix

Damage State (DS)	Damage Ratio (DR) %	Central Damage Ratio (CDR) %	Modified Mercalli Intensity (MMI)				
			V	VI	VII	VIII	IX
None	0-1	0	Damage State Probabilities P(DS, I)				
Light	1-10	5					
Moderate	10-50	30					
Heavy	50-90	70					
Collapse	90-100	100					

DR : ratio of the cost of repairing earthquake damage to the replacement cost of the building.

Types of DPM's

- **Empirical** DPM's: based on damage databases of past earthquakes.
- **Subjective** DPM's: based on expert opinion.
- **Theoretical** DPM's: based on seismic structural analysis.

- The most reliable way for the assessment of damage probability matrices is the use of building damage data compiled after an earthquake provided that personal biases in damage evaluation are controlled.
- Usually the empirical data is not complete and should be supplemented with expert opinion.

Using past earthquake damage data, the empirical P_k (DS, I) values can be calculated as:

$$P_k(DS, I) = \frac{N(DS, I)}{N(I)}$$

N(I) = the number of kth-type of buildings in the region subjected to an earthquake of intensity I,

N(DS, I) = the number of buildings which are in damage state DS, among the N(I) buildings.

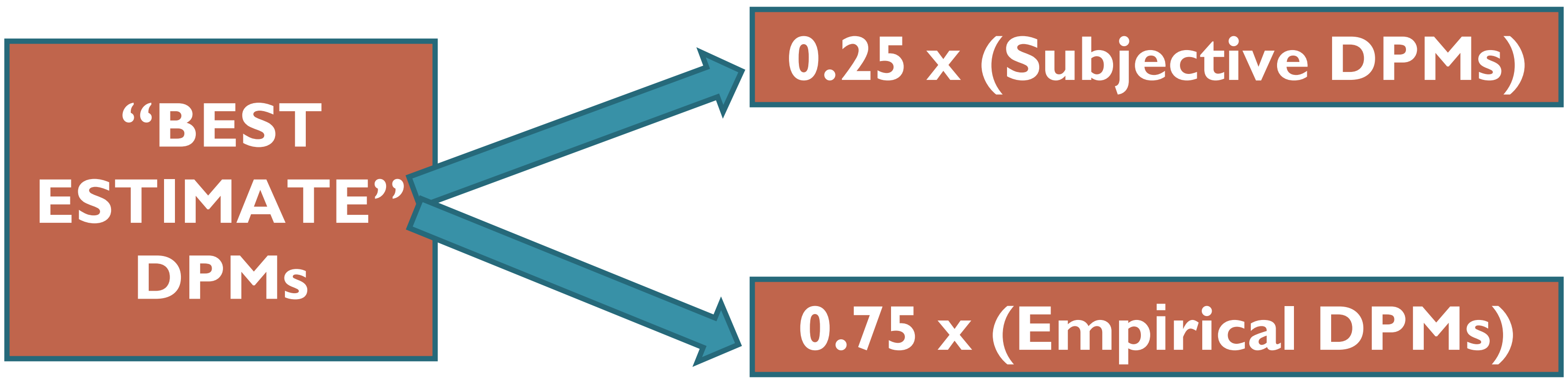
- The information contained in the damage probability matrix and in the damage ratios can be combined by defining the **MDR_k** as follows:

$$MDR_k = \sum_{DS} P_k(DS, I) \times CDR_{DS}$$

CDR_{DS} = central damage ratio corresponding to damage state DS.

Best-Estimate DPMs for Reinforced Concrete Buildings in Turkey

Formation of the "best estimate" DPMs



Best Estimate Damage Probability Matrix for Seismic Zone I of Turkey (Askan and Yucemen, 2010)

Damage State (DS)	CDR (%)	MMI=V		MMI=VI		MMI=VII		MMI=VIII		MMI=IX	
		AC	NAC	AC	NAC	AC	NAC	AC	NAC	AC	NAC
None	0	1	0.95	0.95	0.58	0.70	0.46	0.50	0.28	0.30	0.07
Light	5	0	0.05	0.05	0.29	0.20	0.34	0.20	0.39	0.30	0.27
Moderate	30	0	0	0	0.11	0.10	0.14	0.20	0.20	0.20	0.30
Heavy	70	0	0	0	0.02	0	0.05	0.10	0.07	0.20	0.19
Collapse	100	0	0	0	0	0	0.01	0	0.06	0	0.17
MDR(%)		0	0.25	0.25	6.2	4	10.4	14	18.9	21.5	40.7

where:
AC is used for the buildings that are designed and constructed according to the Code
NAC is used for the buildings that are designed and constructed **not** according to the Code

Determination of the EADR

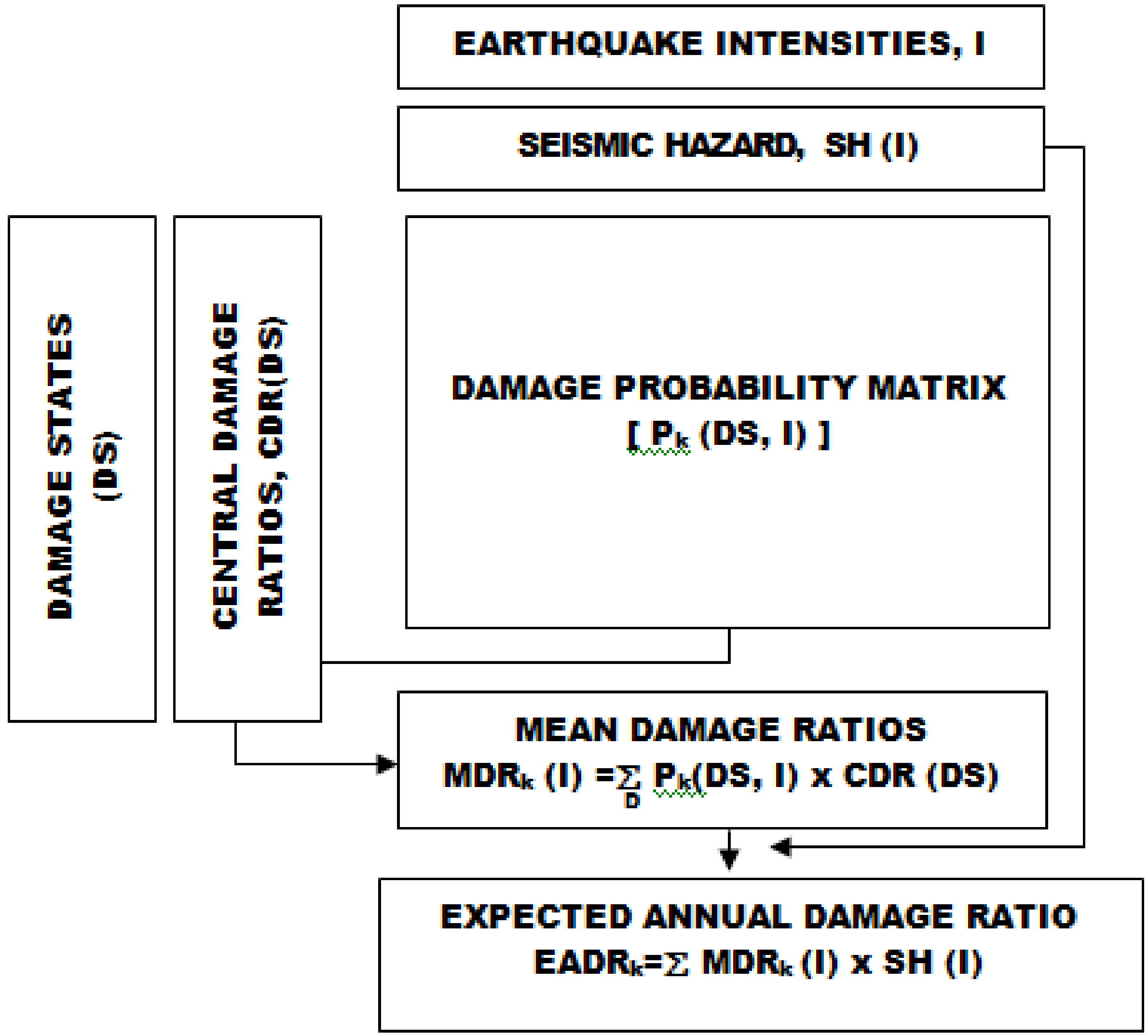
- Expected annual damage ratio ($EADR_k$) is used as a measure of the magnitude of earthquake damage to the kth-type of structure that will be built in a certain seismic zone and is defined as:

$$EADR_k = \sum_I MDR_k \times SH_I$$

MDR_k = the average damage ratio for the kth-type of structure subjected to an earthquake of intensity I,

SH_I = the annual probability of an earthquake of intensity I occurring at the site.

Flowchart of the Loss Estimation Methodology



Expected Annual Damage Ratio for the Antakya Region

Since the DPMs are expressed in terms of MMI, the hazard values are converted from PGA to MMI by using the following conversion equation developed by Arıoglu et al (2001):

$$MMI = 1.748\ln(PGA) - 1.078$$

where PGA is defined in cm/sec^2.

Expected Annual Damage Ratio for the Antakya Region

Finally, in Antakya city center, for the case where the design or construction of a reinforced concrete building is not carried out in accordance with the Code (**NAC**), EADR is computed as **0.78 %**, whereas this value reduces to **0.21 %** if the building is designed and constructed according to the Code (**AC**).

Concluding Remarks

- The EADR value is found to be consistent with those of other cities located in the first seismic zone of Turkey.

- Significantly higher EADR (about four times more) that result from the violation of the Code requirements strongly suggest that compliance with the Code should be an important factor while determining the earthquake insurance rates. In other words, significantly different rates should be charged for buildings depending on their degree of compliance with the Code.

- More accurate results would be obtained if:
  - Detailed hazard assessment is performed based on well-defined faults in the region and their seismicity parameters.
  - Damage state probabilities are calculated using directly the properties of the building stock in Antakya.
  - Detailed site characterizations for the region are made.
  - Spatial variations of damage state probabilities and seismic hazard in Antakya region are taken into account while computing the EADRs.