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A Proposal for a Method to Establish Natural-Hazard-Based Land-Use Planning: the Adapazarı Case Study

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Abstract: As a result of recent disasters in northwest Turkey (Marmara earthquake August 17, 1999/Düzce earthquake November 12, 1999), many buildings collapsed and many people experienced physical and mental problems. We can suppose that the problems caused by these earthquakes will be solved in the future, but geological studies show that the problems will not disappear in that many scientists are predicting a new disaster that will affect the same region. A design of natural-hazard land-use planning for minimising the consequences of recent and possible earthquakes is presented herein. The Adapazarı case is used to demonstrate the fundamentals of this study. In accordance with the aims of the study, a geographic information system is developed by superimposing current physical, socio-economic, demographic and cultural characteristics of the study area on regions that have potential earthquake-damage risk. Accordingly, safe and suitable areas for urban uses are determined by preparing an alternative land-use plan.

Key Words: Land-Use Planning, Disaster Risk Analysis, Disaster Management, Geographic Information Systems (GIS)

Doğal Tehlike Temelli Alan Kullanım Planlaması İçin Öneri Bir Yöntem: Adapazarı Örneği

Özet: 17 Ağustos 1999 ve 12 Kasım 1999'da Kuzeybatı Anadolu'da olan İzmit ve Düzce depremlerinde birçok bina yıkılmış ve birçok insanımız yaşamını yitirmiştir. Gelecekte bu depremlerin verdiği zararların büyük ölçüde azaltılabileceği umut edilse de, yapılan bilimsel araştırmalar göstermektedir ki, bölgede hâlâ ciddi bir deprem riski söz konusudur. Depremlerin ve olası bir depremin etkilerini asgariye indiremek amacıyla kullanılabilecek doğal afet riski analizi temelli bir alan kullanım planlaması için örnek bir yöntem verilmektedir. Yöntemin anlaşılmasının sağlanması amacıyla, Adapazarı örneğinden yararlanılmıştır. Çalışmanın amaçlarına bağlı olarak, bu çalışmada fiziksel, doğal, kültürel veriler olası bir depremin verebileceği zarar riski ile coğrafi bilgi sistemleri ortamında çakıştırılmıştır. Böylece alternatif alan kullanım kararlarının verilmesinde kullanılmak üzere güvenli ve uygun alanlar tespit edilmiştir.

Anahtar Sözcükler: Alan Kullanım Planlaması, Afet Riski Analizi, Afet Yönetimi, Coğrafi Bilgi Sistemleri (CBS)

Study Intervention Logic

The overall objective of this study was to establish a methodology for natural-hazard-based land-use planning for Adapazarı. The objective has relevance to international action programs related to the aim of developing sustainable land-use planning and providing sustainable development for Adapazarı following the recent earthquake in order to minimise the consequences of a future possible earthquake. This study provides a methodology for natural hazard-based land-use planning that may be used in other regions and countries. The suggested dos not consist of a traditional land use planning or of an application of a geographic information system (GIS). The basic aim of this study was to perform alternative land-use planning using a natural-hazard-based information and management system. The land-use planning decisions were based on simulating the damage of a possible future earthquake using geographic information systems. Via this study, damage has been determined beforehand and a GIS-aided crisis-management model set forth.

The purpose of the study can be collected under three main topic headings: (1) providing sustainable development for Adapazarı to recover from devastation caused by the recent earthquake; (2) determining safe areas for urban uses considering the ecological structure of the area to minimise economic, socio-economic, and physical losses from a possible earthquake by taking precautions before the possible disaster; and (3) establishing an auditing and monitoring system for urban and industrial uses, and taking precautions and preparing an action plan to minimise losses in case of an earthquake.

In this context, the main activities of the study are to: (1) determine via mapping the risk areas and the hazard of a possible earthquake; (2) determine the impact of a possible earthquake; (3) develop an alternative land-use plan using GIS and remote-sensing capabilities; (4) determine necessary precautions for existing land uses; (5) determine necessary precautions for existing industrial risk (in the event of another earthquake) to minimise the regional and global environmental impact of said earthquake; (6) establish an environmental auditing and monitoring system for urban and industrial uses; and (7) facilitate sustainable development for Adapazarı to minimise the consequences of the recent earthquake.

Problem analysis, objectives and study purposes are given in Figures 1 and 2. Two basic methods could be applied for the preparation of seismic risk zoning maps: (1) probability concept; and (2) relativity concept.

Using the probability concept, the period of an earthquake possibility for a particular region and with a specific strength can be shown. In the maps prepared using the relativity concept, a region is divided into risk zones by overlaying various parameters. The parameters used in this work are lithological units, seismicity, density of population, urbanisation, etc. (Kasapoğlu *et al.* 1996). The method of determining relative seismic danger zones set forth by Kasapoğlu *et al.* (1996) depends on dividing each parameter relatively into three grades and appointing, on a grey scale, 75 pixels to the first grade, 150 pixels to the second grade, and 225 pixels to the third grade, and then adding the equivalent pixel value of

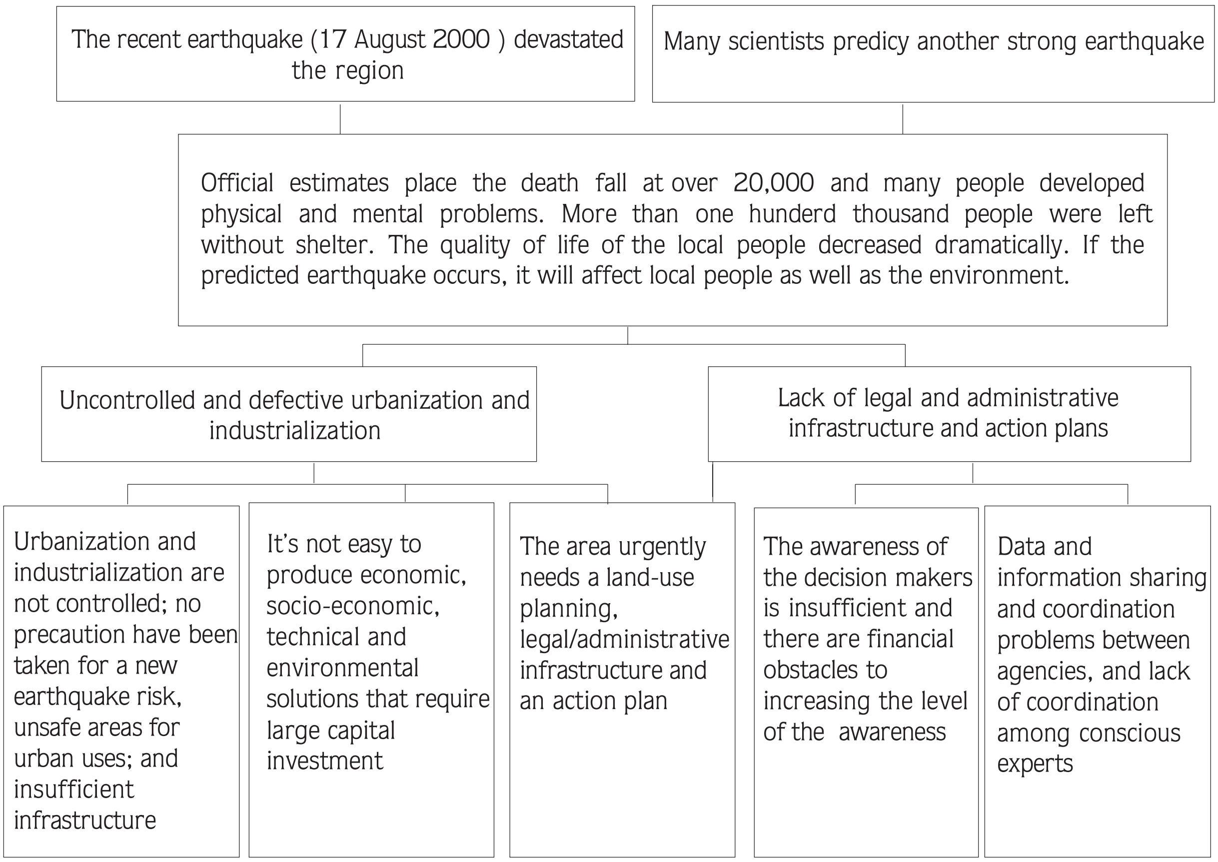

Figure 1. Problem analysis.

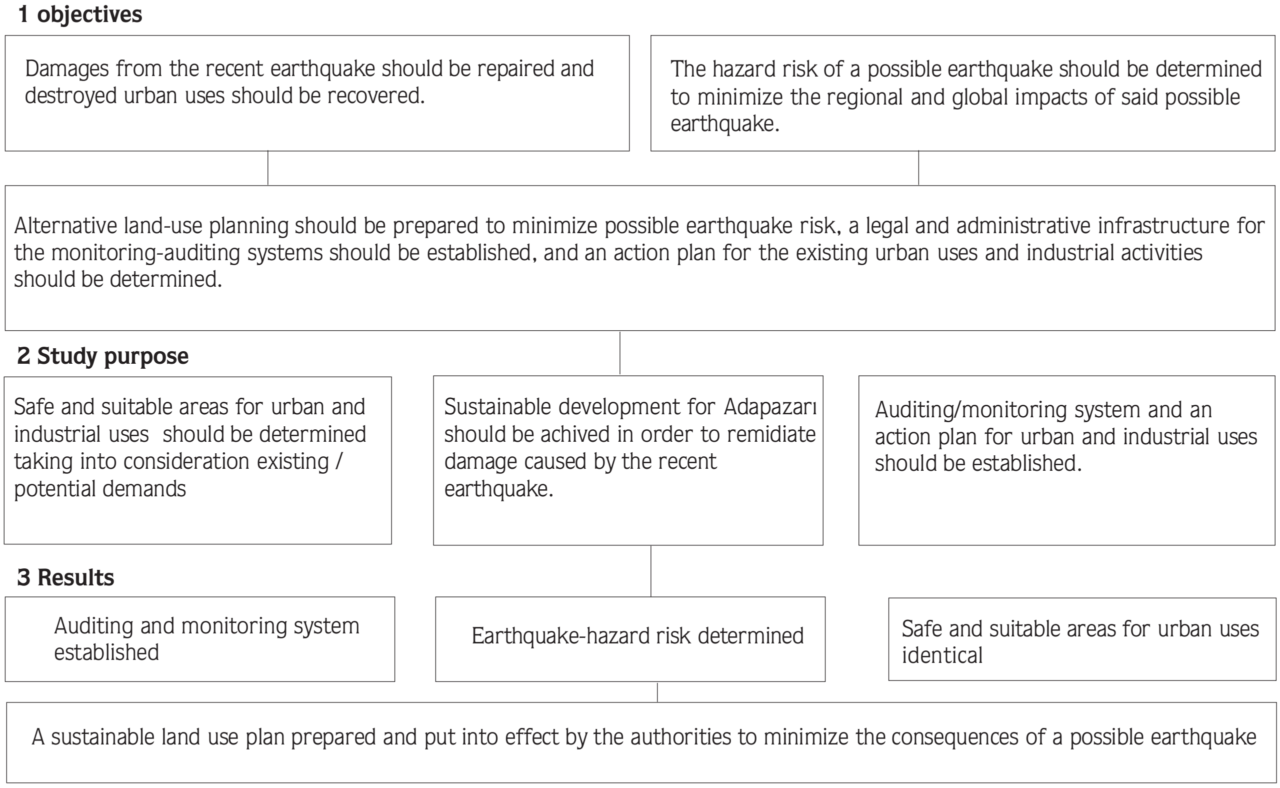

Figure 2. Figure 2. Objective analysis and strategies analysis.

each x/y coordinate and taking their arithmetic means. The arithmetic means obtained by this method are collected in a new data file and these data are converted to images; the result is a map. The model proposed in this paper differs from this method. By giving 1 / 2 / 3 marks in order of importance to the same criteria, the weighted overlay is completed and the seismic-risk area map is prepared. An example of the weighted overlay method is given in Figure 3 and the overlay process and the parameters are given in Figure 4.

The principle of the probability method is based on calculating the damage for possible earthquakes with different strengths which may occur in different epicentres considering the epicentre-length of the region, shear/drift velocity, and surface-wave magnitude. By matching these data with geographical data, thematic maps were produced. After risk analysis, safe and appropriate areas have been identified for places, which are insecure and under high risk, using available data in the system and GIS facilities. With this model, "safe" areas are identified using GIS capabilities.

The site-selection process for the "safe and suitable" urban-use areas involves some socio-economic, socio-cultural and natural data. These layers are: (1) determining safe areas – geology, fault zones, flood risk and slope; (2) determining suitable areas using features of the region – watershed, recent settlements, infrastructure, ecologically sensitive areas, road network, land-use capabilities, hydrographic features, current land-use; (3) socio-cultural and socio-economic features – sex-age-professions-incomes structure and distribution, areas with critical values and rates.

The first step of this study will be to identify safe areas. For this purpose geology, fault zones, flood risk and slope should be superimposed in the GIS using weighted overlay. In this step, areas safe for urban uses are identified. The second step of the study is to determine suitable areas for new settlement via the weighted overlay of regional features in the GIS, using different influences for all features. After these two steps suitable and safe areas for new settlement have been determined via weighted overlay of the results (step 1 and step 2). With this overlay, suitable and safe areas can

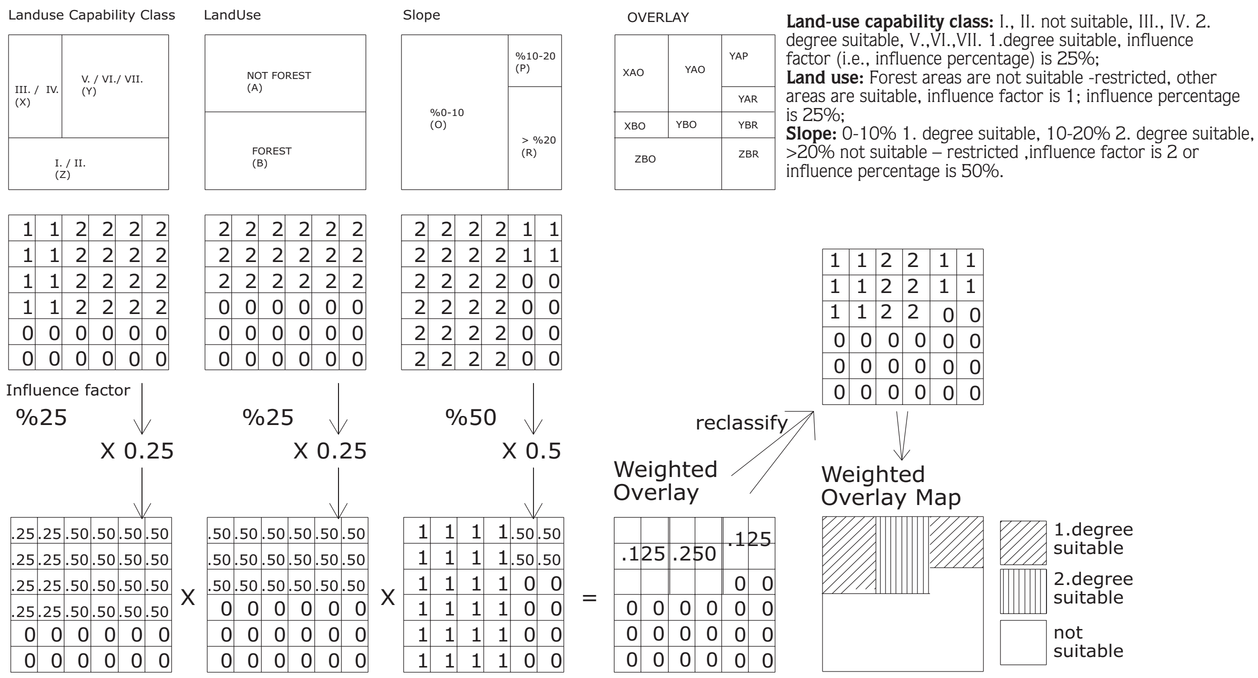

Figure 3. A hypothetical example for the weighted overlay method (from Çabuk 2001).

be found. This process is shown in Figure 5 using maps and flowchart. The result of this last overlay should be superimposed with socio-cultural and socio-economic features of the region in order to identify the most suitable areas for urban uses.

The Adapazarı Case Study

Main data used in this study are: (1) slope–aspect-elevation analyses, drainage basin-boundaries, watersheds, degree of erosion, flood-hazard areas has been developed using an *elevation model* by analysing the data, making GIS analyses, and creating GIS layers; (2) present land cover and land use, road networks is produced *satellite images* by geometric correction, classification and creating GIS layers; (3) geological formation, fault planes, earthquake frequency, earthquake hazard areas, liquifaction is produced using *geological data* by digitising the maps, creation of polygon topology and creation of GIS layers; (4) land-use capability class, degree of erosion, soil types, soil properties are created using *soil data* by digitising the maps, creation of polygon topology and creation of GIS layers; and (5) settlement boundaries, names, road network are created by using other data and maps by registering and digitising the maps, creation of network, point and polygon topology and creation of GIS layers.

The Adapazarı area is divided in to four different categories by using the weighted overlay process. These are: (1) high risk areas – not suitable for urban development – could be used only for recreation and agriculture; (2) risk areas – suitable for some urban development after taking precautions and engineering efforts such as grouting – could be used as commercial areas and buildings should have only one or two floors; (3) minor-risk areas – suitable for urban development and residential areas – could be used for educational facilities, residences, etc.; and (4) areas with very low risk - suitable for mass residential developments.

Depending on these categories, different values are assigned given by weighted overlay process for each feature of the area. These values are listed below. Also, each feature has a different influence factor (the sum of influence factors is 100%) depending on the importance of the features in finding suitable urban-development areas:

- Restricted for high risk areas
- 3 for risk areas
- 2 for minor risk areas
- 1 for very low risk

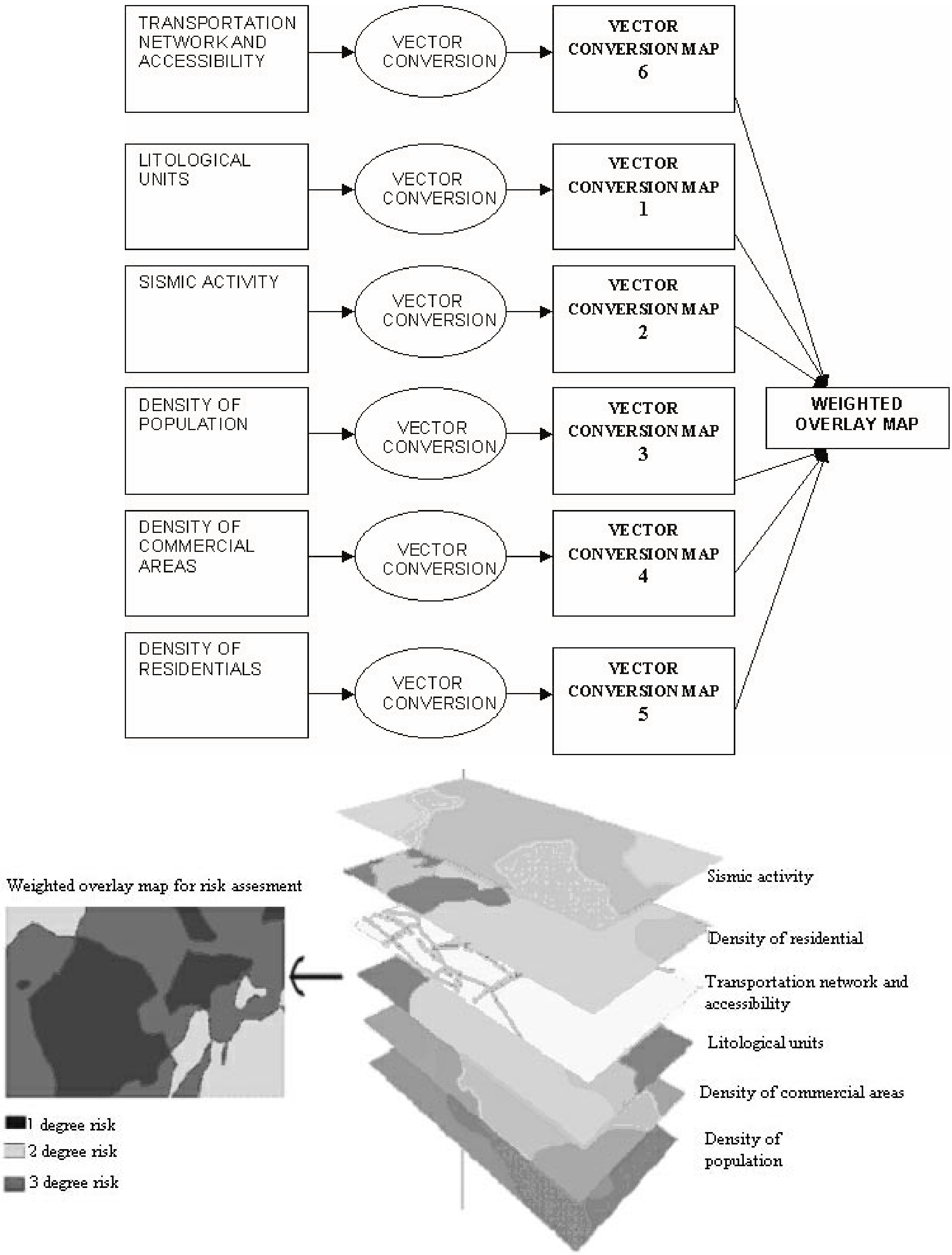

Figure 4. Layers of the risk assessment study and determination of risk levels (from Çabuk 2000).

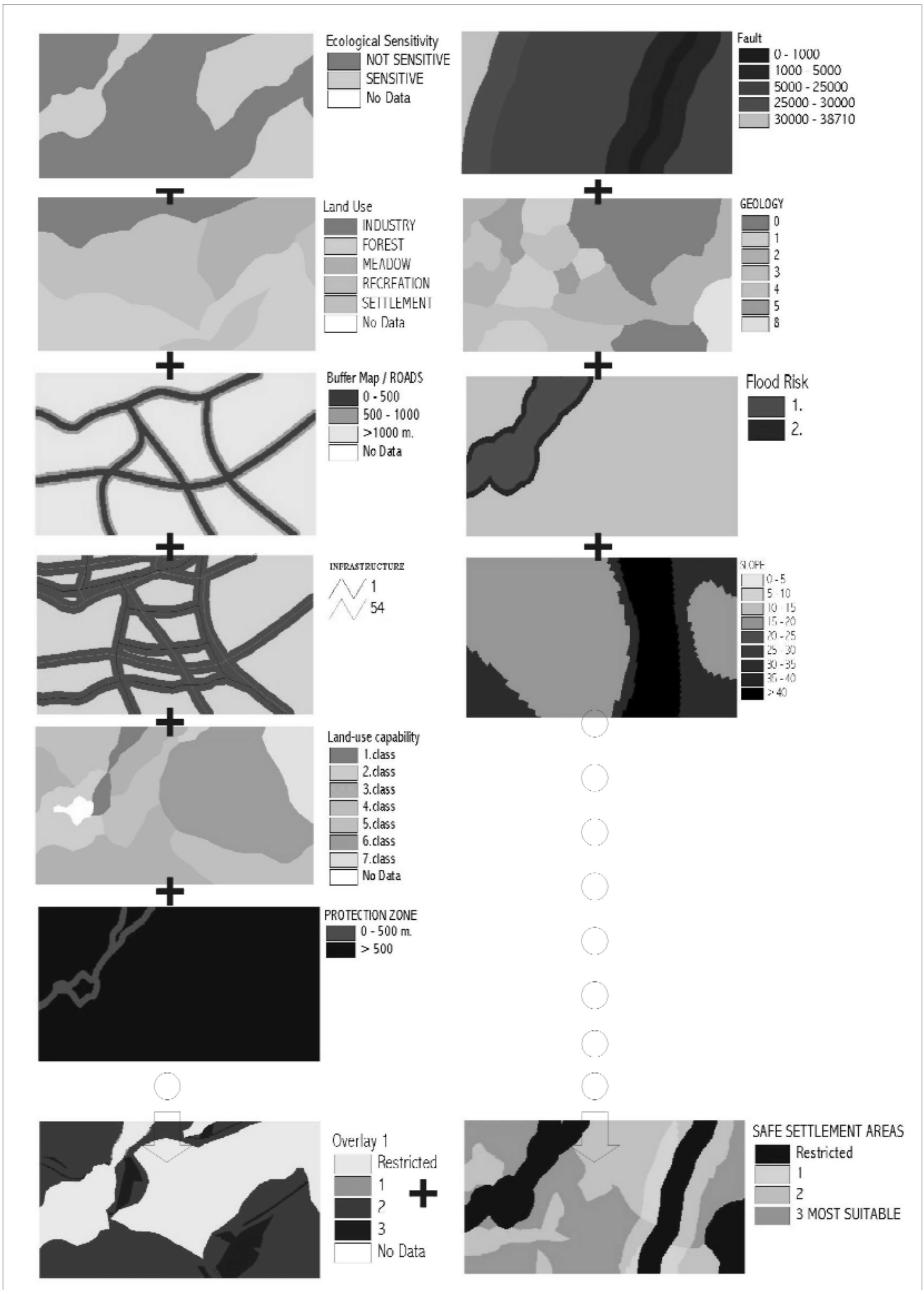

Figure 5. (A) Layers for the site selection;

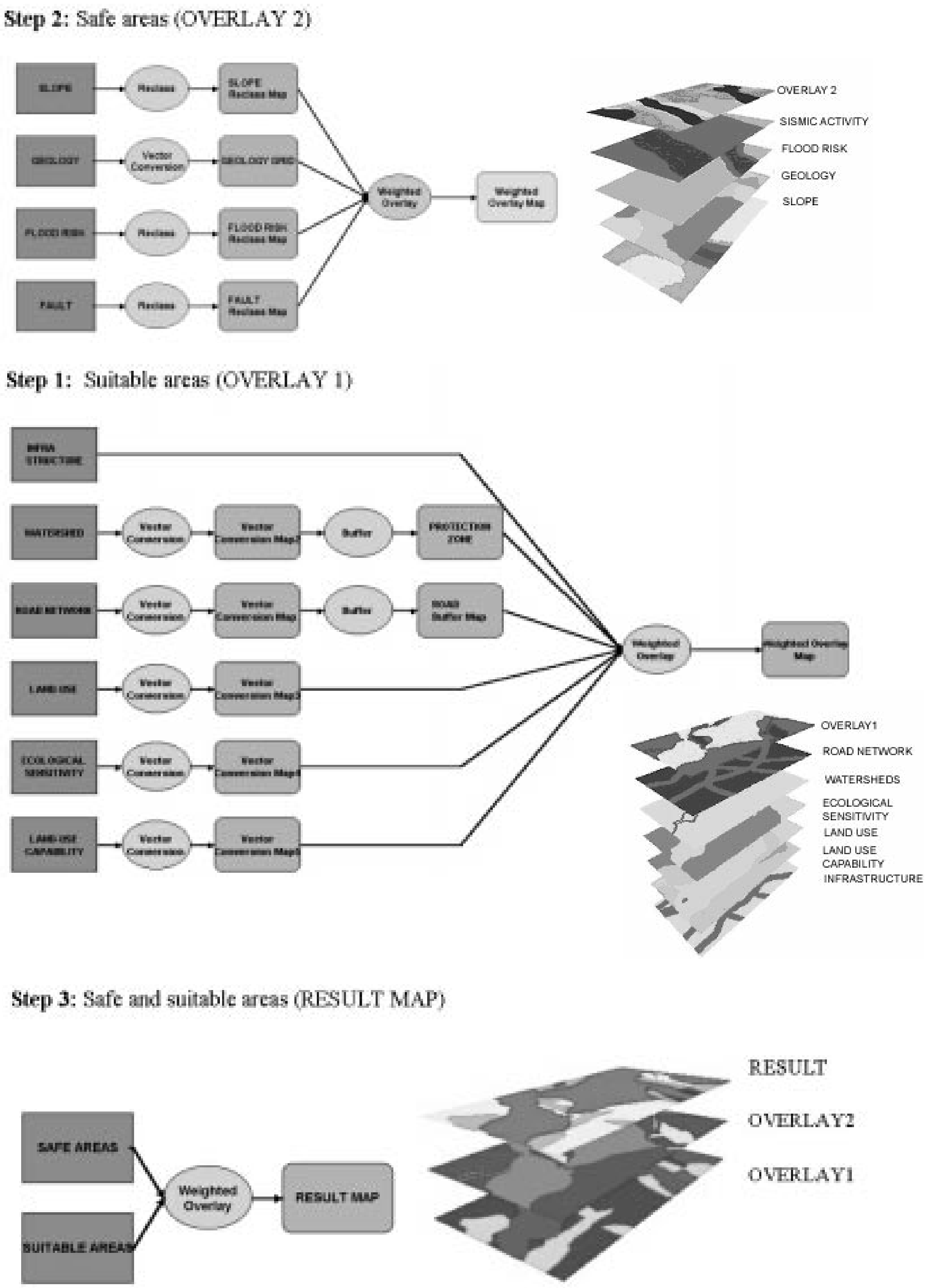

Figure 5. (B) overlay process for the site selection (from Çabuk 2000).

The values for major features are listed below:

1. *Land use capability class* – influence factor is 10%
   - I. Class is restricted;
   - II. Class has '3';
   - III. and IV. Class has '2';
   - Others have '3'.

2. *Slope groups* – influence factor is 10%
   - 3-10 is '1';
   - 0-3 and 10-20 is '2';
   - 20-30 is '3';
   - 30 > is restricted.

3. *Roads* – influence factor is 5%
   - 1000 m. > 'restricted';
   - 1000-500 m from road '3';
   - 500-100 m from road '2';
   - 100 m < '1'.

4. *Distance from fault* – influence factor is 10%
   - 1 km < 'restricted';
   - 1-3 km '3';
   - 3-6 km '2';
   - 6 km > '1'.

5. *Distance from river*– influence factor is 5%
   - 50 m < 'restricted';
   - 50 – 100 m '3';
   - 100 – 150 m '2';
   - 150 m > '1'.

6. *Ecological sensitivity* – influence factor is 5%
   - Highly sensitive areas 'restricted';
   - Sensitive areas '3';
   - Less sensitive areas '2';
   - Not sensitive areas '1'.

7. *Seismic activity*– influence factor is 10%
   - High 'restricted';
   - Medium '3';
   - Low '2';
   - Very low '1'.

8. *Geological formations*– influence factor is 10%
   - Very problematic 'restricted';
   - Problematic '3';
   - Less problematic '2';
   - No problem '1'

9. *Liquefaction*– influence factor is %10
   - Very problematic 'restricted';
   - Problematic '3';
   - less problematic '2';
   - No problem '1'.

Results

According to the weighted overlay, Kürkçüler, Yenigün, Tığcılar, Yağcılar, Güneyler, the Prison district, the Sakarya-River watershed and surroundings, the Mithatpaşa and the Stadium district, Mudurnu - Çarksuyu watershed and surroundings, the corridor between Adapazarı-Çınarcık and surroundings, the riverside near Evrenköy and Köprübaşı, the Maltepe-Hızırtepe corridor, the İstiklal, Karaosman, Orta, Yahyalar, Kurtuluş, Cumhuriyet, Semerciler, Yenidoğan, Akıncılar, Papuççular, Ozanlar, Tekeler, Karakuş, Dağdibi, Köprübaşı, Yazlık, Serdivan, Mahmudiye, Yeşildere and Kuruçeşme corridor and the vicinities, surroundings of Sapanca, Taşkısığı, Poyrazlar and Akgöl Lakes are not suitable as residential areas depending on the type of natural hazard. The area NNW of of the Adapazarı is especially suitable for major urban development. The region between Köprübaşı, Dereköy, Karadavutlu, Yenice, Kaynarcık district, the area which is in the west of Yukarı Kirazcık, northwest and southeast of the Karasu road – the region between Çamyolu, Akarca, Poyrazlar, Rüstemler and Kömürlük, the region between Göktepe, Çaltıcak, Harmantepe, Ikızce –, north of Akçay, Karapınar, Karaman, Resüldivan, Alandüzü and surroundings, the region between Serdivan river, east of Kırcalı, Karadere and west of Serdivan, the region between Çataldere, Çubuklu, Selahiye, Kuruçeşme, Kazımpaşa, Eğrekdere, the region between E-5 and TEM highways the southwest of Hendek are suitable for urban developments. The high risk areas, Sakarya River, Çarksuyu, Mudurnu and the other river watersheds, surroundings of Sapanca, Poyrazlar, Taşkısığı and Akgöl lakes, riverside of Evrenköy and Köprübaşı could be used as recreational areas and agriculture areas. The region between Kazımpaşa, Meşeli, Dağyoncalı, Selahiye, and Çubuklu is especially suitable for agriculture and rural settlement. This area is connected via the Adapazarı Adapazarı-Kazımpaşa and Kazımpaşa-Akmeşe roads. The Adapazarı city centre could be used for commercial purposes. The buildings should have basements, and are to three floors above the basement; some grouting techniques and deep foundations for the buildings should be used. In the Adapazarı city centre, buildings that have more than 3 floors should be renovated and these building would have a maximum three floors. Urban development on streets such as Atatürk Bulvarı, and İzmit, Ankara, Çark, Palmiye, and Sakarya streets, and also the Tığcılar district, should be renewed and used as commercial areas. The region between Adnan Menderes Street, the Vagon Fabrikası, the Şeker Fabrikası and Ankara Street should be renewed and used mainly for recreational and green-area purposes. The highlands to the north of Adapazarı could be used as residential areas. In the same region, the areas near the lowland could be used as commercial or industrial areas, but the number of the floors should be few. Evrenköy could be used for educational facilities. The region between the old meadow of Karamış and the Albayraklar tent city could be used for government buildings. The Kazımpaşa-Akmeşe, Adapazarı-Kaynarca, Adapazarı-Karasu, Kaynarca-Karasu, Adapazarı-Kazımpaşa roads are very important to the renewal of the city, and should be reconstructed according to current needs.

Discussion

If another earthquake occurs in the Marmara Region, as predicted by geoscientists, casualties may be quite high, considering the defective and uncontrolled urbanisation of the region. Therefore, risk areas and safe areas for urban use should be determined immediately and the institutions and authorities should take necessary precautions. It should be noted that safe areas are not always suitable for urban use. Therefore, socio-economic and cultural features of the area should be superimposed (via overlays) on safe areas. The way to find safe and suitable areas for urban use is to develop natural-hazard-based land-use planning studies to remediate recent and minimise possible earthquake damage considering existing land uses, potential development demands, and the socio-cultural and ecological structure of the area. A land-use planning and GIS-based model may solve some of the problems pertaining to precautions and disaster recovery/management, and also problems concerning the socio-economic and environmental impacts of disasters. The benefits of this type of study are:

- the development of a database of earthquake-related features of the region using GIS-based data, and provision of information-sharing and coordination among agencies and organisations, with collection of all geographic data in the system;
- determination of socio-economic, socio-cultural, demographic and natural features of the area using remote sensing and GIS capabilities to define risks and necessary precautions;
- determination of risk areas and potential damage, preparation of a basis for taking precautions using GIS-based potential earthquake scenarios. In the light of this study, take necessary precautions in the risk areas and, after determining risk areas, find safe urbanisation areas for regions with high risk-considering existing land use, the socio-cultural and ecological structure of the area, and potential and existing demands;
- acquisition of citizen-level input into an information-sharing system in order to promote awareness about sustainable development through self-empowerment and the involvement of people in sustainable development, and promotion of sustainable development in affected regions;
- encouraging all parties to conceptualise the disaster as a response to it in its spatial dimension, simply because it is the easiest way of handling and comprehending vast amounts of complex information;
- development of a land-use plan for promoting sustainable urbanisation and safe urban uses against a possible earthquake and natural hazards;
- establishment of legal, administrative and methodological infrastructures of the monitoring and auditing system for existing and proposed urban and industrial uses, and development of an action plan.

This study directly and inexpensively addresses the needs for possible disaster risks in the Marmara Region. In this study, GIS- and remote sensing-based land-use planning have been developed for minimising the environmental, sociological and socio-economical consequences of disasters, and a GIS has been designed that provides a scientific approach to the management of the possible disasters.

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