Correlation Between Geology, Earthquake and Urban Planning

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1. Introduction

Urban planning is the organized planning of the physical environment that the mankind lives by providing the safety in line with the social, cultural and economical needs. The primary objective of the planning is to create healthy, reliable and durable living spaces. At this point, especially earthquakes and their effects in the countries that are located on the seismic belts of the world constitute the primary geologic threshold.

Inadequate consideration of the geohazards and the constraining effects of the geological environment or lack of precaution due to improper projection of the analysis and synthesis results to the planning and the planning decisions give rise to the increase in earhtquake damages. Geological studies aimed at reducing the effects of the ground movements due to earthquakes are of prime significance on the reduction of damage that consitutes the basis of earthquake sensitive planning studies.

Geologists, engineers, architects and planners, in creating the earthquake resistant cities, should determine the geologic hazard processes in advance and for the prevention of hazards turning into the risks and for the reduction of the damage, required precautions should take place in an interdiscplinary work. In this context, the main study is to conduct geologic and geotechnic analyses that will orient the suitability for settlement and land use decisions. The success of the damage reduction work after earthquake is proportional to the scientific base and the accuracy of the decisions.

Geological data that enable the earthquake damage reduction and are analyzed in every plan step seperately should be evaluated in coordination with the criteria of planning and design. The risks resulting from urban texture, building quality, settlement layout and macroform should also be integrated with the analyses and synthesis.

2. Geological and geotechnical parameters in urban planning

Geological and geotechnical investigations that include the details compatible to the planning scale before the planning and design of a city have an indispensible significance in the evaluation of suitability for settlement and land use decisions. The main stage of creating sustainable, durable and safe cities is to carry out natural structure analysis and synthesis by comprehensive investigations (geological, hydrological, engineering geology, geotechnic, seismicity, natural resource analysis etc.) and contemporary scientific methods (GIS, Multi Criteria Decision Analysis, Multi Criteria Decision Support Systems etc.).

Geological investigations are the studies that aim to understand the statigraphic relation of rock and soils and tectonism of the settlement area. Besides, these field data provided by the investigations on the rock and soil of the urban area are to orient the upper scale plans (national and regional scale) and provide a base for detailed geotechnical studies.

Geological studies are the qualitative investigations that mostly cover scientific interpretation, definition and classification. These studies comprise of the tendencies and settlement of upper scale geological structure elements as tectonostratigraphic relations of formations, fault, folding, incompatibility and detailed scale geological structures as layer and of the investigation and the mapping of active fault lines. Geology maps, generally, are prepared in between the scales of 1/100000 and 1/25000 and in planning they serve as a base and guide for the regional and environment plans.

Hydrogeological t models in 1/25000 scale, too, are among the important inputs and natural threshold values of natural structure analyses before the planning. These hydrogeological studies orienting the sustainable planning in the synthesis conducted before the settlement can be listed as the location of aquifer constituting the groundwater, ground water level, direction of motion and its seasonal change, the determination of geological structures (anticlinal, synclinal, fault etc) that direct the ground water and its association with urban structures, surface waters in the areas desired to be opened to the settlement or in current settlements, the feeding and the discharge areas of ground water, natural drainage network detection and its mapping. These geological data, at the city and the basin scale, provide basis for the environment plans which are the planning stages of the settlement decisions. In environment plans, policies regarding spatial distribution of the population, decisions regarding the distribution of infrastructure and settlement units and policies for the reduction of earthquake hazards are developed.

Investigations that reveal the engineering properties of geological units in urban settlement areas are within the context of engineering geology studies. These include experimental studies in the field and laboratory medium rather than observational ones. These studies conducted in rock material and rock mass scale cover the determination of discontinuity properties of the rock masses (its location, number, spacings, discontinuity, infill situation, roughness, etc.) mass weathering degree and mass strength by experimental and emprical methods.

Engineering geology maps provide more detailed information about the soil that the city will rest on with quantitative data and it is an important guide to support the true decision mechanism in both habitability and land use. Generally, prepared in 1/5000 scale, these maps are fundamental basis for the master plans of the planing stage (similarly with 1/5000 scale and on which the macroform of the city is developed) where the decisions on usage such as densities, transportation systems, open green area arrangement, infrastructure, dwelling, commerce are made. When the geological unit in the ground in the urban and new settlement areas has the soil nature, index properties of the ground (grain size distribution, porosity, Atterberg limits etc) and engineering properties (cohesion, internal friction angle, natural unit volume network etc) are determined by in situ (investigation excavations and boring investigation) and laboratory experiments and calculation methods.

Besides, in the urban settlement area, unstable regions and areas that has geohazard (landslide (Figure 1), rock fall-overturn, flood (Figure 2), seismicity, liquifaction, settling-consolidation, carstic cavitations (Figure 3) etc) are analized and their effects on urbanization are investigated.

Fig. 1. An example of landslide in Daly City, California from USGS (US Geological Survey) website. Photographer is unknown.

Fig. 2. An example of flooding in Borçka Town, Artvin, TURKEY. It is taken from http://www.t24.com.tr/haberdetay/54382.aspx. Photographer is unknown.

Fig. 3. An example of karstic space in Yucatan, Meksico. It is taken from http://www.hackturk.net/komplo-teorisi/287458/cukurlarla-ilgili-komplo-teorileri.html . Photographer is unknown.

In the cases where geological, hydrogeological and engineering geology studies are insufficient, more subscale maps (1/1000) are used. These studies covering geotechnical investigations, albeit not sufficient for urban design, provide valuable data as the plans showing the cadastre of urban equipment for master plan decisions, city blocks and layout, roads, slopes, bridges, squares, traditional textures. The data for the urban design in building scale are provided by more detailed geotechnical survey on the basis of parcel. On the basis of the parcel, geological-geotechnical investigations, depending on the geologic threshold and the extent of the hazard, can be worked on 1/2000, 1/1000 or 1/500 scale maps as well as on 1/250 scale depending on the extent of georisk within the context of building plot.

3. Earthquake as a planning threshold

The turning point of the transition of the mankind from the rural life to the urban life is the industrial revolution in 19th century. Migration started after this revolution from the villages to the cities has brought several settlement problems along with it. The studies aimed to resolve these problems resulted in the emergence of the urban planning methods and their development. In paralel with the increasing city population, the need for new land for settlement started to increase. This demand of land increased the urban risks by urging to use of the lands unsuitable for settlement and in physical planning the site selection necessitated multiparametered tough decision process. Thus, this caused the development of scientific methods for spatial based analyses statistically and mathematically.

Geological data within the planning discipline, before the planning, are evaluated in investigation, analysis and synthesis stages. These data with suitability to settlement analysis determine the development potential of the city by revealing the geologic threshold and restrictions.

Before the planning all geoenvironmental limiters, geohazards, geological-geotechnical data are evaluated as geologic thresholds. These natural geoenvironmental restrictions, besides the areas of natural hazard (earthquake, landslide, flood etc.), can be classified as cultivated areas and forest lands, water resources, reservations, geological sites etc. These natural thresholds are assessed with manmade thresholds as historical and archeological sites, mania plans, military zones and the habitability analysis are made including urban parameters.

Urban settlements have the tendency to develop with a varying pace depending on the policy of the urban development, economy, geographical features and geologic hazards. On the growth of the urban areas, there exist several natural structure thresholds as topography, soil condition, accessibility. Coping with these thresholds necessitates the analyses and syntheses that are developed by contemporary scientific methods. The selection of the methods of threshold analysis or habitability analysis is based on the number of criteria in the analysis, their quality, self values of the city and made by planners and project group (geological engineer, civil engineer, architect etc). In literature (Dai F. C.,et al.,. (2001), Darvishsefan A. A. et al.. (2004), Jabr, W.M. and El-Awar, F.A. (2004), Kolat Ç., et al.. 2006, Marinoni O. (2004), Marinoni O. (2005), Saaty T. L. (2008)) there developed several mathematical and statistical methods analyzing based on the space to be used in settlement analysis and land use decisions. These methods (Threshold analysis technique, Spatial analysis via GIS, MCDA, MCDSS etc) beyond the sole natural structure analysis, provide the possibility of testing the habitability by correlating physical planning with economical, sociological and technological factors and by considering the current macroform of the city.

Although the thresholds caused by restricting geological environment, depending on the extent of geohazard, sometimes can be overcome by technical precautions, the cost of technique can deadlock the habitability economically. Therefore, threshold analyses should realize the cost analyses of the alternatives besides providing the avoidance of urban risks and be a guide in creating the sustainable and durable cities with minumum cost.

Therefore, the thresholds playing a role in the planning and development of a urban area can be divided into two groups as geoenvironmental thresholds and structural thresholds caused by the macroform of the city and structural features.The first group can be listed as topography, geological structure, hydrogeology, geosites and geoparks, ecology, climate, vegetation, geological properties of urban soil and excavatability, seismicity etc. On the other hand, the second group is the current land use of the city and its infrastructure system.

These geoenvironmental thresholds affect the development and the settlement of the city in different ways. In some cases, these factors can be both advantage and disadvantage for the urban development. Although the hardness and the durability of the rocks in the settlement ground bring extra cost in excavatability, especially for creating earthquake resistant cities and soundness it is a necessary condition. Loose and swampy soils have features that can harm the structure in terms of load carrying capacity, settlement and consolidation problems. Land use decisions as the selection of multi-storey building, medium storey building, low rise building, open green areas and industrial use areas, when considered with ground properties, one area that is not suitable for one use do not necessarily have the risk for some other use. For instance, a swampy area that is not suitable for the construction of multistorey building can satisfy the requirement for open green area arrangement.

As for topographic threshold, with the increase of slope habitability and the cost increases. Rough topography urges the urban design, construction layout, building type and structuring requirements. While 15% of slope in settlement increases the cost, the slope over 30% results in serious technical infrastructure problems. On the other hand, the slope under 5% creates drainage problems.

In an urban area with earthquake hazard risk, earthquake analysis should have the priority and the directive role. The detail and the qualification of the analysis and synthesis before planning exhibit variability from upper scale studies to subscales ones. In urban settlements and development areas, the distance to the fault, the features of the ground, topographic factors, liquifaction requirements, landslides and floods as secondary threats, the ratio of fullness and emptiness, the selection of open green area should be analyzed. Structural order, structuring requirements should be arranged in a way that the effects of probable earthquake are prevented. In order not to have resonance, the interaction of soil and structure and the vibrational periods should be evaluated well. The selection of technology and material that control the building quality should be determined considering the soil condition and seismicity.

In urban design and settlement, prevailing wind direction and insolation are very important. In settlement pattern there should have air corridors to reach all buildings and buildings should be designed in a way that does not interrupt others's light. As for the site selection for the industry, similarly, prevailing wind direction is very important in the sense that spreading malodor to the city and air pollution. Besides, in rainy regions, the risk of flooding should be taken into account and flood risk analysis should be conducted. At the regions under risk, appropriate precautions (correcting the stream beds, leaving the stream beds for open space arrangements rather than opening those to the settlement) should be taken. Moreover, climate properties also affect the foundation type and depth regarding the settlement.

Ecological values are destroyed with the effects of urban development and the natural balance is degenerated. Therefore, in any kind of habitability analysis natural balance should be taken into consideration and the living habitats should be protected.

Urban development areas should be in relation with the current land use. The current transportation and infrastructure system, social equipment, commerce and important centers of the cities should be associated with new subcenter and settlement units. A settlement pattern disconnected from the current city will have difficulty in supplying the needs and developing.

Geoenvironmental and urban thresholds, after evaluated one by one and their priorities and the weights calculated by statistical methods (MCDA, MCDSS, GisVBA, AHP, Grey relation analyses etc.), are superposed with the maps showing natural and human activity thresholds and in final synthesis map the remaining areas out of the thresholds are defined as the urban development directions. Afterwards, the decisions on urban use areas (residential, commercial or industrial) are given in line with threshold analysis and cost analysis.

4. Urban earthquake risk

In the settlements with earthquake risk, for the determination of urban risks geological data analysis is not sufficient alone. Building stock and quality in the urban area and the authentic nature of urban texture are also important factors in the evaluation of the earthquake effects. Therefore, while the urban risk analyses are conducted, all the parameters based on the current settlement quality and features, concentration, equipments, infrastructure and transportation networks should be included in the analyses.

Hazard mitigation studies before an earthquake is the most significant stage of disaster preparation process. In this process, the determination of the primary risks and the corresponding precautions for these risks decrease the life and monetory losses during an earthquake. The first step of the determination of the risks at urban areas is to understand the soil behavior that the city rests on by investigations. Besides, the identification of the building quality of the building stock and the revealing of the soil-structure interaction define the type and the approach of the precautions. New settlements are to be realized under the light of the geological data of the city. The inputs of geological data into the planning and design scale play an effective role in the reduction of urban risks. However, these data should be simple enough for planners and designers so that they are understood and implemented. The accurate use and the synthesis of those data banks are of prime importance in understanding the behavior of earthquakes on urban elements. These data providing inputs for architecture, planning and design shape the city. It is an indispensible necessity that in the creation process of earthquake resistant sustainable cities, geology, planning, architecture and design disciplines work together in a way developing a common terminology.

The risk level of the city changes with the population density, building quality, local ground conditions and distance to fault line. The city is subjected to one single earthquake magnitude and threat, however, settlement units that constitutes the city are faced to different levels of urban risks. The resistance of the settlements that have high quality and earthquake resistant buildings resting on hard soil to the same magnitude earthquake, certainly, will be higher than that of ordinarily constructed areas on problematic and loose soil conditions (Figure 4) due to their geotechnical properties. Therefore, the former will have less urban risks. In other words, in urban areas buildings are constructed with different materials in different structural systems and they can be newly constructed or already completed the economic life. Therefore, at the instant of the earthquake the reaction of the building and the extent of the damage will be controlled by the structural features and the geotechnical characteristics of the ground.

In earthquake prone areas, the effect of earthquake waves on the ground, how this effect is reflected to the building and the reaction of the building to this effect should be clarified in an accurate way by interdisciplinary work. These valuable data obtained by experimental analysis, synthesis and calculations help to the determination of the precautions against urban risks. These precautions can be as strengthening of the buildings or evacuation of weak buildings or abandoning of the settlement area before the earthquake during the stage of hazard mitigation as well as the providing of the transportation of the aids in emergency and constructions after earthquakes through a short and alternative routes and the determination of the regions of emergency action.

Fig. 4. An example of loose soil in Adapazarı after 1999 Marmara earthquake. It is taken from http://avnidincer.8m.com/depfoto.html. Photographer is Eşref Yalçınkaya.

Therefore, urban earthquake risks, essentially, result from the geological, geotechnical characteristics of the ground, tectonism of the region and the relation of settlement area with active faults, soil-structure interaction and topography of the city. These risks, in the soil, can be observed as faulting (Figure 5), settling-consolidation, slipping, liquefaction, land slide, rock fall (Figure 6) etc. The most important risks due to soil-structure interaction are that resonance causing the collapse (prevailing natural period of the building being equal to that of the soil) and soil amplification. The velocity of the earthquakes waves in the soil changes with the hardness and the properties of the soil. For instance, the waves passing through a hard rock mass pass very quickly and the quake is less felt due to the firmness and the voidless nature of the rock while those passing through loose and weak ground pass very slowly filling the voids in the ground and result in the severe feeling of the quake. This behavior of the soil is defined as soil amplification. Therefore, soil amplification factor of alluvial material, which is higher than that of the rock, causes the strong quaking on the alluvial settlement areas with high rate of damage while that of granite will empower the settlement above it.

Fig. 5. An example of faulting on North Anotolian Fault Zone in Turkey. It is taken from USGS (US Geological Survey) website. Photographer is unknown.

Fig. 6. An example of rockfall. It is taken from USGS (US Geological Survey) website. Photographer is unknown.

The closeness to the fault in settlements is not a sole requirement, although it is very important, in the development of urban risks. Certainly, the constructions on the active fault line will feel the quaking more than others. However, the earthquake experiences in the world and in Turkey showed that strong building resting on hard soil could stand

Fig. 7a. An example of landslide. It was devoloped in valley plains. It is taken from http://www.harikasozler.net/img3851.htm. Photographer is unknown.

Fig. 7b. An example of landslide in Laguna Beach, Bluebird Canyon, California .
It was devoloped in steep and high slope. It is taken from USGS website (US Geological Survey). Photographer is Jim Budak.

regardless of its being on the fault line while the buildings on filled soil far from the fault line collapse. For that reason, in the spatial plans made in earthquake regions with hard topography, it should be avoided to settle on the valley plains (Figure 7a) and high slope (Figure 7b) areas that are prone to landslides.

The liquefaction is a geologic hazard that occurs in the grounds that are cohesionless and have underground water and if it occurred in the settlement area, it is an urban risk (Figure 8a, b). On the soil that the building rest on, soil-water mixture moving with liquefaction creates deep enormous voids under the buildings (Figure 8a). That results in the subsidence or the overturning of the building. Especially, the buildings constructed very closed to the sea on the sand soil when they are under seismic excitation have the serious risk of urban collapse and subsidence risk (Figure 8b).

As seen, in the site selection, land use, urban planning and design, geological data are the main actors of decision process.

During an earthquake, besides the geologic hazards, planning and design errors as wrong site selection, wrong land use decisions, urban uses off the objective, error regarding the design, insufficiency of infrastructure, low building quality give rise to the serious urban risks. For that reason while taking the precautions for the mitigation of the hazard before earthquake not only risks from the geologic thresholds but also analysis, synthesis and evaluations regarding all spatial criteria as macroform of the city, design, urban equipment, concentrations etc should be done and urban risks should be reflected on plan decisions.

Fig. 8a. An example of liquefaction in TURKEY after 1999 Marmara Earthquake. It is taken from http://www.el-aziz.net/img4381.htm. Photographer is unknown.

Fig. 8b. An example of liquefaction in TURKEY after 1999 Marmara Earthquake. It is taken from http://www.kenthaber.com/marmara/kocaeli/Haber/Genel/Normal/depremde-yikilan-konuta-imza-atti/3d13f1c8-4158-4ce1-b380-13e53de1be21. Photographer is unknown.

5. Earthquake sensitive planning

Tam (2010) defined the earthquake sensitive planning as an integrated planning which aims to mitigate the earthquake risk factor by considering the physical properties and socioeconomic structure of the settlements and which starts from upper scales and develops socioeconomical development policies and supra-national, national and regional plans to further continue to local planning and subscales in which the progressive synergy is assured. (Reference: Deniz Tam)

Earthquake sensitive planning is a planning action that primarily analyzes the earthquake hazard and risks in the planning, prevents these risks and hazards to turn into disasters, internalizes the planning to mitigate earthquake hazards and urban design approaches. The main approach of earthquake sensitive planning is to include the risk mitigation precautions of all disciplines related to earthquake in the planning process for the realization of urban planning that provides healthy, reliable, livable urban environment development.

Earthquake sensitive planning includes the evaluation of geologic hazards and restrictions as risk factors in planning process and their reflection in planning decisions. Within this context, in planning the use of geological data should be assured and regarding the earthquake sensitive planning for hazard mitigation and prevention policies and approaches should be developed.

The process of building earthquake resistant cities comprises the analysis of geoenvironmental natural hazards that can be occurred during an earthquake or after it, the evaluation of the damage assessment and the revealing the corresponding urban mistakes and the conduction of urban risk analyses. Besides, earthquake sensitive planning approach should be developed to eliminate the risk factors due to land use, site selection, settlement pattern and the structuring.

Earthquake sensitive planning is a dynamic action that zooms out urban planning from the spatial design based traditional planning approach, integrates the risk mitigation precautions in the planning process and incorporates the detailed microzoning maps that go beyond the standard geological investigations.

Earthquake sensitive planning involves an analysis perspective starting from the world scale to national, regional, urban and local scale which covers the small settlement units. This perspective bases on the physical, economical and social development and urban risk analysis under the earthquake scenarios.

In every stage of this planning approach, geoenvironmental hazard and risk factor should be determined by geological-geotechnical investigation and microzoning maps and with this geological data analysis there should made feedbacks in every planning stage.

For the reduction of urban risks and hazard, potential development areas with alternatives developed for physical plans by the directive of the geological data should be selected by using the multi decision analysis techniques as well as with the inclusion of socioeconomic analyses.

In earthquake sensitive planning, the interpretations on the analysis of geoenvironmental thresholds and their implementation on the plan are discussed above in the section "Earthquake as planning threshold". In the case where the macroform of the city, layout and socioeconomic development are taken into account, the required action that should be considered in earthquake sensitive approach can be listed as follows:

1. Engineering structures like highway, railway, viaduct, tunnel and construction layout should not intersect the fault line perpendicularly. In the cases where the development

close to the fault is obligatory, urbanization and settlement should be ensured to be in parallel with the fault line (Figure 9).

2. Multicentered development pattern should be adopted and the urban growth should be limited depending on the risk.
3. Population and densities should be arranged in a way to mitigate the risks after earthquake and a balanced distribution should be supported while preventing the increase of the concentrations in one region.
4. The factors that inhibit the socioeconomic development and growth should be resolved and the weight should be given to the process of creating economically powerful and earthquake resistant city.
5. The continuity of the green areas should be provided and in the macroform of the city safe open and empty areas should take their places in settlement units as gathering areas.
6. The transportation network should be built up and for the roads closed after earthquakes, alternative transportation systems should be developed. Within these transportation systems, the shortest route to the areas where the urban risk level is high should be defined to provide means for immediate aid by the analysis of shorthes path via GIS.
7. Technical infrastructure systems should be made resistant to the expected earthquake magnitude by strengthening. Especially, the systems having a vital importance as natural gas pipelines, energy and water lines should be improved against earthquake effects and protective measures should be taken.

Fig. 9. An example of rail way which build on fault zone and is cutted by this zone in Turkey after 1999 Marmara Earthquake. It is taken from http://www.resimkarikatur.com/resim1684.html. Photographer is unknown.

In earthquake sensitive planning, building layout should not be attached. In the cases where it is needed to be attached, story heights should be equal to each other. Different story heights mean different vibration periods. Thus, it may lead to impacts and collapses (Figure 10).
Especially in the developing countries, commerce, urban uses such as residence and social equipments can change their functions in line with the newly emerged needs. This results in the change in the projects of interior design and structural disorder and as a result the building becomes under the risk due to the change in its bearing capacity.
The areas with high geohazard in urban settlements in earthquake prone regions should be left for open green area use.Urban functions should be green buffer zones. These green areas relieve the dense traffic in panic state and easen the intervention as well as being gathering areas after earthquakes.

Fig. 10. An example of collapsed structure because of building design and different construction height after 1999 Marmara Earthquake. It is taken from http://www.haberingundemi.com/haber/Depremin-Simgesi-Bina-Yikildi/80399. Photographer is unknown.

6. Urban settlement site selection and microzoning

Microzoning is defined in a variety of ways by different researchers in the literature (Hays (1980), Sharma ve Kovacs (1980), Nigg (1982), Özçep and et.al, Sherif (1982), Finn (1991)). However, the common point of view of all researchers is that microzoning is to be analyzed in the preparation stage before earthquake to realize the reduction after earthquake while the habitability is to be analyzed especially in the high risk regions by dividing into the smallest subregions. Microzoning maps, depending upon the local geological, seismological and geotechnical conditions, is the mapping of the geohazards of the areas where potential of liquefaction, landslide sensitivity, flood risk, soil amplification etc or combinations of those hazards are seen, as a basis of the planning, the development and the design.
Geological studies and the synthesis of the data used in the planning exhibit a rapid development in terms of directing the planning. Within the framework of this development, geological-geotechnical studies, assessment of the suitability for settlement and microzoning

maps provide highly important data to determine the land use and settlement for the planning.
Microzoning maps can be prepared as a base for the 1/100000 scaled regional plans. At the same time it reveals the development direction and the potential of the city by identifying geohazard thresholds for 1/25000 environment layout plans, 1/5000 master plans and 1/1000 tentative plans.
Earthquake resistant building designs advance significantly to decrease the risk of collapse and make the building safe under earthquake loding. However, these designs accompanied by expensive methods and techniques become insufficient in the implementation due to economical reasons especially for the developing countries. Therefore, microzoning maps gains more importance since the selection of a settlement area far from the geohazards will decrease the need for the precautions with high technology.
Microzoning maps direct the plans with an integrated risk approach by evaluating geologic hazards and advantages that are provided by geological-geotechnical investigations with the risks resulted from the constructions.

7. Results

In the planning and the design of new settlement areas and the environment with current settlement, in every stage of the plan geological data with out-of-traditional planning understanding for the reduction of urban earthquake risks should be functionalized in compliance with the objectives.
In the process of creating earthquake resistant safe cities, geological-geotechnical investigations and microzoning maps being an understandable synthesis of geotechnical data play a key role in the integration of hazard mitigation precautions to the planning. However, this geohazard based maps should be developed in complience with the requirements of planning scale and its context. At this point, there seen the necessity of the collaboration of the experts of both geological and planning disciplines.
The planning made in the regions with high earthquake risk should be supported by identifying with the probable earthquake scenarios. In earthquake sensitive planning, the formation of gradual centers system with one main center, the identification of the intensities in correlation with settlement potential, the development of multicentered urban form by preventing urban sprawl are essential.
In the urban areas with high earthquake risk, the improvement of the current plans, the reconfiguration in the required locations and the planning of development areas based on the microzoning maps and probable earthquake scenarios would decrease the probable earthquake damages. In earthquake sensitive planning, the integration of geotechnical parameters of the soil as soil amplification, liquefaction and landslide after evaluation to the planning is of vital importance since these parameters during an earthquake can cause secondary urban risks.
The main factors effective in the distribution of earthquake damage can be summarized as the distance of the settlement to the active fault line, geological structure, local soil conditions, the state of ground water, site selection and land use, population density and distribution, building density, quality, order and design.
As it is seen, the basis of creating a safe and sustainable living space in the urban settlement areas with high seismic risk is the evaluation of urban planning and design, geological synthesis and earthquake analysis in coordination with modern scientific methods and techniques.

8. References

Dai F. C., Lee C. F., Zhang X. H. (2001) GIS based geo-environmental evaluation for urban land-use planning: a case study, Engineering Geology, 61, 257-271.

Darvishsefan A. A., Setoodeh A., Makhdom M. (2004) Environmental consideration in railway route selection with GIS (Case study: Rasht-Anzali railway in İran), Map Asia 2004, Beijing, China.

Jabr, W.M., El-Awar, F.A. (2004) GIS and analytic hierarchy process (AHP) for siting water harvesting. ESRI Proceedings; Available from: <http://gis.esri.com/library/userconf/proc04/docs/pap1539.pdf>.

Kolat Ç., Doyuran V., Ayday C., Süzen M.L., 2006, Preparation of a Geotechnical Mikrozonation Model Using Geographical İnformation Systems Based on Multicriteria Decision Analysis, Engineering Geology 87, 241-255.

Marinoni O. (2004) Implementation of the analytical hierarchy process with VBA in ArcGIS, Computers&Geosciences, 30, 637-646.

Marinoni O. (2005), Adiscussion on the Computational Limitations of Outranking Methods for Land-Use Suitability Assesment, International Journal of Geographical Information Science, 20, 1, 69-87.

Saaty, T.L. (1990) How to make a decision: The Analytic Hierarchy Process. European Journal of Operational

Zhang F., Yang Q., Jia X., Liu J., Wang B. (2006) Land-use optimization by geological hazard assessment in Nanjing City, China, IAEG 2006, paper number 324, Natthingam.

Saaty T. L. (2008) Decision making with the analytic hierarchy process, Int. J. Services Sciences, 1, 1.

Hays, W.W., 1980. Procedures for estimating ground motions, U.S.G.S Professional Paper, 1114, 77 p.

Sharma, S. and Kovacs, W.D., 1980, Microzonation of memphis, tennessee area, A report on research sponsored by The USGS, No: 14.08.0001-17752.

Nıgg, J., 1982. Microzonation and public preparedness: a viable approach, Proceedings of the 3thInternational Earthquake Microzonation Conference, Seattle.

Sherif, M.A., 1982, Introductory Statement of 3 th International Earthquake Microzonation Proceedindgs, June 28-July1, Seattle, USA.

Fınn, W.D.L, 1991. Geotechnical Engineering Aspect of Microzonation, Proc. Fourth Intern.l. Conf. On Seismic Zonation, Vol.1, pp. 199-259.

Tam D., 2004, Çevre Duyarli Planlamanin Ve Deprem Duyarli Planlamanin Bütünleştirilmesinin Sağlayacaği Faydalar, Journal Of The Chamber Of City Planners Union Of Chambers Of Turkish Engineers And Architects, Sayı: 29 Planlama, ISSN 1300-7319.

USGS (US Geological Survey) website.

http://www.t24.com.tr/haberdetay/54382.aspx.

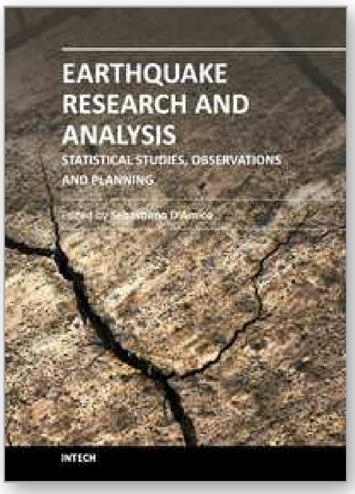
http://www.hackturk.net/komplo-teorisi/287458/cukurlarla-ilgili-komplo-teorileri.html .

http://avnidincer.8m.com/depfoto.html.

http://www.harikasozler.net/img3851.htm.

http://www.el-aziz.net/img4381.htm.

http://www.kenthaber.com/marmara/kocaeli/Haber/Genel/Normal/depremde-yikilan-konuta-imza-atti/3d13f1c8-4158-4ce1-b380-13e53de1be21.
http://www.resimkarikatur.com/resim1684.html.
http://www.haberingundemi.com/haber/Depremin-Simgesi-Bina-Yikildi/80399.



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The study of earthquakes plays a key role in order to minimize human and material losses when they inevitably occur. Chapters in this book will be devoted to various aspects of earthquake research and analysis. The different sections present in the book span from statistical seismology studies, the latest techniques and advances on earthquake precursors and forecasting, as well as, new methods for early detection, data acquisition and interpretation. The topics are tackled from theoretical advances to practical applications.