Earthquake and Physical and Social Vulnerability Assessment for Settlements: Case Study Avcilar District

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ABSTRACT
In this study, a vulnerability assessment model has been developed for earthquake prone areas in Turkey. The vulnerability assessment model includes ground factors, building's physical conditions, and social (demographic and socioeconomic) aspects of the settlement. This vulnerability assessment model is applied to a case study - that of the Avcılar district of Istanbul. Forty different reinforced concrete residential buildings of 1225 people are assessed using the developed checklist. In order to evaluate the checklist and to assess the importance (relevance) of vulnerability factors, a questionnaire is forwarded to various related professional groups (architecture, urban planning and civil engineering). The results of the questionnaire are examined using SPSS software with factor analysis. According to the results, most of the samples in the case study area can be classified as high vulnerable.

Keywords: earthquake, risk, disaster, physical vulnerability, social vulnerability

1. INTRODUCTION

Turkey had experienced physical, economic, and social losses at significant levels due to the disasters caused by the natural hazards. The clarification of the physical and social vulnerability condition of a settlement at the building scale is significant for the prevention studies before the disaster.

Vulnerability, as its most general meaning, is “the entity of conditions, which are defined by physical, social, economical, and environmental factors and processes, that increases the sensitivity of the societies against the impact of the hazards” (UNDP, 2004). Disaster is directly related to the hazards, population facing these hazards, and built physical environment. Most of the disaster losses are caused by the interaction of three main systems; physical environment, social and demographic features of the societies experiencing the disaster, and other elements of the built environment such as buildings, roads, and bridges. The effect of a disaster can be changed according to the characteristics of these three elements (Mileti, 1999).

The social groups who are at risk against the disasters can be listed as; elders- particularly ill ones, physically or mentally disabled people, large families, tenants, areas with large concentration of children/youth, people with a low education level, poverty, homeless, single women, tourists, settings in which people stay at groups, ethnic minorities (in relation with the native language), and newly settled/immigrants (Morrow, 1999). The vulnerabilities of these risk groups, on the other hand, can vary in each country. Thus, it is important to develop risk evaluation studies specifically for a country or region.

Risk assessment studies which are prepared by taking earthquake threat into account, are mainly building stock centered studies where physical vulnerability is taken as a basis. In these studies, socio-demographic characteristics are limited to definition of population density in threatened areas and include possible death and injuries due to building damage. Determining and considering socio-demographic and socio-economic structure as well as population density enables identification of points which are highly vulnerable in various aspects, before earthquake. For an effective risk assessment, vulnerability of physical, social, economic and environmental components under threat should be determined in advance.

2. EARTHQUAKE AND VULNERABILITY ASSESSMENT OF EXISTING SETTLEMENTS

In the existing settlement, clarifying vulnerable specific points can give very important data base before the disaster for the risk reduction studies. The vulnerability assessment of settlements includes the building's vulnerability, the ground vulnerability and building occupant vulnerability. The ground vulnerability factor is calculated using factors such as the earthquake zone, soil classification, land sliding and liquefaction threats. The physical vulnerability factor depends on the structural and non-structural threats of the building. The building's vulnerability factors include building's general specification, structural vulnerability factors and nonstructural vulnerability. The building's general specifications question the construction year, adaptation of the original plan and presence of construction permission. The building's structural vulnerability factors asks if there exists any bad construction quality, short column, soft storey, vertical continuity problem, pounding effect, earthquake damage history and bad repair and maintenance condition. The nonstructural vulnerability factors look for un-reinforced masonry parapet wall height, chimney height, roof covering material and building's cladding problem.

Socio-economic status plays an important role in increase of social vulnerability related to hazards. It is difficult for the people with low socio-economic status to restore their living order, which was disrupted due to the disaster (Mileti, 1999). Family structure can be determinant in terms of vulnerability due to disaster. The families with a single parent and children are the most affected group. Although households with low number members have freedom of movement during the disaster, they have limited economic and human resources for an effective defense (Mileti, 1999).

The vulnerability evaluation of the building user is to understand the distribution of the socially vulnerable pattern in the urban region, not the number of injuries or deaths due to the building collapses. The sociodemographic and socioeconomic concepts such as age, education level, the structure of the users, and ownership etc. are studied in detail within this case study. The social vulnerability factor considers the age group, gender, family type, education, ownership, income etc of the building users.

This study, which is carried out to assess the vulnerability of physical and social parameters in earthquake-prone settlements, aimed to provide a database within the scope of disaster which would enable a holistic approach to the settlement area. It is important to make use of available data in the study. Performing site survey will bring a significant economic burden to determine the building stock of the settlements within the scope of the study. Therefore, the study shows the importance of turning the information in local administrations and other relevant public institutors into data in a standard form to use them in assessments for disasters. The study is aimed to determine and standardize effective parameters usable for earthquake disaster among the available information.

2.1. Database Sources

The vulnerability assessment model sources are different such as municipality and muhtarlık and site survey checklist is prepared according existing studies (Table 2.1, Table 2.2) in these sources. To assess the importance (relevance) of vulnerability factors, a questionnaire (a total of 208 responses) was forwarded to various related professional groups (architecture, urban planning and civil engineering). The results of the questionnaire are examined using SPSS software with factor analysis. Factor analysis is used to form groups which explain a certain phenomena using the relationships between the variables of the analyzed subject. The groups which are formed by the collection of related variables are called factors. In the analysis, each factor is listed as the highest most significant, lowest lest significant according to their own exploratory power. Acceptable KMO (Kaiser-Meyer-

Olkin) sub-limit value for the applicability of factor analysis is 0.5 and exploratory ratio is greater than 67%. Results of factor analysis were used for data assessment. At building scale, separate assessment was proposed in ground, building, non-structural components of the building and building residence occupant titles. In these assessments of different areas, it is aimed to perform an independent interpretation process.

Table 2.1. Vulnerability Assessment, Database and References

	Assessment area	Assessment Database	Reference
01	Ground	BİB (2004) Microzoning Guideline for the Municipalities	BİB (2004) Microzoning Guideline for the Municipalities
02	Building General Specification	İDMP Istanbul Earthquake Master Plan (2003)	İDMP Istanbul Earthquake Master Plan (2003), Survey Database (2009)
03	Building non-structural component	FEMA 154, FEMA 274, DBYBHY (2007)	DBYBHY (2007), Survey Database (2009)
04	Building Occupant	NOAA (1999)	NOAA(1999), Survey Database (2009)

Vulnerability components, data group and data sources are presented in detail in Table 2.1 and Table 2.2. Available examples and opinions of the members of related professional groups collected though questionnaires were used to determine physical and social vulnerability of the settlements from an earthquake. The references used for forming data groups and classification to assess vulnerability is presented in Table 2.1. A significant part of the required data for vulnerability assessment can be obtained from the available database in local administrations. However, for a proper assessment based on the real situation, it is necessary to perform site survey analysis and collect the existing situation.

Data about the ground on which a building is constructed can be obtained from official data in municipalities. Data on general characteristics of building and structural problems are based on the data collected from relevant municipality and site survey. Non-structural component problems, maintenance, repair and material quality involve site survey.

Table 2.2. Vulnerability Assessment Model Variables, Database and References

Assessment area	Main Vulnerability component	Database Group	Database Sources
01.Ground	Ground specification	Surface faulting map, Ground shaking map, Liquefaction potential map, Landslide and rock fall (slope instability) map, Earthquake-related flooding susceptibility map	Municipality
02.Building	Building General and Structural Specification	Presence of construction permission, Adaptation of the original plan Discontinuities of vertical load carrying members Bad construction quality Earthquake damage history Soft story existence Short column existence Construction permission period, Pounding effect	Municipality, site survey
03. Building	Building non-structural component	Roof, Parapet wall, Chimney, building facade	Muhktar
04. Building Occupant	Building Occupant	Age, education, income, family type, ownership	Muhktar, site survey

2.2. Assessment Procedure

The vulnerability assessment is defined at four levels for each area (Table 2.3). The place in the ranking is important in assessment of parameters. The place in the ranking and classification affect the total of the assessment. The status of the parameters in the first ranks affects general assessment. In the assessment, level is determined according to the integration of factor groups. Assessment of each section depends on factor groups and rank. Since assessment data were collected as “available” or “not available” excluding the ground and building occupant, the presence of negative parameters is assessed according to the factor group it belongs. For example, in the analyzed sample, the presence of all factor groups is assessed as “very high” vulnerable group.

Table 2.3. Vulnerability Assessment Level

Vulnerability level	Explanation
Very high (1)	The highest vulnerability level. 1.factor and 2.factor and 3.factor and 4.factor
High (2)	The second highest vulnerability level. 1. factor and 2.factor and 3.factor or 4.factor
Moderate (3)	1. factor or 2.factor and 3.factor or 4.factor
Low (4)	3.factor and/or 4.factor

2.3. Physical and Social Vulnerability Factors

In this study, a vulnerability assessment model has been developed for earthquake prone areas in Turkey. The vulnerability assessment model includes ground factors, building's physical conditions, and social (demographic and socioeconomic) aspects of the settlement.

2.3.1. Ground specification

The buildings behave differently in different soil types during an earthquake. For the building's performance during earthquakes, the specifications of the soil on which the building is located, seismic zone and the liquefaction and landslide risks of the soil are the significant factors. The evaluation of the distribution of the damage occurred as a result of the previous earthquakes and the studies on the records of the obtained powerful ground motions showed that the local soil characteristics, such as the distance from the source of earthquake or fault, fracture direction, time, surface and underground topography, non-linear soil motions, are significant (Ansal et al, 2003).

Table 2.4. Building Ground Specification (Micro-zonation Mapping)

	Explanation	Classification			
		1	2	3	4
1	Surface faulting map: Active fault zones where surface faulting has been observed several times in the project area	High	-	-	None
2	Ground shaking map: Three different relative shaking intensity zones.	High	Moderate	Low	
3	Liquefaction potential map: Liquefaction susceptibility, with characterization of three susceptibility classes	High	Moderate	Low	
4	Landslide and rock fall (slope instability) map: Landslide hazard, with characterization of three hazard classes	High	Moderate	Low	
5	Earthquake-related flooding susceptibility map: Earthquake-related flooding hazard, with characterization of two hazard classes	High		Low	

The assessment of the soil specifications were organized within the scope of the data defined in the "Microzoning Guideline for the Municipalities" (Ansal and Studer, 2004) prepared by the Ministry of Environment and Urban Planning for the determination of the vulnerability (Table 2.4). The five determinant parameters related to the soil for the case study area are examined according to their level of classification as high or low seismic risk. In the study area, the status of the parameters specified in Table 2.4 is determined according to ranking degree. High level for any parameters points out to total high risk classification for the ground group without considering assessment class of others.

2.3.1. Building General and structural problems

The physical vulnerability factor depends on the structural and non-structural threats of the building.

The study of determining the physical vulnerability includes reinforced concrete multi-storey housing buildings, having a usage type of both housing and "housing + commerce" in an existing urban settlement regions developed according to a plan, that face the threat of the earthquake. In this study, the assessment of the vulnerability of the urban pattern for the possible disaster risk caused by the earthquake was obtained by examining the soil specifications, on which the reinforced concrete frame structure buildings are located, the structural system and non-structural features of the building. The determination of the physical vulnerability is performed within the soil and building conditions. The majority of the information required for the determination can be obtained from the existing data base embodied within the local governments. Nonetheless, the investigation and assessment of the existing conditions on the site is necessary for the realization of the evaluation according to the actual conditions.

Table 2.5. Building General and Structural Problem

		Explanation
1	Presence of construction permission	
2	Adaptation of the original plan	
3	Discontinuities of vertical load carrying members	At column, shearwall
4	Bad construction quality	
5	Earthquake damage history	
6	Soft story existence	
7	Short column existence	
8	Construction permission period	Before 1998
9	Pounding effect	Pounding effect (with adjacent building)

During the evaluation of the building's vulnerability, the main factors are if the building has any construction permission or not, adaptation of the original plan, structural problems, maintenance/ reparation conditions, and construction quality (Table 2.5). The parameters were located according to the order of importance. Enquiry classification of the components is based on the presence of variables.

Since the inspection is achieved through visual observation of the building from outside, the information related to the structural system of the building is limited to the project included in the building license file. The pertinence of the existing building layout and project, the maintenance, modification conditions and the material quality of the building were controlled at site and evaluated among the vulnerable variables. The vulnerability variables also included the structures on which the damage occurred in previous earthquakes and did not undergo any rehabilitation procedure.

2.3.1. Building non-structural problems

The risks related to the non-structural elements include roofs, parapets, chimneys, and facade claddings (Table 2.6). All these elements, which are not considered in the structural system, are the elements that might cause injuries outside the building. Problems such as falling and breaking of the facade claddings are related to the material used and the method of application. The roof specifications are also examined for the problems that might cause injuries outside the building as falling of the roof covering etc. The information related to the dimensions of the chimneys, on the other hand, is used for determining the risk of overturning during the earthquakes.

Table 2.6. Building Non-structural Problems

		Explanation
1	Roof	Roof covering material falling risk, roof slope > 33%
2	Parapet wall	Unreinforced masonry parapet wall collapse risk H > 60 cm
3	Chimney	Unreinforced masonry chimney collapse risk H > 2xNarrow side
4	Facade	Heavy facade cladding falling risk

2.3.1. Building occupant (residential) vulnerability factors

The social vulnerability factor considers the age group, gender, family type, education, ownership, income etc of the building users. The social vulnerability parameters in the evaluation were based on the project developed by NOAA (1999) with some modifications. NOAA (National Oceanic and Atmospheric Administration) Project (1999), aiming at forming a basis for risk reduction of the economical, environmental, social, and emergency units of the cities facing various hazards, points for eight different concepts within the social vulnerability (NOAA, 1999).

Age is a very significant compound in the socially vulnerable group. Due to their limited mobility, incapability for physical escape and withstanding disasters and their dependence in home make old ones especially vulnerable during the disasters. The increment in the number of the old people and child who are dependent on other people during their daily life increases the vulnerability against disasters. The total age dependence ratio is defined as "the number of people in the age groups of '0-14' and '65 and over' for every 100 people in the age group between '15-64' (TUIK, 2003).

The low level of education and not knowing the native language are the factors that increase the difficulty of accessing the necessary information. The level of education is significant in relation with the necessity of the trainings that present the necessary precautions to be taken before the disaster. These trainings, performed for helping the orientation of the social behaviours of the individual encountering the disaster, are important for the works performed to decrease the number of fatalities and injuries (Mileti, 1999).

The income status of the family is important for compensating the losses due to the disasters. The vulnerability increases as the level of income decreases. Income is a positive factor in reaching a better and safer shelter.

The structure of the family can also be determinant for the vulnerability in the disaster. The group most affected is the families with a single parent with child. Although the freedom of movement exists for the small sized families, such families have limited economical and human resources for an effective defence in the disasters (Mileti, 1999).

Table 2.7 Building Occupant (residential) Vulnerability Factors and Vulnerability Level

	Percentage of	Vulnerability level group			
		(1) Low	(2) Medium	(3) High	(4) Highest
1	Population over age 65	%0–8	%8–13	%13–20	%20–67
2	No high school diploma	%0–13	%13–22	%22–33	%33–80
3	Low household income	%0–5	%5–11	%11–27	%27–100
4	Rental house	%0–17	%17–35	%35–56	%56–100
5	Single parent with child families	%0–8	%8–11	%11–25	%25–70

Table 2.8. Building Occupant Vulnerability Factors

		Explanation
1	Family Type	Single parent with child families
2	Age	Population over age 65
3	Ownership	Rental house
4	Income	Low household income
5	Education	No high school diploma

Tenancy within property is a significant criterion in regard to social vulnerability. Although tenancy shows parallelism with the economical status, this condition creates difficulties for solving the sheltering problems of the low-income groups with limited economical resources, after the disasters. Furthermore, the maintenance of the rental houses are not realized sufficiently; and such houses become more physically vulnerable.

Age, gender, education status, household structure and residential preferences, ownership etc socio-demographic and socio-economic issues were analyzed in detail within the scope of building user characteristics. In assessment at building scale, separate enquiries were performed for all residences in the building and obtained results were evaluated at building scale. Vulnerability levels were determined in percentages in reference to variables and assessment criteria NOAA (1999) (Table 2.7, 2.8). The ratio of social vulnerability variables and the percentile bands that determine the vulnerability levels were obtained from NOAA (1999) (Table 2.7).

3. THE VULNEREBILITY ASSESSMENT FOR THE CASE STUDY AREA

Avcılar, a district in Istanbul metropolitan municipality, has 14030 building and 233749 populations according to Turkish Statistical Institute census of population and building census year 2000. The case study is applied on Avcılar district where 1337 buildings (total ratio 9, 53%) were damaged with different damage level, 28 building collapsed and 274 people died due to the Marmara earthquake in 1999. Avcılar is a disaster risk district in the future earthquake on the North Anatolian Fault which is close to district.

The assessment of the physical vulnerability of Mustafa Kemal Paşa Area of Avcılar, Istanbul was performed on the 40 buildings, for 453 independent units consisting of 349 houses and 102 commercial building/office and 2 multi-purposed centres, during the March-May 2005 period. The information was obtained through observations on site and evaluation of the project file of the building. This information was transferred to the building vulnerability forms developed for this study. The study implemented includes the vulnerability factors at the building scale within the entire settlement. The buildings examined were chosen randomly among the buildings that represent the general characteristics of the region. These buildings were chosen so that they have different building land, function, zoning status, soil and transport specifications etc.

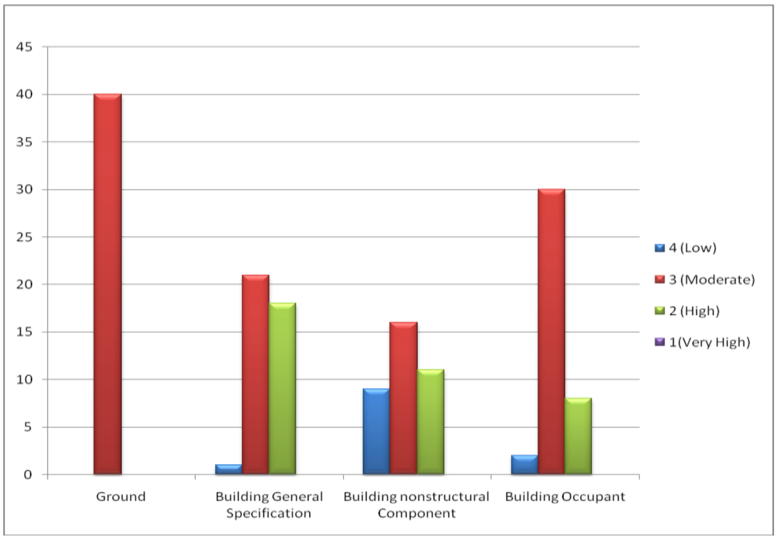

Figure 3.1. The Results of the vulnerability assessment for the case study area

Building ground, building structural and non-structural vulnerable variables, building occupant characteristics were assessed separately for each of analyzed 40 buildings and it was observed that the area was vulnerable to a disaster (Figure 3.1). This is largely caused by the fact that the ground of the settlement is 1.degree (high) seismic zone and that building and building occupants are also vulnerable. It can be stated that analyzed samples were generally moderately or highly variables in all component groups. However, instead of assessment results, it is more important to determine the distribution of data collected from the region. Combined assessment of settlement data through geographic information systems and the possibility of monitoring the distribution will contribute to performing pre-disaster operations and identification of post-disaster needs.

Within the building structural elements, short column effect, pounding effect with the adjacent building, additional storey, irregularities in the vertical structural elements, and elevation difference between the stories were evaluated. The building roof specifications, falling risk of the roof covering material and overturning risk of the parapets and chimneys were evaluated within the non-structural elements of the buildings. In this study area, it was observed that the majority of the buildings were vulnerable structures.

For the buildings, in addition to the ground of the building, presence of vulnerable properties in structural system is also important. The assessment indicated that the majority of the buildings were vulnerable in terms of structural system. Presence of problems in structural system, particularly soft storey problem, is a problem arising from usage type in parallel to the applied development plan of the settlement area. In this respect, presence of soft storey problem in buildings with commercial use in the ground floor and mixed use for residential purposes in normal floors arise due to the plan. However, it is believed that this problem will be overcomed in the long-term thanks to the structural solutions to eliminate this negative effects and possibilities of the new regulation. On the other hand, for the existing buildings, it is suggested to eliminate negative situations also considering other problematic issues.

4. CONCLUSION

In this study area, it was observed that the majority of the buildings were vulnerable structures. According to the results obtained from the case study area, it can be stated that the region is sociodemographically and socioeconomically vulnerable in relation with the disasters.

Since the assessment of the earthquake vulnerability conditions of ground of the building involves other fields of expertise, settlement suitability maps produced by local administrations and earthquake threat maps at country scale provide important data for such assessment. However, it will be appropriate to fulfil required standards as per Circular of Ministry of Environment and Urban Planning, to produce appropriate microzoning maps and to make assessment over these documents.

Although the archives of the related local governments are significant for creating the data related to the building, the problems of the building manufacturing process and modifications in the building use necessitates the assessment of the present conditions. In this respect, the determination of the seismic risks and other risks that threatens the settlement areas, if there exists any, and the present vulnerability of the physical environment is necessary.

Earthquake-prone variables which will serve as basis for risk analyses include ground properties of building, building characteristics, building user socio-demographic structure. Identification process of vulnerable variables can vary according to the characteristics of settlement area.

The main resource for displaying the vulnerable structure of the building users is the data information system of the muhktar offices. The development of this recording system towards the evaluation of the vulnerable regions before the disaster will simplify the use of these data with the other data during the risk analysis. The development of cooperative projects by the local governments with the other institutions, using these data with the others, could make significant contributions to the disaster preparedness programs.

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