**ESKİŞEHİR TEKNİK ÜNİVERSİTESİ BİLİM VE TEKNOLOJİ DERGİSİ B- TEORİK BİLİMLER**

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# A GEOGRAPHIC INFORMATION SYSTEM DESIGNED FOR DISASTER MANAGEMENT

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## ABSTRACT

Measures taken for disasters are typically the recovery practices after the disasters take place. However, recovery actions besides their low efficiency in Hazard Mitigation, are very expensive and conflict with sustainable development progresses. Hazard mitgation that constitutes the basis of Integrated Disaster Management regards all of the aspects of disaster management such as preparedness, emergency response, post disaster management, recovery and building resilience. Hyogo Framework for Action 2005-2015 organized by UNISDR encourages systematic actions for reducing risk and ease vulnerability. Sendai Framework for Disaster Risk Reduction 2015-2030 that is a 15-year, voluntary, non-binding agreement prioritise building resilience and enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction. This study examines the multi-disciplinary data and standards for a Geographic Information System (GIS) that facilitates Hazard Mitigation and building resilience. Collecting geodata from various sources and binding them through spatial analyses is of crucial importance. The Geographic Information System to store, manage, analyze and query data should be designed to cope with multi-disciplinary issues. Analyzing a region that is subject to a hazard prior to a hazard event has the potential to exhibit the weaknesses of the region and enables proposing specific measures for building resilience. Reducing vulnerability of the people living in the hazard-prone areas and rapid recovery is however only possible with putting the offered measures into practice.

**Keywords:** Disaster management, Hazard mitigation, GIS, Geodata, Resilience

## 1. INTRODUCTION

When we look at the natural disasters happening on the Earth, as especially the earthquakes reveal the yield and the livability potential in the areas which they occurred, they made these areas suitable for human accommodation. However; we have to take some precautions and raise our resistance against the devastating effects of these disasters. The periods in which the precautions are not taken will cause loss of life and property increase.

"Integrated Disaster Management" which have successful examples in the world is tried to be applied in our country. However, the experiences we had shows that we haven't reached enough level.

If we want a society ready for a disaster and want to create livable cities, it is necessary to put forward the risk value before a disaster. The works which will put forward the risk value should be fictionalized on a disciplined, updateable and controllable system.

The last and the most important keystone of the fictionalized system should be the features belonging to the population. After calculating the exposure potential of the building and environment, it is a must to connect the people, who live in these and have potential to be affected, with the structure. After the disaster, defining the needs in the area and the coordination of the rescue efforts must be defined according to the features of the population in these damaged buildings.

In our study, there is gender, age and numbers of the people who lived in the address ID taken from General Directorate of Civil Registration and Nationality. That much core information is enough to provide after disaster coordination.

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In the project numbered 112M421 and titled as “The Project of Hazard Analysis for Urban Hazard Risk Management for Gölcük- Değirmendere District of Kocaeli” supported by TÜBİTAK, 3 disciplined systems (Geology, Planning, and Architecture) was designed and applied successfully.

The part of the study about geology composes of my doctorate thesis completed in January 2016 [1]. Material, Method and Working Area samplings have been adapted from my doctorate thesis.

## 2. WORKING AREA AND ITS GEOLOGY

As working area; Kocaeli city, Gölcük district, Değirmendere town has been chosen. (Figure 1). There are 7 neighborhoods and 3456 buildings in the working area. 17 August 1999 Gölcük Earthquake surface break, happened in the north section of North Anatolian Fault Zone, goes from the north of the working area (Fig1).

Within the scope of the study, the studies done in the area after 1999 earthquake have been examined to transfer to GIS and 4 different geology maps have been obtained [2, 3, 4]. In the places of the gathered maps during field survey, the correlation has been done. With the observations and examinations, it is seen that the most suitable map to use as base in GIS in our study is the map prepared by Konak (2002). Konak (2002) has divided the area as 3 main units in his geology map. He considered appropriate to divide alluvion unit in to two because of its architectural features (Qal-1 and Qal-2).

In our study area, 3 units have been picked out and these are from old to the young; Top Triyas-Middle Jura old meta-particle rocks, Ponsiyen-Pliyosen old least-stapled pebble-sand-clay-konglomera series and Kuvaterner old sand-silt-clay combined alluviums. (Figure2).

Fault used in the study is the surface break trace in 17 August 1999 earthquake. End of the examinations about the studies done in the area, it has been decided to use fault trace Barka et al. found in 2002 [5].

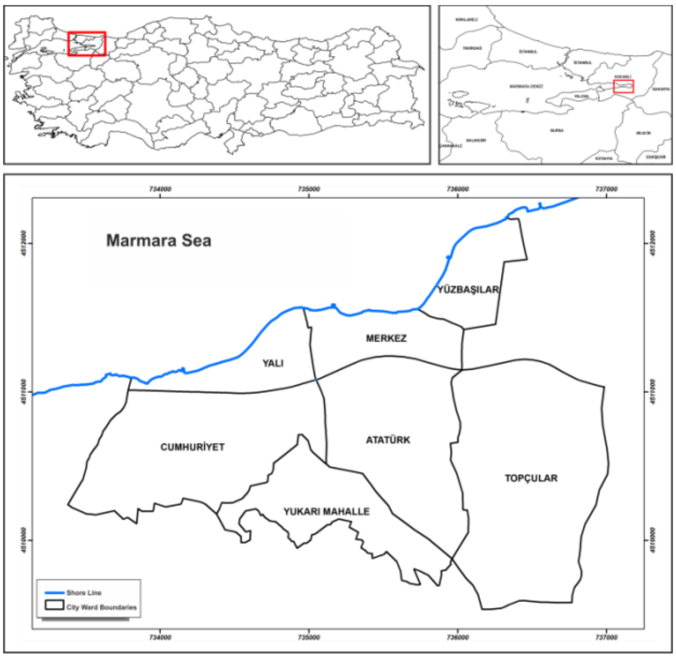


**Figure 1.** Location of Değirmendere

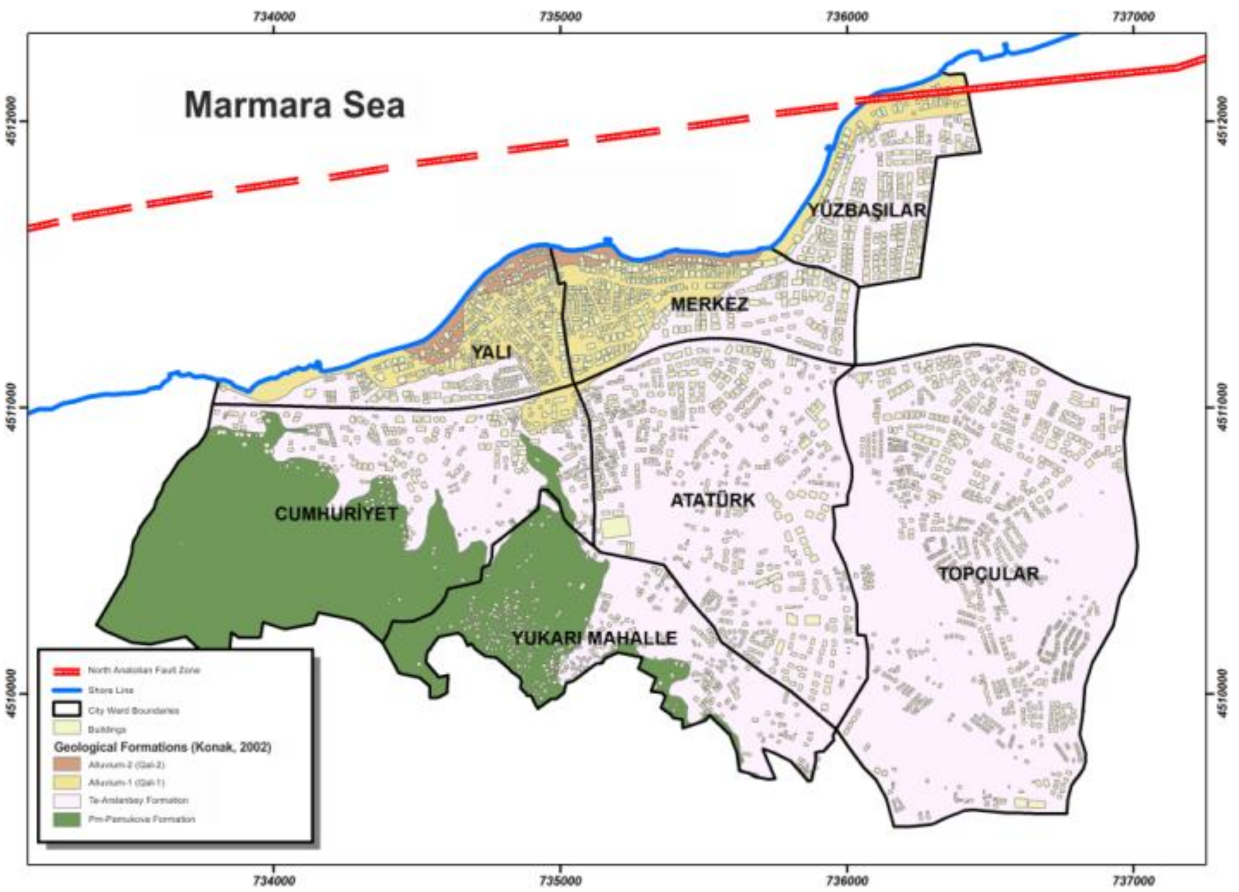


**Figure 2.** Geological Formations of Değirmendere

## 3. MATERIAL AND METHOD

Suggested system consist of 4 main steps,

1- Data Collection,
2- Transfer to GIS system,
3- Data Weighting,
4- Obtaining of the maps,

### 3.1. Data Collection

For all types of disasters, important data should be defined specific to working areas. Even though Değirmendere, which is defined as the example area, was a settlement area damaged in 17 August 1999 earthquake, it is face to face with a flood risk because of the many brooks and land topography. That's why 28 geological data was tried to be defined by taking into consideration not only earthquake but also other disasters. (Table1). Data in Table 1 have been gathered from the geo-technical reports, academic studies  and observational evaluations done in the area [6,7].

**Table 1.** Criteria used in Building Hazard Analysis

| Local soil conditions and earthquake effects | Remarks |
|---|---|
| Distance to the fault | Meters or kilometers |
| Primary axis direction to the fault<br>Perpendicular<br>Parallel<br>Others | 1-perpendicular to fault<br>2-parallel to fault<br>3-others |
| Distance to stream bed | m or km |
| Groundwater level | m |
| Bedrock depth | Özlaybey et al., (2008) [1] |
| Consistency Condition | 1 – Very soft<br>2 – soft<br>3 – stiff<br>4 – hard<br>5 – very hard |
| P velocity | 2nd layer P wave velocity |
| S velocity | 2nd layer S wave velocity |
| Vs(30) | S wave velocity within 30 m |
| Cohesion (C) | |
| Internal friction angle (θ) | |
| Geological Formation effect | Will be entered by using regional geological maps |
| RQD | For rock sites |
| Poisson ratio | Elastic parameters from S waves |
| Bulk modulus | Elastic parameters from S waves |
| Sliding modulus | Elastic parameters from S waves |
| T0 (resonance period) | From seismic data |
| Bed coefficient | From seismic data |
| Liquefaction | 1 – exist<br>2 – non exist |
| Carrying power | From borehole data |
| Soil safety stress | From seismic data |
| Soil amplification | From microtremor |
| Resonance period | From microtremor |
| Soil classification | From microtremor |
| Residential compliance status according to DEMA terminology | From available studies |
| Acceleration value | |
| Damage distribution after the August 17, 1999 earthquake | From observational reports of Ministry of Environment and Urbanisation<br>1 – no damage<br>2 – light damage<br>3 – moderate damage<br>4 – heavy damage<br>5 – collapse |
| Slope/hill-slope effects | % slope data |

### 3.2. Data Transfer to GIS System

Design of the database which will be created in Disaster Management studies and can work with each other collaboratively will increase the success of the method and studies. Therefore a jointly working system can become true only on GIS data base.

System to be created should be transferred to GIS by connecting to 1 or 2 main ID. In also 112M421 numbered Tübitak Project used by the system, ID definition was made. In ID definition, MERNİS system building identity number which was started to be applied throughout the country has been used. By using the interior door number, used by KBBID and MERNIS subsystems of Kocaeli Municipality, all buildings in the area (3452) have been transferred to GIS as polygon (Figure 3).

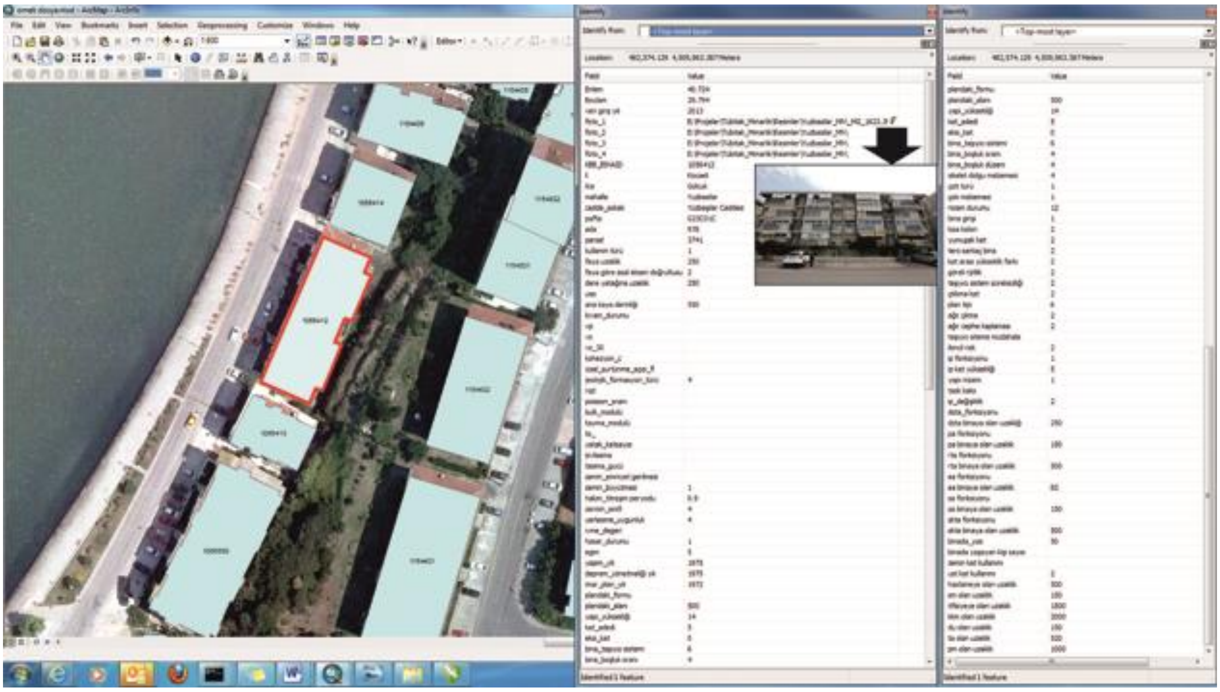

**Figure 3.** Disaster management database table of Değirmendere

All data gathered from working area have been added to building attributions in GIS. This base database has been created in an updateable and integrable way with multi-disciplined studies.

Front photos of the buildings in the working area have been added to building attributions table.

Besides other data, demographic features gathered from General Directorate of Civil Registration and Nationality has been transferred to system by adding to the building attribution values.

Data branches created from 11478*10 matrix obtained from General Directorate of Civil Registration and Nationality can be seen below.

- NEIGHBOURHOOD NAME
- CSBM NAME
- OUTERDOORNO1, OUTERDOORNO2
- INNERNO1
- ADDRESS NO
- GENDER
- AGE
- TOTAL PERSON
- BUILDING IDENTITY NO

In 112M421 numbered Tübitak Project where the system is used, besides the data transferred to GIS, planning belonging to the area and architectural features belonging to the building have been transferred to GIS as the buildings attribution. This database has an updateable and developable structure. By adding the data of other departments to the system, more different disaster management system can be created.

### 3.3. Data Weighting

Besides choose of criteria to create solution maps and reports used in disaster management, weighting process which will be applied to these criteria is also important. It is necessary for the chosen criteria for the working area to be trustworthy and danger reflecting. These obligations put forward the method which will be used in data weighting.

Method to be used;

- Should include a flexible model which can compile big scale problems as in our study,
- Could be included in the solutions of many criteria and problem,
- Should provide objectivity in problem solution,
- Values that appear should easily be implemented in GIS,
- Should have a wide implementation area.

Analytic Hierarchical Prosess (AHP) method which is a prominent method of giving multi-criteria decisions has been used in our study.

Analytic Hierarchical Prosess (AHP), was firstly put forward by Myers and Alpert in 1968 and it became useable in the solutions of the giving decision problems by being improved as a model by Saaty in 1977 [8,9,10].

AHP is an action of giving decision based on the work of the executive decision mechanism by giving relative importance values to the decision alternative and criteria in complex decision problems. [11].

AHP steps divided into different steps in different sources have been applied in this study by compiling according Yaralıoğlu 2004 and Timor 2011.

Flow Chart of AHP method is seen in Figure 4.

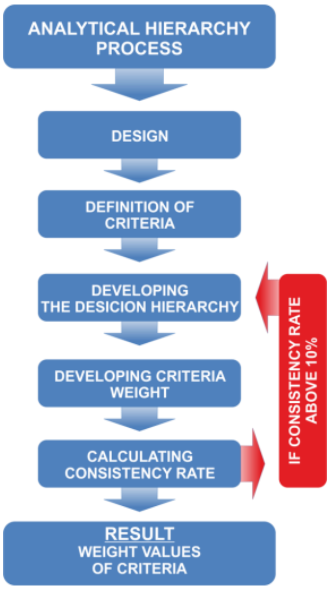


**Figure 4.** Flow chart for AHP method (Güven, 2016)

AHP is implemented in 4 stages. These;

- Decision-making problem identification (Step 1)
- Factors establishing inter- comparison matrix (Step 2)
- Determining the percentage distribution of important factors (Step 3)
- Consistency Factor measurements in comparison (Step 4)

The skills of multi-criteria decision giving methods in putting forward the danger in the area is in proportion with the number and liability of the data in evaluation. Before applying AHP method, Data transferred to GIS has been evaluated by experts in subject. 7 data which have potential to affect the building during an earthquake have been chosen and weighted (Table 2).

**Table 2.** Geoscientific data effecting hazard analysis

| Geoscientific factors | Weight (%) |
|---|---|
| Distance to fault | 9,39 |
| Primary axis direction (Perpendicular, parallel, others) | 4,81 |
| Groundwater level | 15,84 |
| Vs(30) | 10,79 |
| Geological formation effects | 29,68 |
| Soil classification (microtremor data) | 24,89 |
| Slope/hill-slope effect (larger than 30%) | 4,58 |

In 112M421 numbered Tübitak Project where the system is used, for every department, data which have an active role in earthquake have been chosen and weighted [12].

However, in multi-disciplined studies, it is necessary to have two-step weighting process. Besides weighting the department data affecting the building during disaster, the weights of the all disciplines with each other must be defined and so the effect portions to the solution map should be calculated.

Multi-disciplined and GIS based disaster management systems will reach faster and accurate results.

### 3.4. Obtaining of the Maps

As a result of the weighting of the geology data, by calculating the sub-weights of the data in Table 2 (Figure 5), it has been separately mapped. According to the sum of the weight percents, solution map for geology data has been obtained. (Figure6).

In 122M421 numbered Tübitak Project solution map which is an example of multi-disciplined study, total risk change according to geology, planning and architecture weights is seen in Figure 6.

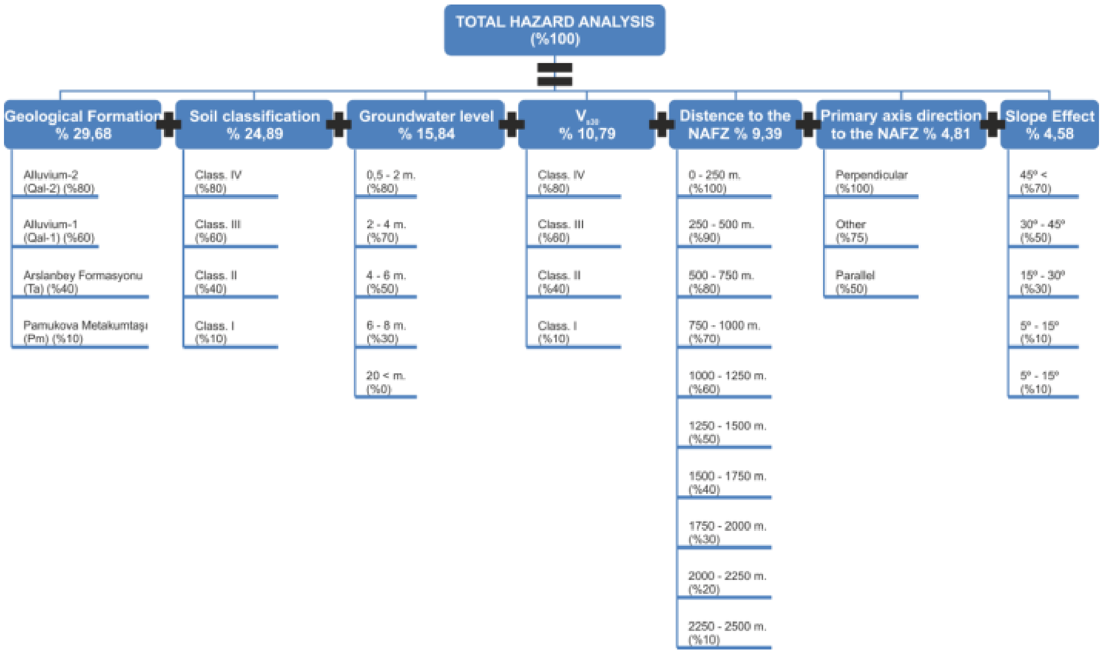


**Figure 5.** Weights obtained by AHP results

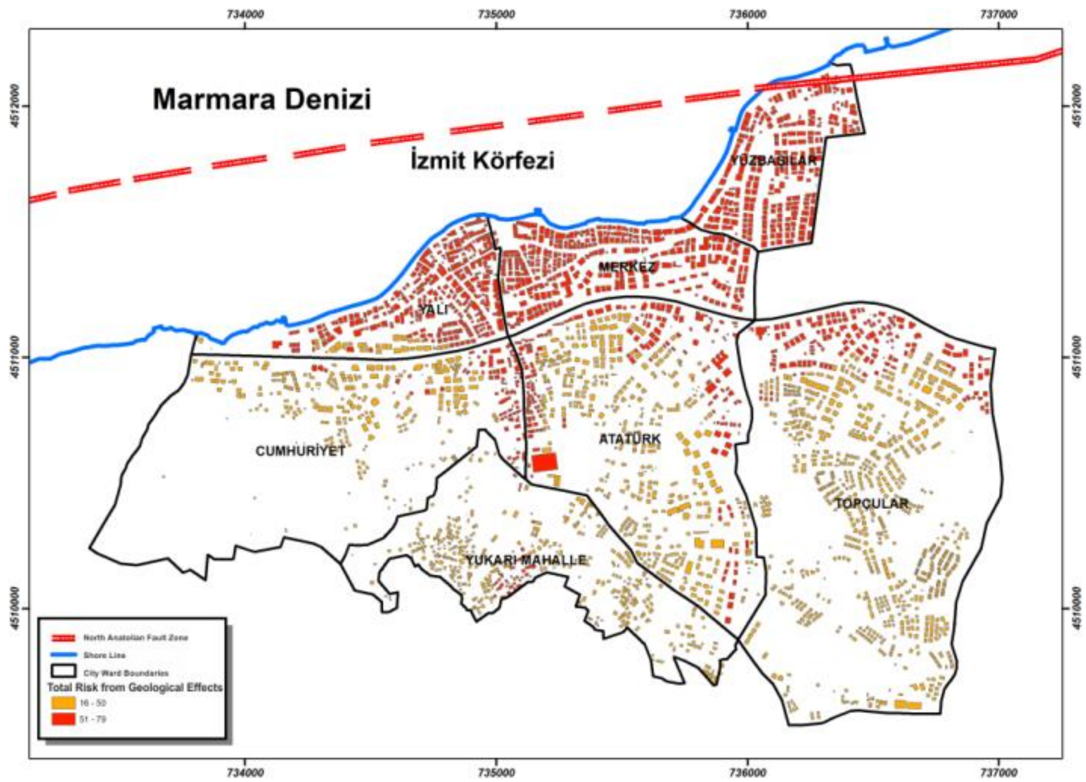


**Figure 6.** Total risk effect from earth science datas

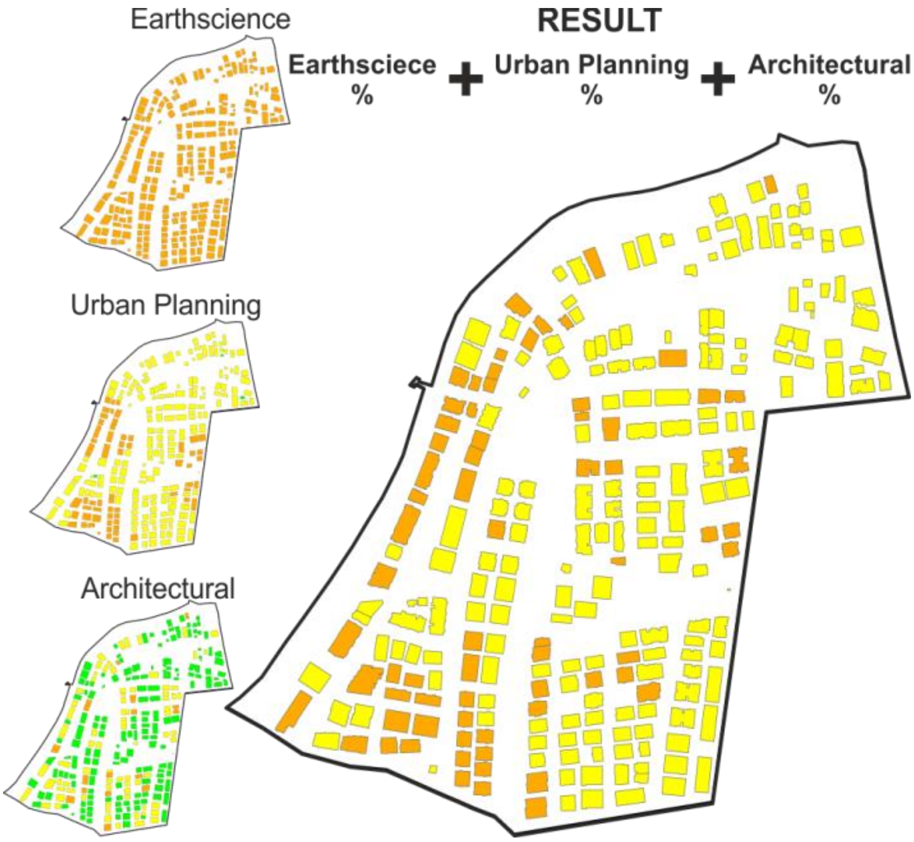


**Figure 7.** Total risk effect in Yüzbaşılar District

## 4. RESULT AND SUGGESTIONS

In GIS based disaster management studies, though it is a must to collect all the data in GIS, it is not an enough solution. It is necessary for the system created in GIS to be updateable and developable. It is necessary for the system to be designed appropriate for multi-disciplined studies. While the area is evaluated as risky for a department, after other departments joining to the evaluation, more meaningful results can be obtained for the area (Figure 6).

The final important criterion in disaster management system is the population information. Addition of the people living in the building to the building attribution table in GIS will not only guess the damage of the building which will get after a disaster but also the affected population and the needs of that population will come to a predictable level.

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