

# **ISTANBUL EARTHQUAKE RISK AND MITIGATION STUDIES**

O. Metin Ilkisik,  
M. Nilay Ergenc and Murat T. Turk

Disaster Coordination Center, Istanbul Metropolitan Municipality, Istanbul, Turkey  
e-mail: omilkisik@hotmail.com

## **ABSTRACT**

As a result of the growth of the cities in number and population, which led to increase in the number and complexity of the buildings, services and infrastructure, the vulnerability in disasters has much more aggravated today than those in past.

The city of Istanbul has been a major population center with a prominent role in commercial cultural activities for at least two millennia. Although Istanbul is a very old city of 2500-3000 years, it grew very rapidly especially after 1950s. Accordingly its population increased from 1 million (in '50s) to 12 million today. As an important social, economical and geopolitical centre, Istanbul has been the destination of the people emigrating from rural areas. This increased the need for housing and other infrastructural facilities. There are about 1,200,000 buildings in Istanbul as of 2006.

According to historical records on earthquake, 120 earthquakes in destructive scales occurred in Istanbul and its surroundings during the last 2000 years. Considering the local features of the ground of Istanbul where the buildings are situated, construction quality of the buildings, deterioration and corrosion problems related to the age of the buildings, the earthquake risk increasingly growing.

In order to assess the risks Japan International Cooperation Agency had prepared a "Study on Disaster Mitigation/prevention in Istanbul Including Seismic Microzonation". To follow up studies on the "Assessment of Earthquake Risk in Istanbul" and to find proper solutions for complex "risk mitigation" issues, the "Earthquake Master Plan for Istanbul (EMPI)" has been commissioned by Istanbul Metropolitan Municipality (IMM) to a consortium involving four leading Turkish Universities. The implementation of EMPI was done in Zeytinburnu which was determined in JICA study and EMPI as one of the risky district in Istanbul. Similar pilot projects in Fatih and Kucukcekmece Districts still on going.

## **EARTHQUAKE RISK AND GEOLOGICAL SITUATION**

Seismic hazard for the Turkish mega city Istanbul is extremely high; the western continuation of the North Anatolian Fault Zone (NAFZ) which accommodates 25 mm/yr of right lateral motion runs in close vicinity through the Marmara Sea.

Istanbul and its surroundings are the settlements, which were damaged by many earthquakes along the history. Historic records for past 2000 years (Ambrayses, 2002) reveal a statistical recurrence of one destructive earthquake hitting Istanbul each century.

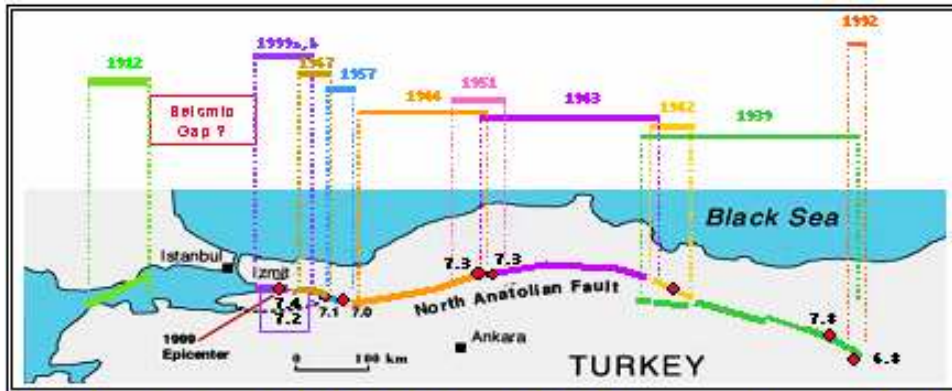


Figure 1 a) Westward migration of EQs on NAFZ since 1939 M=7.8 EQ.

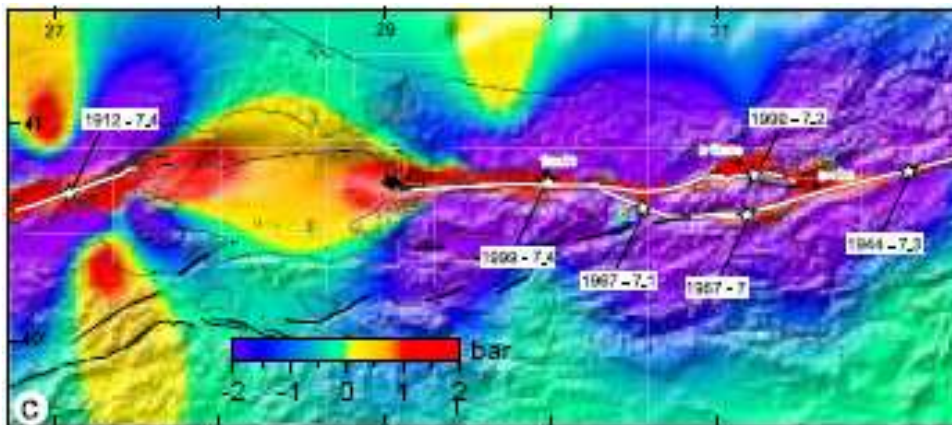


Figure 1 b) Coulomb stress accumulation after 1999 EQ around Istanbul

Seismologists (Parsons et.al. 2000) have noted that the epicenters of strong earthquakes seemingly migrate from east to west along the NAFZ and they point out the possibility of another big earthquake hitting Istanbul where the western edge of the NAFZ is situated. New earthquake probability calculations for the Marmara Sea providing a forecast of 30 year Poisson probability of an  $M > 7$  earthquake affecting Istanbul is 41 % (Parsons, 2004).

It is necessary to have values that are realistic but it is a fact that damage experienced can differ enormously between points separated by a distance of kilometers or even just hundreds of meters in some circumstances. This experience means that it is important to understand the characteristics of the intervening ground very well. Detailed geological, geotechnical and geophysical studies of the surface strata on a definition down to 250 m on a side has to be done in order to realistically forecast likely earthquake motions. The proposed 3-D models also explain quite well the main amplification features at the area of interest. Recently Metropolitan Municipality running a microzoning project at Southwestern part of the city. This detailed information of local ground conditions will be used to establish the appropriate design parameters for construction in the city, which should be adopted as part of the city's building code.

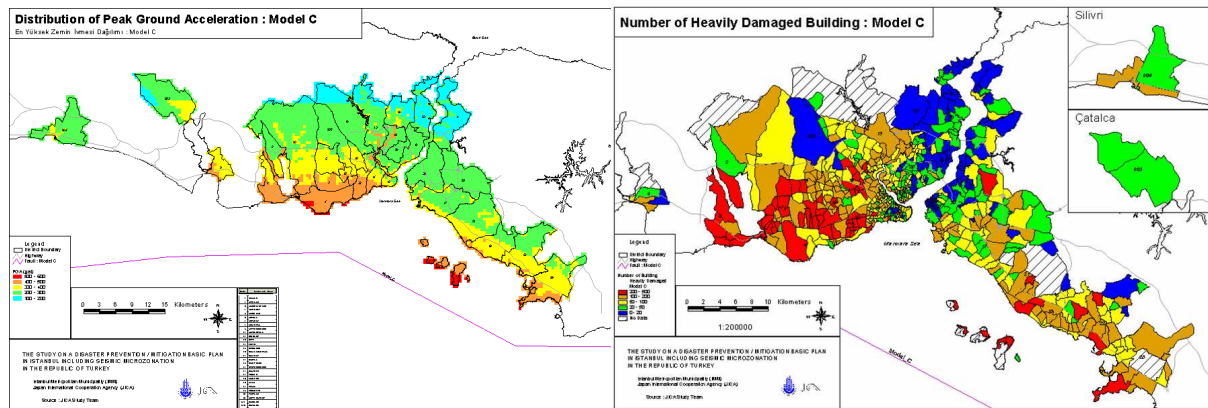
## VULNERABILITY and LOSS ESTIMATION

The peoples emigrating from rural areas increased the need for housing and other infrastructural facilities. There are about 1,300,000 buildings in Istanbul as of 2007.

The 17 August 1999, Mw=7.4 Kocaeli earthquake killed 18,000 people, destroyed 17,000 buildings, and caused \$25 billion in damage -official numbers-. Approximately 1000 people in the Istanbul were killed and damage of buildings was rather serious, though the epicenter of the 1999 earthquake on NAFZ was more than 110 km away.

JICA study (2002) in coordination with Istanbul Metropolitan Municipality (IMM) estimate that a major earthquake of Mw=7.4 near to Istanbul might cost more then 50,000 lives and cause economic losses of more than \$ 60-70 billions. Although expected number of injuries requiring hospitalization will be around 150,000; 30% of hospitals (in total of 635) are located in risky areas of southwest part of the city.

This research will allow the underlying processes to be better understood, and prediction and forecasting methods to be improved on the basis of a probabilistic approach.



Considering the local features of the ground of Istanbul where the buildings are situated, construction quality of the buildings, deterioration and corrosion problems related to the age of the buildings, the earthquake risk increasingly growing.

A study by Chamber of Civil Engineering (2005) which is conducted on 1278 buildings (0.1% of total) from different locations of Istanbul show that the average concrete quality (uniaxial compressive strength) is about 15.33-18.97 MPa with a variation coefficient of 50%. Actually, Seismic Code of 1998 requires minimum 20 MPa for new designed buildings. 16.2% of the buildings have less than C8 (8 MPa) concrete quality -including school buildings. Only 7% of total buildings more than C30 (30 MPa).

The problems in Istanbul concerning the earthquake risk range from the poor quality or depreciation of buildings from an engineering point of view to the poor urban environment generated by social, economic and physical deterioration as well as uncontrolled urban growth and an inflexible planning system which remains incompatible with the dynamics of the city.

## EARTHQUAKE MASTER PLAN FOR ISTANBUL

Managing natural disasters requires a multi risk approach. There is a need for improved knowledge, methods and integrated framework for the assessment of hazards, vulnerability and risks. Furthermore mapping, prevention and mitigation strategies including consideration of economic and social factors need to be developed.

In order to manage the potential earthquake disaster in Istanbul, it is necessary to prepare a seismic disaster prevention/mitigation plan, emergency rescue plan and restoration plan of the earthquake stricken area from middle to long-term points of view.

To follow up studies on the "Assessment of Earthquake Risk in Istanbul" and to find proper solutions for complex "risk mitigation" issues, the "Earthquake Master Plan for Istanbul (EMPI)" has been commissioned by Istanbul Metropolitan Municipality (IMM) to a consortium involving four leading Turkish Universities (2003).

The scope of Earthquake Master Plan for Istanbul comprises work to be done in the following areas:

- Assessment of current situation
- Seismic assessment and rehabilitation of existing buildings
- Urban planning issues
- Legal issues
- Financial issues
- Educational issues
- Social issues
- Risk and disaster management issues

This list would be complemented by specific programs aimed at planning of the activities in these fields, preparation of implementation programs, and identification of the responsibilities and responsible authorities for earthquake disaster mitigation works to be carried out in Istanbul.

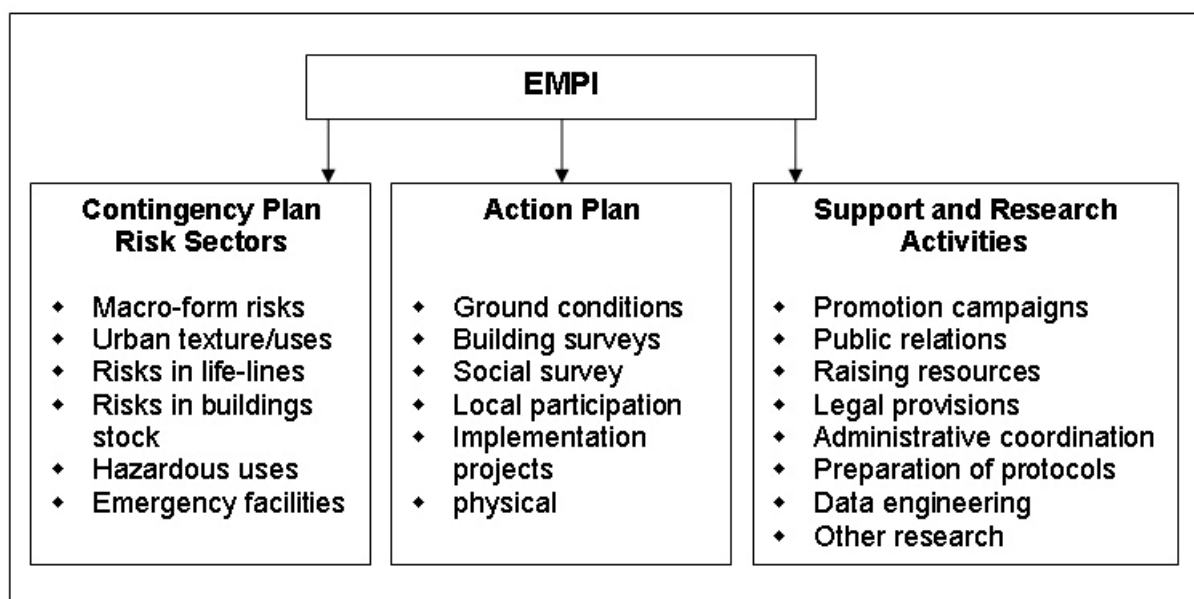


Figure 3 a) Schematic Outline of Earthquake Master Plan for Istanbul

Earthquake disaster mitigation efforts for Istanbul should be multi-disciplinary and have a broad vision. These efforts will be pioneering examples of Urban Development Projects and Local Transformation Programs, or total "Action Planning" for Turkey.

A comprehensive master plan is related in a complex way to legal, administrative, financial and social matters. Solutions in such contexts are not necessarily unique as in technical matters, and can reflect a multitude of syntheses leading to some different set of recommendations.



Figure 3 b) Essential ingredients of the Master Plan

Seismic evaluation of existing buildings and strengthening of those, which do not have acceptable seismic safety, constitutes one of the mitigation activities considered in the Master Plan. Although there are various evaluation and strengthening methods available for individual buildings, there exists a strong need for the development of screening procedures for large number of undocumented buildings in campaign-type applications. In the evaluation of the seismic safety of buildings, three stages were adopted. The first stage inspection/evaluation works are also referred as "street survey" and correspond to preliminary assessment. In the second stage assessment, starting with the high priority buildings and regions, more detailed investigation/evaluation works will be executed for seismic assessment of buildings. The third stage involves an almost through analysis of the building and decision on its earthquake worthiness and economic feasibility of retrofit.

The realization of the Master Plan can not be accomplished only within the province of the local government machinery, but requires support and close cooperation of the parliament and the executive branch of government.

The problem areas in the Turkish legal system which may create obstacles in the way of these Strategic Plan applications are:

- \* Problems Associated with Institutional Responsibilities
- \* Problems Associated with Planning
- \* Problems Associated with the Built Environment

Following amendments are to be made in the legal system in order to tackle the problems associated with institutional responsibilities:

1. The duties and responsibilities of some of the institutions are to be reorganized.
2. Local authorities, including metropolitan municipalities and regional seismic commissions, are to be empowered to assess disaster risks and prepare strategic plans and programs.
3. The issues concerning the preparation of various maps and other related documentation for disaster management are to be identified in the legal framework.
4. The financial models and their instruments proposed by the planning and finance working groups are all to be specified within the legal system.

## PILOT PROJECTS

### Zeytinburnu District

For Istanbul Metropolitan Municipality an important part of administrative policy is disaster prevention in order to protect the lives and property of the local residents in respect of possible anticipated major earthquake. For this aim during last decade Municipality supported several disaster prevention projects.

As an example the implementation of EMPI was done in Zeytinburnu district which was determined in JICA study as one of the risky districts in Istanbul.

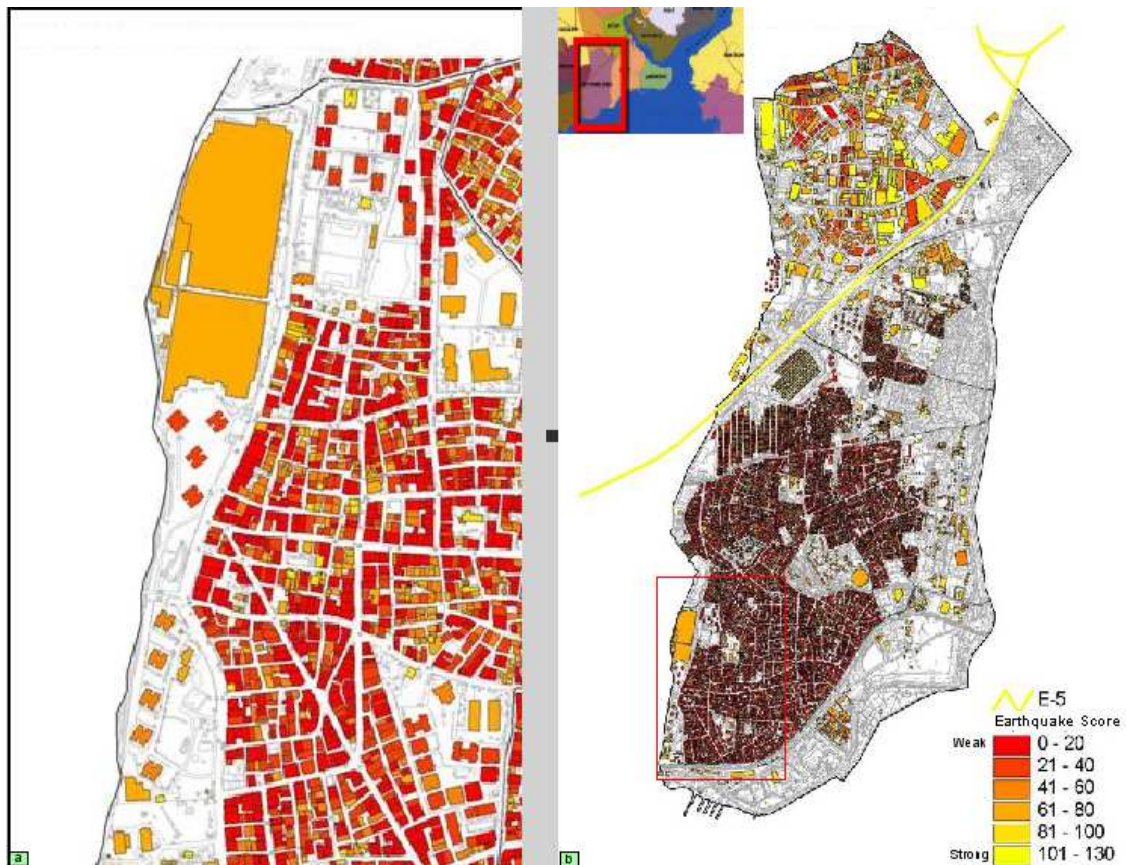


Figure 4 a) Distribution of vulnerable buildings in Sumer neighborhood;  
b) Distribution of earthquake weakness scores through the Zeytinburnu District

As a result of detailed building surveys during 2004, it became evident that at least 2295 buildings of 16031 in total will have extremely high risk of heavily damage in the case of  $M > 7$  EQ in the Marmara Sea. Unfortunately two of them has already been collapsed recently by it's own without any cause of disaster.

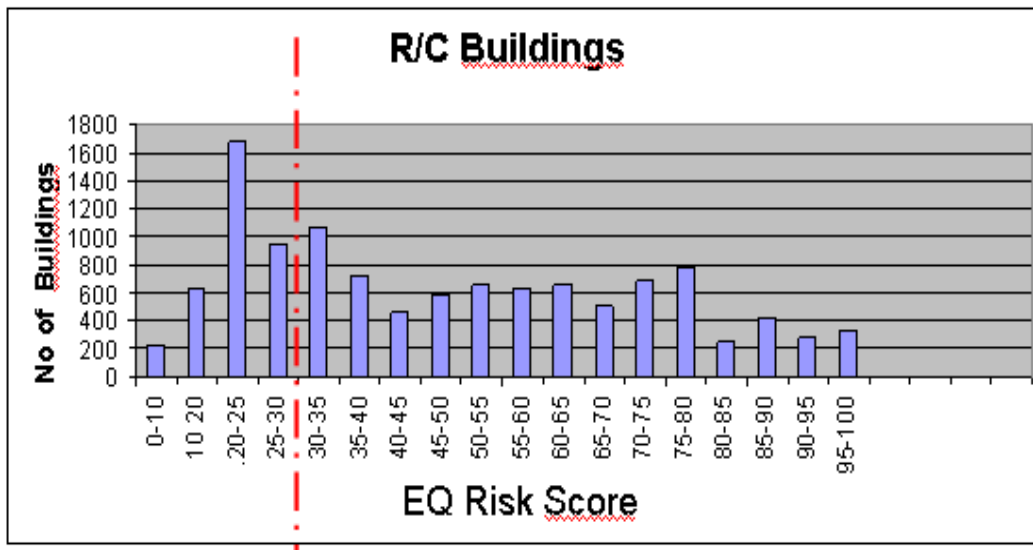
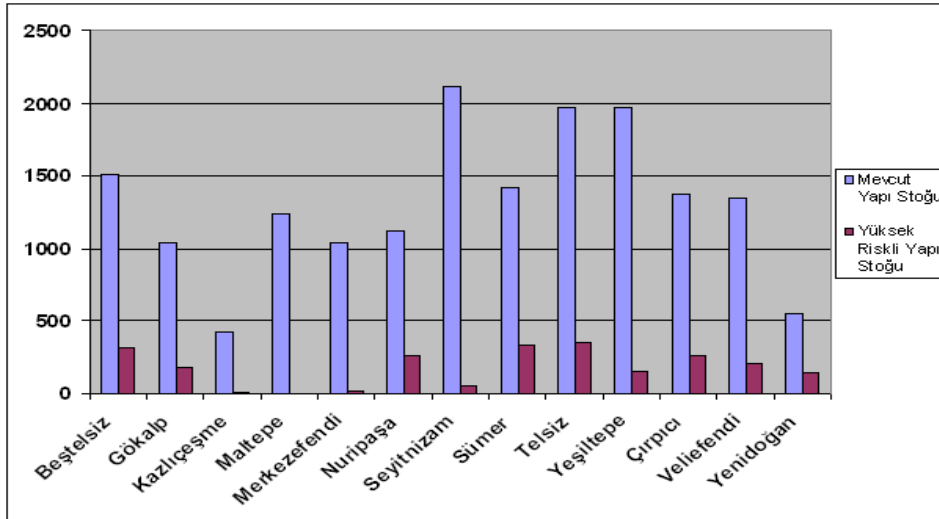


Figure 4 c) Number of vulnerable buildings by neighborhoods of Zeytinburnu District; d) Distribution of earthquake scores of reinforced concrete buildings in Zeytinburnu District.

Currently, IMM is to undertake a building programme with resources provided by the Housing Administration of Turkey.

After the accomplishment of Zeytinburnu pilot project in 2005, Istanbul Metropolitan Municipality has recently started to two more projects on diagnosis of the buildings of Fatih and Kucukcekmece Districts (32,000 and 53,000 buildings respectively).

### **Istanbul Seismic Risk Mitigation and Emergency Preparedness Project**

In addition to the expenditures of the Istanbul Metropolitan Municipality and the Governmental sources, currently, the World Bank is in the process of developing a 400 Million US\$ project for Istanbul. which is aimed on a retrofit programme for public buildings such as schools and hospitals? This is a unique experience as it is structured as a demand-driven disaster mitigation programme. In the second stage of this application it is proposed that the citizens should decide and request to improve their own risky situation.

## PREPAREDNESS for EMERGENCY RESPONSE

The Disaster Management Centre of Istanbul City, code named AKOM, was constructed and installation of the necessary equipment related on disaster information collection and dissemination systems had been completed in 2001.



The object of AKOM is to coordinate tasks among organizations within Istanbul Metropolitan Municipality. In order to manage a large-scale earthquake disaster, this center should be networked effectively with district offices or other disaster-related offices by secure telecommunication systems. These telecommunication systems must be maintained and operated at the time of an earthquake disaster occurrence to collect damage information, dispatch necessary orders for rescue operations, and communicate with each related agency.

Developing and adhering to standards is of utmost importance in the design of information systems. Large systems such as urban information system or a disaster information system necessitate the coordination and information sharing of many institutions. In many cases, a distributed information system formed by different databases may be appropriate.

To minimize plausible losses first of all it should be recognized that the more successful the pre-earthquake plans and their implementations are, the lower will be the financial burden after the earthquake. Moreover, the allocation of funds before an earthquake occurs is certainly needed for humane reasons, and also technically easier

To carry out the pre- and post-disaster management activities, the current legal structure and organizations are evaluated, distribution of authority among the central and local government bodies is analyzed, responsibility and coordination mechanisms are identified, and the insufficiencies in the system have been determined. and recommendations and legal requests are made to Governmental Institutions for additional clauses for risk mitigation.

The main guiding principle has been the fact that while no natural disaster can be prevented from happening, the incorporation of well-formulated planning and technical counter-measures will mitigate damages and losses significantly. **The main principle of the Istanbul Metropolitan Municipality is to prevent and protect individuals against the risk rather than to rescue them from the debris.**