A FUZZY BASED DECISION SUPPORT SYSTEM FOR LOCATIONAL SUITABILITY OF SETTLEMENTS; ODUNPAZARI, ESKIŞEHIR CASE STUDY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

İSMAİL ERCAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
GEODETIC AND GEOGRAPHIC INFORMATION TECHNOLOGIES

JANUARY 2006

Approval of the Graduate School of Natural and Applied Sciences

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ABSTRACT

A FUZZY BASED DECISION SUPPORT SYSTEM FOR LOCATIONAL SUITABILITY OF SETTLEMENTS; ODUNPAZARI, ESKIŞEHIR CASE STUDY

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January 2006, 90 pages

Spatial Decision Making as a branch of decision making science deals with geographically related data in order to achieve complex spatial decision problems. Fuzzy set theory is one of the methods that can be used to come up with these types of problems. On the other hand, Geographical Information Systems (GIS) is one of the most powerful tools that we can use to accomplish spatial decision problems. Selection of the suitable site or land-use for the real estate is also a spatial decision making problem. When we consider the initial dynamics of the suitably located property from the point of view of value and potential we observe that the “good location” is the dominating factor. This study reports on the development of a kind of decision support system for locational suitability of settlements that integrates the fuzzy set (FZ) theory, a rule-based system (RBS) and GIS. This study is thought as the assistant for the property managers that are buyers and sellers. It can function as the property consultant for the buyers when they are looking for a property to buy and also it helps the real estate agencies to sell their properties. On the other hand, different scenarios of the potential areas according to the different user's preferences are depicted and they are joined and compared with the results of the vulnerability to earthquake hazards' of the same area. Odunpazarı - Eskişehir area is selected for implementation of the case study because of the data availability. As a result of this study, it can be said that most suitable property changes depending on the people's preferences. In addition, it is seen that most of the buildings that are locationally suitable are highly vulnerable to the earthquake hazards.

KEYWORDS: Spatial Decision Making (SDM), Geographical Information Systems (GIS), Fuzzy Set Theory, RBS (Rule Based System), Locational Suitability

ÖZ

YERLEŞİMLERİN KONUMSAL UYGUNLUĞU İÇİN BULANIK TEMELLİ KARAR DESTEK SİSTEMİ; PROJE ALANI: ODUNPAZARI, ESKİŞEHİR

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Yüksek Lisans, Jeodezi ve Coğrafi Bilgi Teknolojileri Anabilim Dalı

Tez Yöneticisi: Yrd. Doç. Dr. Zuhal AKYÜREK

Ocak 2006, 90 sayfa

Karar verme biliminin bir dalı olarak, mekansal karar üretme, karmaşık mekansal karar verme problemlerini aşmak için coğrafi olarak ilişkilendirilmiş veri ile ilgilenir. Bulanık küme teorisi de bu tür problemleri çözmek için kullanılabilecek metodlardan biridir. Diğer taraftan, Coğrafi Bilgi Sistemleri (CBS) mekansal karar verme problemlerini çözmek için kullanabileceğimiz güçlü araçlardan biridir. Gayrimenkul için uygun alan veya arazi kulanımının seçimi de bir mekansal karar verme problemidir. Değer ve potansiyel açısından uygun olarak konumlanmış gayrimenkulün iç dinamiklerini göz önüne aldığımızda, "iyi konum" un baskın faktör olduğunu görüyoruz. Bu çalışma bulanık küme teorisi, tanımlanmış kurallar sistemi ve CBS yi entegre eden, yerleşimlerin konumsal uygunluğunda bir çeşit karar destek sistemini anlatır. Bu çalışma alıcılar ve satıcılardan oluşan gayrimenkul yöneticilerine

asistan olarak düşünülmüştür. Bu, satın almak üzere mülk arayışında olan alıcılar için mülk danışmanı gibi işlev görebilir ve aynı zamanda garimenkul acentalarına satışlarında yardımcı olabilir. Diğer taraftan, bu çalışmada kullanıcıların tercihlerine göre potansiyel alanların farklı senaryoları üretildi ve bunlar aynı alanın deprem felaketine karşı hasasiyet değerleriyle birleştirilerek karşılaştırıldı. Örnek çalışmanın uygulanması için veri elde edilebilirliğinden dolayı Eskişehir Odunpazarı Bölgesi seçildi. Bu çalışmanın bir sonucu olarak en uygun gayrimenkulün kişilerin tercihlerine göre değişebileceğini söyleyebiliriz. Buna ek olarak konum olarak uygun olan gayrimenkullerin büyük bir kısmı depreme karşı oldukça hassas durumda.

Anahtar Kelimeler: Mekansal Karar Verme, Coğrafi Bilgi Sistemleri (CBS), Bulanık Küme Teorisi, Tanımlanmış Kurallar Systemi (RBS), Konumsal Uygunluk

To my family

ACKNOWLEDGMENTS

I would like to express my sincere thanks to my supervisor Dr. Zuhal Akyürek for her guidance and insight through out this study.

I would also thank Mehmet Servi, Levent Karagöl, Onur Yumuş, Gökhan Oğuzhan for their great assistance.

Thanks also go to Eskişehir Greater Municipality and Hakan Uyguçgil who shared their information and data about Eskişehir.

Finally, my greatest thanks go to my family for their great patience and support during my life and education.

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CHAPTER 1

INTRODUCTION

1.1 Aim and Scope of the Thesis

Planning is a discipline that uses different kinds of data and information in order to reach a result. City planners sometimes as decision makers try to find solutions or try to generate ideas for complex and high level strategic decision problems. To achieve this goal they try to make long term plans. City planners mainly use spatial data that are related to the economic, social, cultural, environmental etc. factors while they are making future plans. These spatial data are sometimes original as they are directly used without any interpretation and they are sometimes resultant data or information that are gathered as a result of decision making processes. As one of the branches of decision making (DM) science, Spatial Decision Making that uses spatial (geographically referenced) data is the main idea of this study.

The decision-making process begins with the recognition of a real world problem that involves searching the decision environment and identifying comprehensive objectives that reflect all concerns relevant to a decision problem. Spatial decision-making (SDM) focus on the spatial problems that is either dependent or influenced by geographical information (Gao et al., 2004).

Broadly speaking, two types of information are used in the spatial decision-making process: geographical information and information about the decision maker's preferences (Malczewski, 1999).

Land-use planners and locational decision-makers often face the problem of having to deal with complex decision situations. This complexity is mainly due to the fact that a huge amount of influential factors or variables have to be considered and that the interactions and internal dependencies between these different factors are sometimes difficult to understand (Wiltox, 2005).

It is also a necessity to develop decision-support systems that help decision-makers to screen possible locations against their set of locational requirements. Finally, formal representations of locational requirements may be of help in analysing location factors and locational decision-making processes (Wiltox and Timmermans, 2002).

Increasingly, geographical information systems (GIS) are used as an important aid for spatial decision making (Carver 1991, Pereira and Duckstein 1993). GIS is an integrated assembly of computer hardware, software, geographic data and personnel designed to efficiently acquire, store, manipulate, retrieve, analyze, display and report all forms of geographically referenced information geared towards a particular set of purposes (Burrough, 1986; Kapetsky and Travaglia, 1995). Geographic data, stored and processed in GIS, form a conceptual model of the real world (Aronoff, 1989). A model is a simplified representation or abstraction of reality. It is a simplified representation because reality is too complex to copy exactly and because much of the complexity is actually irrelevant to the specific problem (Malczewski, 1999).

However, despite the long history of DM theories and its applications (Lowry 1964, Gaile and Wilmott 1984, Parker and Rardin 1988, Maier 1993, Daskin 1995, Zeng and Zhou, 2001), SDM using GIS only emerged recently.

Geographic Information Systems (GIS) can enhance the efficiency and effectiveness of decision making in the residential real estate industry. They can organize, manage, and analyze information in ways that were not possible with traditional information management systems (Peterson 1998).

The spatial decision problem may involve uncertainty and imprecision (fuzziness) that make it difficult to predict the outcome of particular decisions (Malczewski, 1999). Fuzzy set theory enables the decision makers to make more appropriate spatial decisions by its capabilities so in this study; the aim of using fuzzy set theory is the fuzziness problem of the data in the identification of the good located property.

A property can be referred to as an unmovable (mostly, if not all) commodity that exists in physical and social space. Its location, as well as price, is the premier factor that affects decision making in property selection (Lin et al., 2002). Spatially no two properties are the same and valuers generally regard location as the most important factor affecting value (Turner, 1977, Britton et al., 1989; Millington, 1990). It is one of the important things that a man can have during his /her life. It represents strength for a man sometimes and it makes the person feel much more confident through the future as it can be seen as an investment. Also houses are places where the people spend most of their time and so wanted to feel comfortable. By the way while a person selects a property, he tries to be careful because he can not change the owned property frequently. Because of all these reasons there are some basic factors that he takes into consideration while selecting a property.

Finding the good located (locationally suitable) property is a kind of site-selection operation. In addition, it can be understood that site selection for the good located real estate is also a complex spatial decision problem. In this study, it is aimed to develop a fuzzy based decision support system for locational suitability of settlements.

Data used for SDM should represent the physical and social environment, and be easily obtained. Ideally, the basic factors that cover most of the essential aspects in finding an optimal site are listed by Zeng and Zhou (2001) as follows:

Environmental factors: slope and aspect, vegetation, parks and natural reserves, rivers and beaches; floodplain, dump-sites/hazardous sites and other pollution sites.

Social factors: shops and shopping centres, railway stations, schools, hospitals, theatres, roads, bus stops, railway, power-lines, aeroplane noise, house prices and population data as surveyed by census.

Personal factors: income, place of work, location of relatives' residence, household size, the value of housing loan, and the preferred population group.

Considering the nature of the application and data availability in this study, a simplified version of these factors was used as the main selection criteria:

- Physical environment (Parks, River (Porsuk), Slope, and Aspect)
- Amenity and transport (Schools, Shopping Centers, Tramway Stations)
- Pollution and noise (main road pollution and noise, railway noise)

These criteria are analyzed from the point of view of how they affect the people's lives in terms of location in the case study. They are used for the site-selection operations. After the suitable sites are obtained by using the 9 criteria described above, they are matched with the existing buildings in Odunpazarı – Eskişehir. As a result the buildings are divided into five groups from the point of view of suitability then they are compared with the vulnerability values of the buildings assessed for the İnönü and Gölcük earthquakes in the study prepared by Servi (2004).

The "good located" real estate depends upon the purchaser's preferences. Workplace, no and age of child(ren), personal income, house tenure, age of person etc. within a metropolitan area are the fundamental criteria that differentiates for the different social groups. In addition to these, the choice of person for the property may also depend on the purpose of purchase, e.g. live-in, sole investment, or both. So in this study for the sensitivity analysis of suitability assessments four different scenarios are created in addition to the Fuzzy Rule - Based System (FZRBS) result obtained by the execution of the 9 criteria simultaneously.

This study, which is a kind of real-estate GIS, is thought as the assistant for the property managers that are buyers and sellers. It can function as a property consultant for the buyers when they are looking for a property to buy and also it helps to the real estate agencies to sell their properties.

In the study, commercial GIS software, namely ArcMap is used for the necessary GIS analysis. In addition, for the fuzzy set theory implementations "FuzzyCell" (Yanar and Akyürek, 2006) designed to run on Arcmap is used.

1.2 Organization of the Thesis

The organization of the thesis is as follows;

In the **first chapter** it is started with a brief summary of aim and scope of the thesis and problems related to spatial decision-making in real estate business. Also some brief information is given about the study area.

In the **second chapter**, the theoretical framework is discussed. A brief information is given about decision making (DM) and spatial decision-making (SDM) theories. The uncertainty and the Boolean logic are described. In addition to these fuzzy sets & fuzzy set theory are briefly described. Chapter is ended with the description of the site selection analysis which can be a type of land suitability assessment.

The **third chapter** generally gives information about the data and the methodology of the thesis. The evaluation of the criteria used in the study is discussed. Standardization of the criteria using fuzzy logic is explained and the method used in the case study is explained. The Fuzzy Inference System (FIS) used for the fuzzy logic implementations is described. Fuzzy rule-based system and the sensitivity analysis using the different criteria weights are the other topics that are discussed in the chapter.

In the **fourth chapter**, the case study prepared for the Odunpazarı-Eskişehir area is explained in detail.

In the **fifth chapter**, sensitivity analyses are explained and the results of the case study are discussed. Recommendations on problems related to the system are mentioned in the fifth chapter.

In the **sixth chapter**, concluding remarks about the importance of real-estate GIS are given, and recommendations on problems related to the system are also mentioned in this chapter.

CHAPTER 2

THEORETHICAL FRAMEWORK

2.1 Spatial Decision Making (SDM)

A decision is a choice between alternative actions, hypotheses, locations, and so on (Eastman et al., 1993). Taking each possible combination of alternative as a subset, the decision process is essentially one of allocating alternatives to the subset that will be chosen or acted upon (Jiang and Eastman, 2000).

Spatial problems are complex because they are semi-structured or ill defined in the sense that the goals and objectives are not completely defined. Each spatial problem can have a large number of decision alternative solutions. Spatial Decision-Making (SDM) is an important aspect of our lives and critical for business. SDM focus on the spatial problems that are either dependent or influenced by geographical information (Gao et al., 2004). Moloney et al., (1993) observe that about ninety percent of business information is geographically related and covers wide diverse domain e.g. resource management, environmental modelling, transportation planning and geo-marketing. Spatial problems are normally categorised into allocation, location, routing and layout problems based on their geographical features.

Table 2.1. gives idea about some spatial problems, their application domain and some examples from spatial problems.

Table 2.1 Spatial Problems and Implementation Domains (Gao et al., 2004)

Spatial Problem	Application Domain	Example Spatial Problems
Allocation	Geo-Marketing	Find geographical distributions
Layout	Running	Design and select best running path
Routing	Delivery	Identify the fast route
Location	Housing	Search the most suitable house
Spatio-Temporal	Health	Trace the spread of a disease over space and time

Geographic Information Systems (GIS) are widely used in local and regional planning for managing, integrating and visualizing spatial data sets. However, beyond basic levels of decision support, GIS remain largely external artifacts to the decision-making process (Feick and Hall, 1999).

According to Nath et al. (2000) ideally, any GIS study will consist of seven phases: identifying project requirements, formulating specifications, developing the analytical framework, locating data sources, organizing and manipulating data for input, analyzing data and verifying outcomes, and evaluating outputs (Figure 2.1).

Much of the use of GIS in planning assumes use of a rational mode of decision-making, which entails a linear process initiated with the identification of a problem, followed by a comprehensive search for alternatives and concluded with the selection of the optimal alternative as indicated by the gathered information (Batty, 1993).

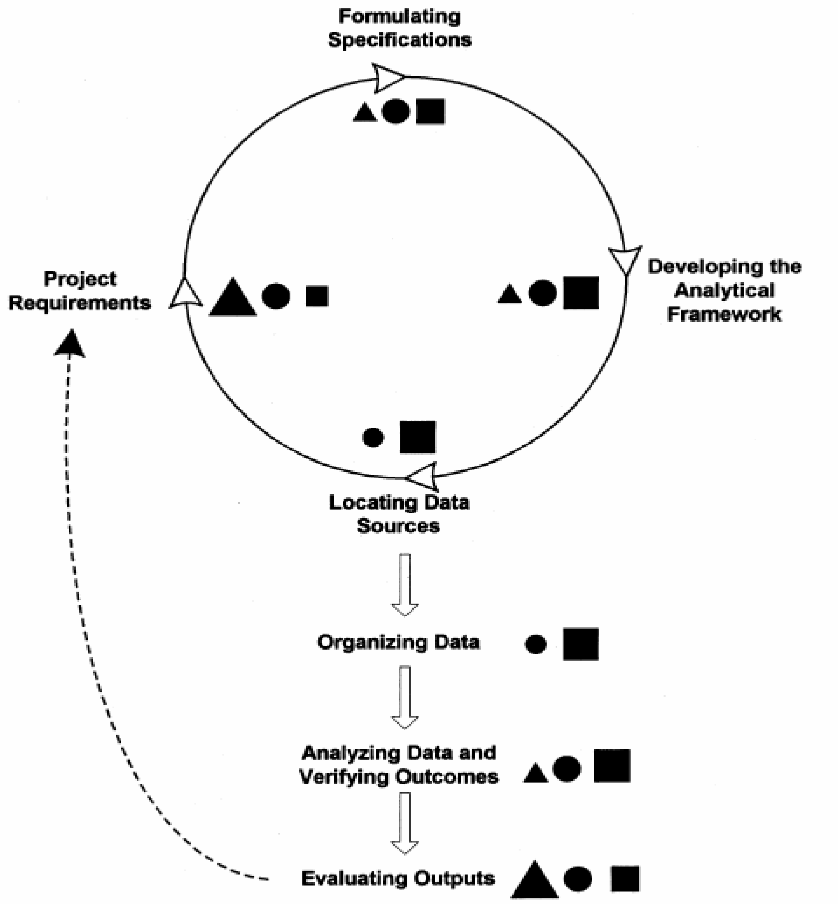

Figure 2.1 Schematic representation of the phases in a GIS project (Nath et al., 2000)

In practice, most of the iteration within the overall process is to be found within the first four phases. Involvement of end users (▲), subject matter specialists (●), and GIS analysts (■) within each of the phases is also indicated, with symbol sizes reflecting the importance of their respective roles (Nath et al., 2000).

Broadly speaking, two types of information are used in the spatial decision-making process: geographical information and information about the decision maker's preferences. Geographic data are raw materials. To be useful for decision making the data are processed to obtain relevant information. The process of converting data into information is central to spatial decision making. It adds value to the raw original data. Successful decision making depends on the quality and quantity of information available to decision makers. Any decision-making begins with a recognition of the decision problem. A spatial decision problem is the difference between the desired and existing state of a real-world geographical system. The ultimate aim of GIS is to provide support for making spatial decisions (Malczewski, 1999).

According to Gao et al. (2004) spatial decision making process is divided into three main steps: Intelligence, design and choice (Figure 2.2.). In the Intelligence Stage, *Problem Identification* and *Problem Modeling* are made. The Design stage is composed of the *Model Instantiation*, *Model Execution*, *Model Integration-Scenario Modeling*, *Scenario Instantiation*, and *Scenario Execution* steps. *Scenario Evaluation* and *Decision Making* are the steps of the Choice stage.

The decision-making process begins with the recognition of a real world problem that involves searching the decision environment and identifying comprehensive objectives that reflect all concerns relevant to a decision problem (Gao et al. 2004).

Man is capable of making decisions based on vague and uncertain concepts because of his ability to grasp the information that is stored away in a linguistic expression. The direct translation of such processes to formal languages is not an easy task. Scientific analysis, however, requires a formal representation of spatial terms. The translation of linguistic concepts to spatial terms like ‘‘steep slopes’’ involves inherent uncertainties that are dealt with by implementing fuzzy logic tools to computer based GIS (Benedikt et al. 2002).

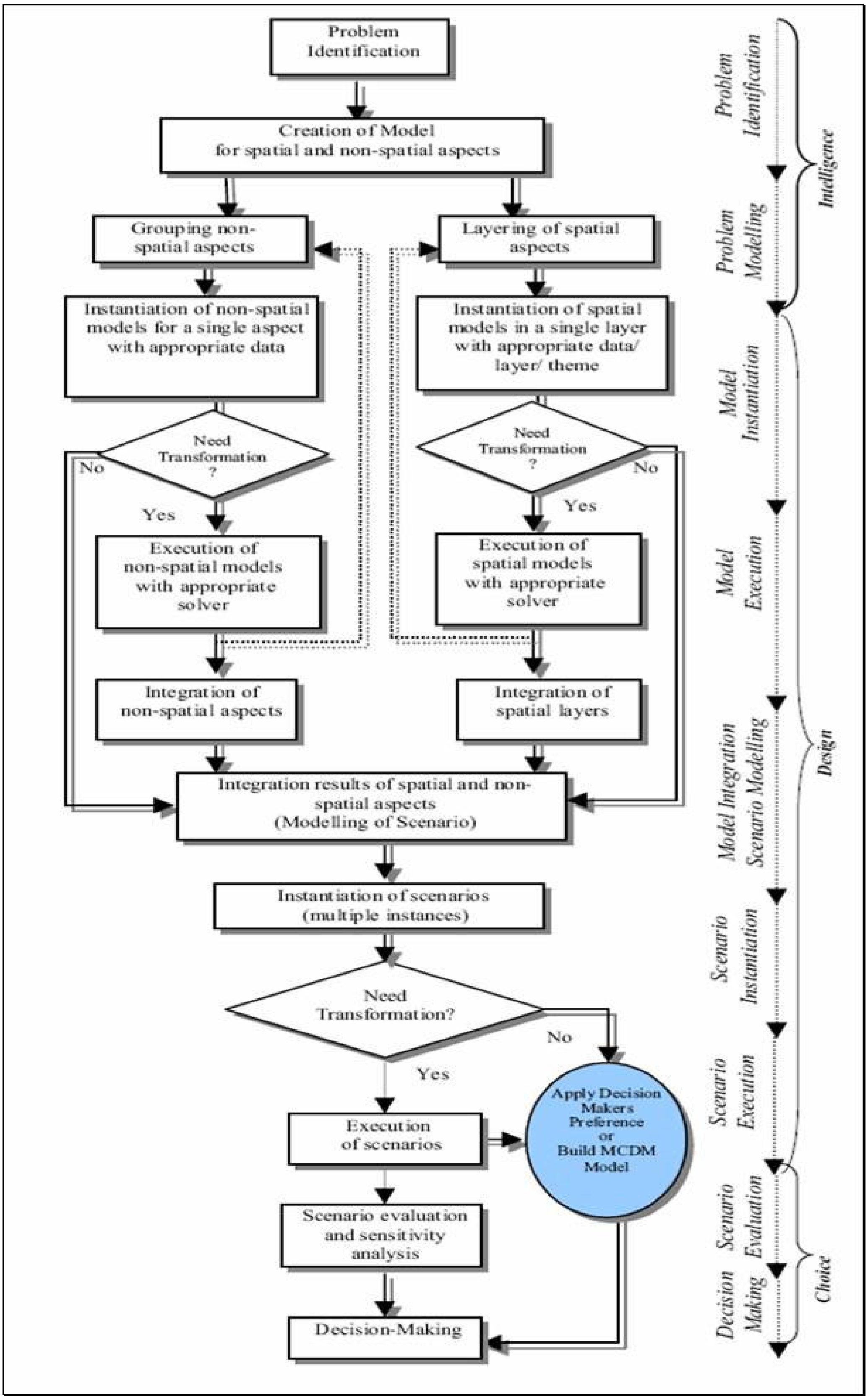

Figure 2.2 Spatial Decision-Making Process (Gao et al., 2004)

2.2 Uncertainty & Classical Set Theory

Uncertainty (sometimes the terms imprecision and vagueness are used instead) refers to the imperfect and inexact knowledge concerning some domain of interest (Goodchild and Gopal, 1989; Openshaw, 1991; Kruse et al., 1991).

The uncertainty is an inherent feature of geographical data and may arise through (Altman 1994): (a) incomplete information associated to them; (b) the presence of varying concentrations of attributes; and (c) the use of qualitative descriptions of their attribute values and relationships.

Currently used methods for the representation and analysis of geographical information are inadequate, because they do not tolerate uncertainty (Wang et al., 1990). This is largely due to the underlying membership concept of the classical set theory, according to which a set has precisely defined boundaries and an element has either full or no membership in a given set (Boolean logic) (Stefanakis et al., 1999).

It is argued that the employment of Boolean logic (the all-or-nothing system) in GIS design causes the following problems (Leung and Leung 1993): (a) it imposes artificial precision on intrinsically imprecise information, graded spatial phenomena and processes; (b) it fails to determine and communicate to users the extent of imprecision and error; (c) it is inappropriate to model human cognition, perception and thought processes, which are generally embedded with uncertainty; and (d) it is inadequate to model natural languages, which are imprecise in nature.

Specifically, the linkages between the spatial entities (e.g. individual locations on a layer) and their non-spatial attributes are based on the membership concept of classical set theory, that is, an entity either has an attribute entirely or does not have it at all. No third situation is allowed. Hence, all spatial entities are associated with single attribute values regarding each theme of interest (Stefanakis et al., 1999).

The employment of a sequence of basic GIS operations to support a real world problem, such as that of residential site selection, is accompanied with all problems of an `early and sharp classification' (Stefanakis et al., 1996). First, the overall decision is made in steps which drastically and sharply reduce the intermediate results. Any constraint is accompanied with an absolute threshold value and no exception is allowed (Stefanakis et al., 1999).

2.3 Fuzzy Logic & Fuzzy Set Theory

Apparently, inexact concepts are rampant in human cognitive and decision-making processes. For example, when choosing the location of our home, we may employ criteria such as easy accessibility, inexpensive, good public services, and low crime rate. In deciding on a mode of transportation, economical, relatively comfortable, good service, and low accident rate may serve as standards. In determining a place to shop, the basic requirements may be not too far away, relatively high quality products, and reasonable prices. The italiazed terms are inexact concepts whose meanings are fuzzy (Leung, 1983).

Nowadays, the methods used in commercial GIS packages for both the representation and analysis of geographical data are inadequate, because they do not handle uncertainty. This leads to information loss and inaccuracy in analysis with adverse consequences in the spatial decision-making process (Stefanakis et al., 1999).

Except for some situations where regional concepts are immaterial, most spatial analyses are directly or indirectly related to the concept of a region (Leung, 1983).

Conventionally, region is treated as an entity or a theoretical construct which can be exactly defined and delimited. Boolean logic, a two valued system, has been employed to subdivide space into a set of mutually exclusive and exhaustive regions with clear-cut boundaries.

Such a system ignores the fact that two spatial units are only similar, with respect to specified attributes, to a certain degree, or their interaction exist in varying degrees of intensity (Leung, 1983).

A region is obviously a fuzzy theoretical construct with an ambiguous boundary. A spatial unit may belong to a region only to a certain degree. In place of the Boolean logic, a new theoretical foundation is required to construct a more natural characterization of the regional concepts (Leung, 1983).

Therefore, the major contribution of fuzzy sets theory to spatial classification is that it provides a more natural definition of a region and a more appropriate procedure for regionalization. Instead of avoiding ambiguity while it exists, fuzzy sets approach gears to the formal representation and analysis of uncertainty in spatial classification problems (Leung, 1983).

In the case of single-objective land allocation, a decision set contains two subsets: suitable (for allocation), and not suitable (for allocation). A decision is then derived from an assessment of suitability, the degree to which a location belongs to the set `suitable' (in most cases, fuzzy membership in the set `not suitable' is assumed to be the complement of `suitable' set membership). In most decision making processes, multiple criteria are considered to assess the degree of suitability each location bears to the allocation under consideration. Thus suitability is commonly not Boolean in character, but expresses varying degrees of set membership, i.e. a fuzzy set. Each criterion chosen by the analyst thus constitutes direct or indirect evidence, based on which fuzzy set membership (or suitability) of a location can be evaluated. We recognize two kinds of criteria, factors and constraints, with a factor signifying a continuous degree of fuzzy membership (in the range of 0 - 1), and constraints acting to limit the alternatives altogether (i.e. fuzzy membership is either 0 or 1). The latter is the special case of fuzzy sets (Eastman et al., 1993).

Fuzzy logic is based on the central idea that in fuzzy sets each element in the set can assume a value from 0 to 1, not just 0 or 1, as in classic set theory. Thus, qualitative characteristics and numerically scaled measures can exhibit gradations in the extent to which they belong to the relevant sets for evaluation. This degree of membership of each element is a measure of the element's "belonging" to the set, and thus of the precision with which it explains the phenomenon being evaluated (Bagnoli and Smith, 1998).

Fuzzy set theory (Zadeh 1965, 1988) provides useful concepts and tools for representing geographical information. In addition, fuzzy analysis procedures are clearly relevant to many areas of GIS, because they provide a means of dealing with uncertain data (Wang et al. 1990, Leung and Leung 1993, Altman 1994). The question is basically how to incorporate fuzzy analysis into GIS (Openshaw, 1991).

When we examine the Figure 2.3 we can determine the main difference between the classic and fuzzy classification for an example linguistic variable 'slope'. In the classic one, the whole area is divided into four different slope classes and each class has its own membership value. For example, 31% and 59% slope values are in the same class and it does not make any difference from the point of view of membership degree. However in the second one every slope value has its own membership degree changing 0 to 1.

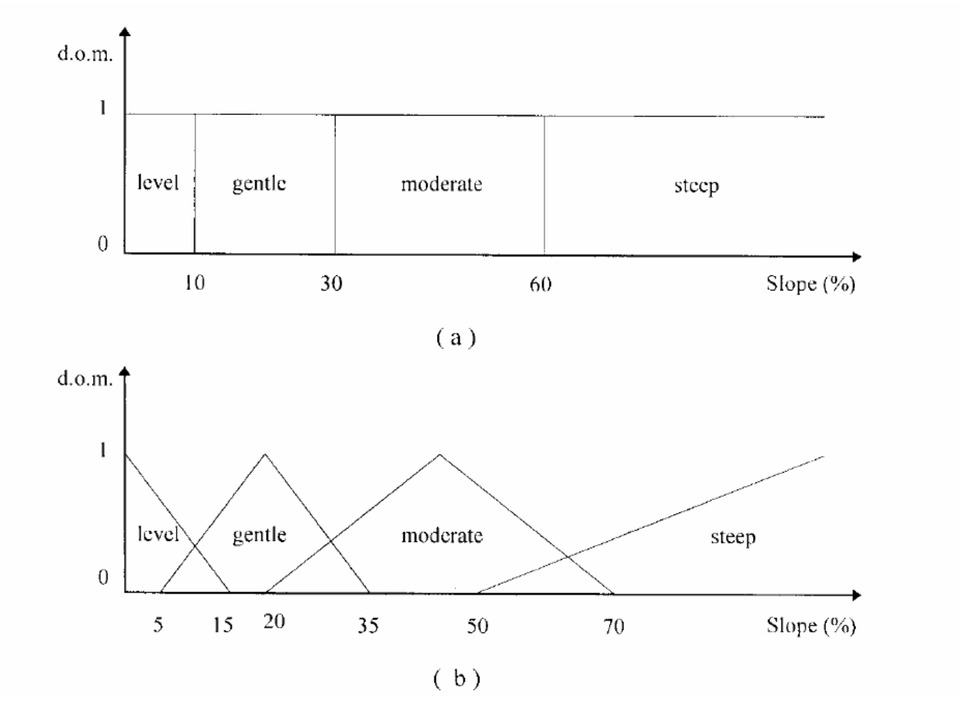

Figure 2.3 An example of the classic (a) and fuzzy (b) classification for ground slope (Stefanakis et al., 1999)

Developing a fuzzy GIS application involves three tasks that are believed to be of crucial importance:

• The selection of an appropriate membership function.

• The selection of a suitable operator to combine fuzzy sets.

• The definition of linguistic hedges to further describe fuzzy sets.

For none of them evaluation methods exist in terms of geographical coherence (Benedikt et al., 2002).

2.3.1 Linguistic Variables & Membership Functions

The fuzzy modeling approaches (including the fuzzy screening methods) are based on the concept of linguistic variable. Linguistic variable is a word or sentence in a natural or artificial language (Kickert, 1978). The significance of linguistic variable is that it facilitates graduate transitions between its states and, consequently, it possesses a natural capability to express and to deal with imprecise and ambiguous statements (Malczewski, 2002).

To illustrate the concept of a linguistic variable, consider an evaluation criterion `distance to a river'. It is a numerical variable that can be measured in kilometers. The variable assumes as a value any number between 0 and 10 km, for example. This is referred to as a universe (or a base variable). In general, the based variable may be measured on the quantitative (e.g. distance) or qualitative scales (e.g. ordered categories of land use). Now consider `distance' as a linguistic variable (Figure 2.4.). This variable can assume the values: `long', `medium', `short', etc. Each of these terms is a linguistic value or linguistic term of the variable. The linguistic term set consists of the linguistic values. A linguistic value is characterized by a label (or syntactic value) and a semantic value (or meaning). The label is a word or sentence belonging to a linguistic term set (e.g. `long') and the meaning is a fuzzy subset defined in a relevant interval, which is described by a membership function (Malczewski, 2002).

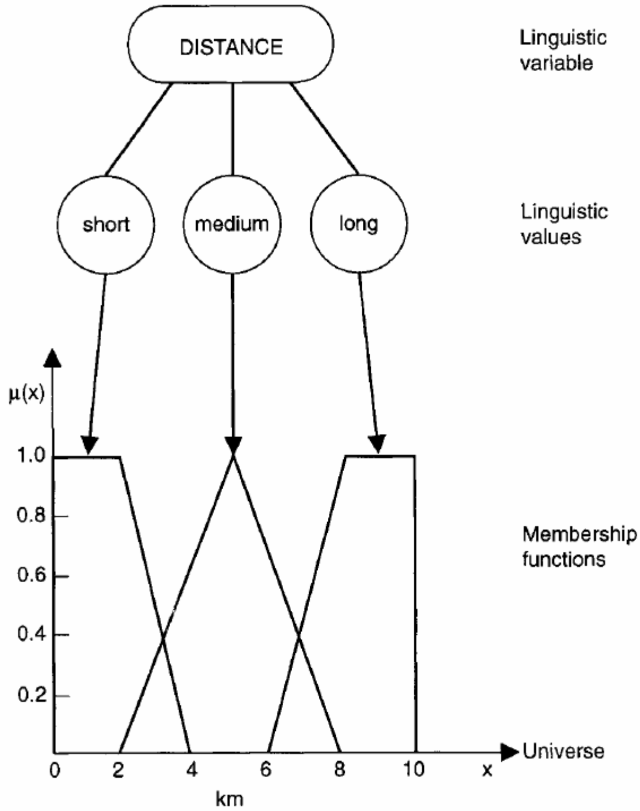

Figure 2.4 The linguistic variable ‘distance’

The concept of linguistic variable is not only based for operationalizing evaluation criterion and preferences, but also for the aggregation procedures in the fuzzy screening methods. There are two main approaches for performing the aggregation of linguistic information. First, the approximation or indirect approach uses the membership functions associated with the linguistic terms. The trapezoidal or triangular membership functions are typically employed to capture the vagueness of the linguistic terms (Eastman, 1997; Munda, 1995). Second, the direct or symbolic approach makes direct use of labels for computing. It is based on the premise that the set of linguistic terms is an ordered structure uniformly distributed on a scale (Malczewski, 2002).

Both the approximation and symbolic approaches involve two basic fuzzy operations: MIN (minimization) and MAX (maximization) operations for aggregation qualitative information. The MIN or intersection operator corresponds to the logical AND. It produces for any given fuzzy sets the largest set from among those produced by all possible fuzzy intersections. This interpretation implies no positive compensation (trade-off) between degree of membership of the fuzzy sets under consideration. It is a non-compensation operator. This means that an alternative is rejected on the basis of poor performance with respect to at least one attribute, even if it performs well above average on other attributes. On the other hand, the fuzzy MAX operation corresponds to the logical OR operation and it generates the smallest fuzzy set among the fuzzy sets produced by all possible fuzzy unions (that is, the union operation is modeled by the fuzzy MAX operator) (Kickert, 1978; Ross, 1995). In aggregation several evaluation criteria the MAX operator generates the maximum degree of membership achieved by any of the fuzzy sets representing evaluation factors. This amounts to a full compensation of lower degrees of membership by the maximum degree of membership. Consequently, it is a fully compensation operator (Malczewski, 2002).

According to (Bagnoli and Smith, 1998), the central idea that differentiates Fuzzy Set Theory from Classic Set Theory is the generalization of the characteristic function so that it can assume values between 0 and 1, not just 0 or 1, depending on the degree of membership of the element in the set. Given the universal set U, a fuzzy set A* can thus be expressed by the equation (2.1)

$$A^* = (x, m_{A^*}(x) | x \in U), \tag{2.1}$$

where $m_{A^*}(x)$ is the membership function that expresses the degree of belonging of the general element x to the fuzzy set A*, assuming the following values (2.2):

$$\begin{gathered} m_{A^*}(x) = 1 \text{ if } x \in A, \\ 0 < m_{A^*}(x) < 1 \text{ if } x \text{ partially belongs to } A, \\ m_{A^*}(x) = 0 \text{ if } x \notin A. \end{gathered} \tag{2.2}$$

Since the membership function is a generalization of the characteristic function, we may define a fuzzy set as a generalization of classic sets.

The choice of the membership function, i.e. its shape and form, is crucial and strongly affects the results derived by a decision-making process (Stefanakis et al., 1999). Figure 2.5. shows the conventional and fuzzy set theory procedures of generating the layer(s) characterizing a theme.

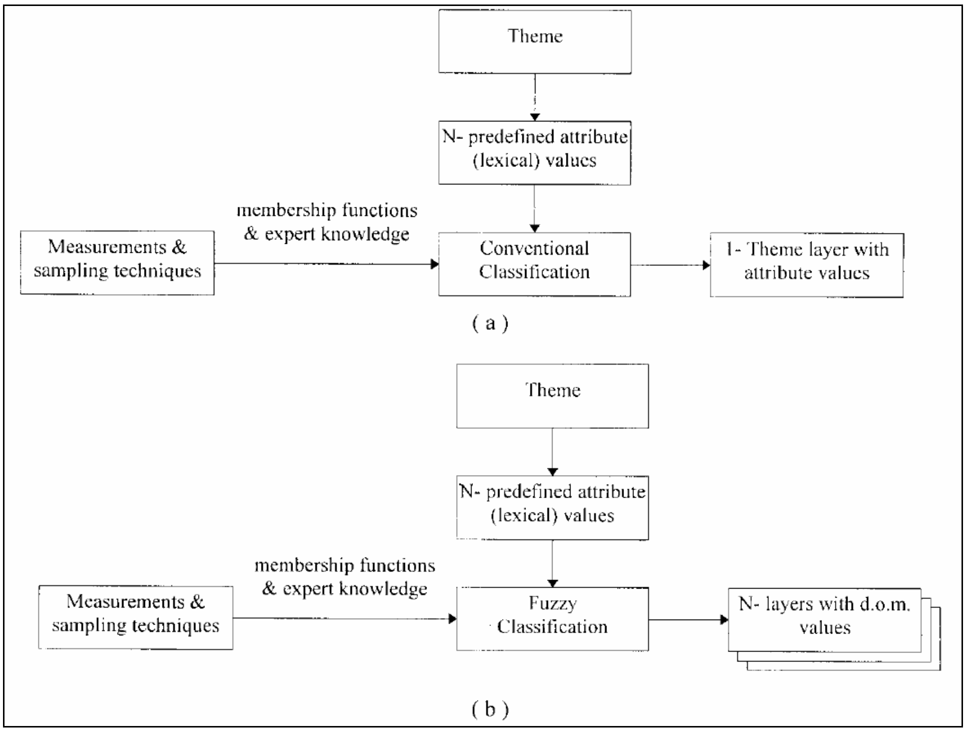

Figure 2.5 Procedure of generating the layer(s) characterizing a theme in conventional (a) and fuzzy (b) set theory (Stefanakis et al. 1999)

Fuzzy logic is based on the way the brain deals with inexact information. Fuzzy systems combine fuzzy sets with fuzzy rules to produce overall complex nonlinear behavior. Fuzzy systems are structured numerical estimators. They start from highly formalized insights about the structure of categories found in the real world and then express fuzzy if-then rules as some expert knowledge. Being numerical model-free estimators and dynamical systems, fuzzy systems are able to improve the intelligence ofsystems working in an uncertain, imprecise, and noisy environment (El-Hawary, 1998).

Therefore, the Theory of Fuzzy Sets and specifically fuzzy logic is highly appropriate to the spatial decision making processes especially to the task of real estate valuation and decision making.

2.4 Site Selection

The value of property reflects its capacity to fulfill a function. With regard to commercial property, functional qualities may include (with examples given in brackets).

- locational influences (accessibility to the market-place, proximity to suppliers of raw materials and important nodes such as railway stations, car parks and open spaces)
- physical attributes (size, shape, age and condition)
- legal factors (lease terms and restrictive covenants)
- planning and economic factors (planning constraints, permitted use and potential for change of use)

Property valuation is the process of identifying and quantifying these ‘value factors’ (Appraisal Institute 1992; Horsley 1992).

When we examine all the factors we see that they are inherently related to each other but the good location is the main factor that affects the value of the property. As a result, the location is the focus of this study.

One of the most useful applications of GIS for planning and management is the land-use suitability mapping and analysis (McHarg, 1969; Hopkins, 1977; Brail and Klosterman, 2001; Collins et al., 2001).

In the context of land suitability analysis it is important to make distinctions between the site selection problem and the site search problem (Cova and Church, 2000). The aim of site selection analysis is to identify the best site for some activity given the set of potential (feasible) sites. In this type of analysis all the characteristics (such as location, size, relevant attributes, etc.) of the candidate sites are known. The problem is to rank or rate the alternative sites based on their characteristics so that the best site can be identified. If there is not a pre-determined set of candidate sites, the problem is referred to as site search analysis. The characteristics of the sites (their boundaries) have to be defined by solving the problem. The aim of the site search analysis is to explicitly identify the boundary of the best site (Malczewski, 2004). GIS have been developed to assist in site selection and location analysis for residential subdivisions (Barnett and Okoruwa 1993).

Site selection process depends on a number of spatial and business related factors, making it a complex decision-making task. It is common for the decision makers to use their subjective judgment and gut feelings based on their experience in selecting the most appropriate site for development. The reason is that data for site selection originate from varied sources and are not organized in a format that decision makers can readily use to derive any meaningful information (Ahmad et al., 2004).

CHAPTER 3

METHODOLOGY

The proposed methodology in determining the locational suitability of settlements is based on the techniques of spatial decision making integrating with the fuzzy set theory. The spatially referred data (input) are processed and transferred into a resultant sitability score (output). Then the results are integrated by the vulnerability results of the same area.

The flowchart that can represent the methodology proposed in this study can be seen in (Figure 3.1)

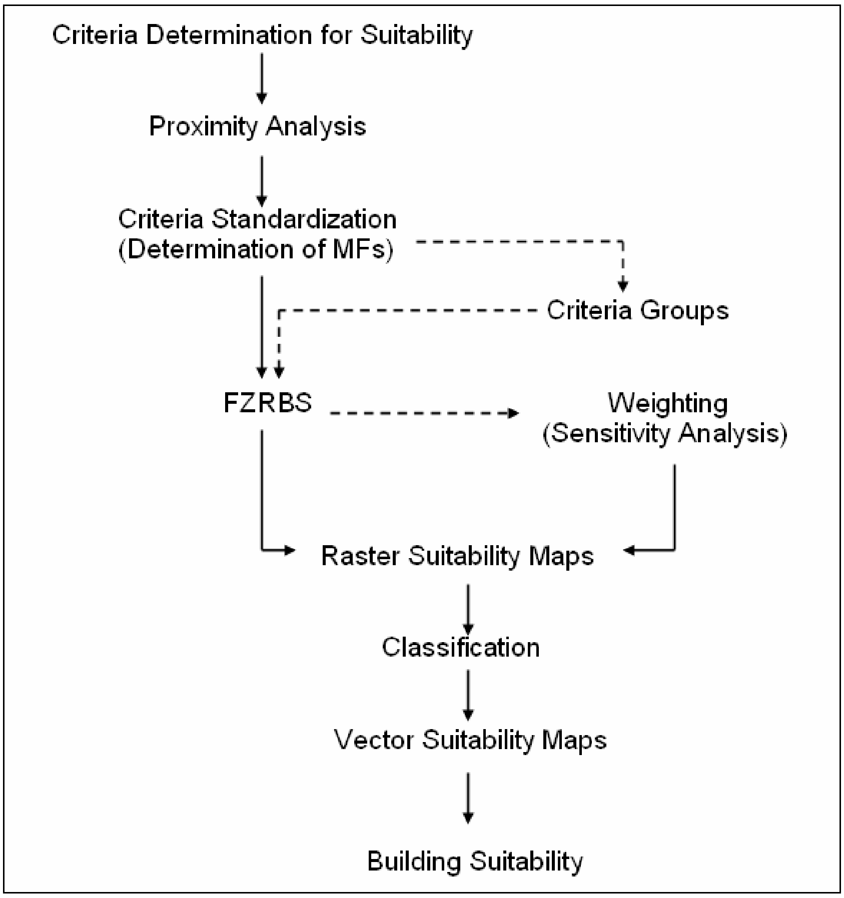

Figure 3.1 Flowchart representing the methodology proposed in the study

3.1 Identifying Evaluation Criteria

Physical and social environment data have to be used for SDM for finding suitable site. The fundamental factors that cover most of the essential needs in suitable site-selection include (Zeng and Zhou, 2001):

Environmental factors: slope and aspect, vegetation, parks and natural reserves, rivers and beaches; floodplain, hazardous sites and other pollution.

Social factors: shops and shopping centers, railway stations, schools, hospitals, theatres, roads, bus stops, railway, power-lines, aeroplane noise, house prices and population data as surveyed by census.

Personal factors: income, place of work, location of relatives' residence, household size, the value of housing loan, and the preferred population group.

In this study, according to special characteristics of the study area and data availability, a simpler version of these factors is used as the main selection criteria:

Physical environment: slope and aspect, parks, river (Porsuk)

Amenity and transport: shops and shopping centers, schools and tramway stations

Pollution and noise: Highway pollution and noise, railway noise

The proposed methodology in the locational suitability GIS is based on the techniques of spatial decision making. The spatially referred data (input) are combined and transferred into a resultant suitability score (output).

3.2 Land-use Suitability Assessment – Site Selection

According to (Malczewski, 2004) the methods for GIS-based land-use suitability analyses are as follows:

- Computer-assisted overlay mapping
- Multi-criteria decision making methods
- Multi-objective methods
- Multi-attribute methods
- Artificial intelligence methods
- Fuzzy logic techniques
- Neural networks
- Evolutionary (genetic) algorithms
- Cellular automata

In this study, the fuzzy logic technique which is a kind of artificial intelligence method is used because of the processing capabilities of fuzzy set theory for the determination of locational suitability.

As it is discussed in the previous chapter, from the point of view of used methodologies the selection of the suitable land-use is a kind of site selection process.

3.3 Standardizing the Criteria

In the GIS context, in decision making regarding land allocation, suitability is considered as a fuzzy concept expressed as fuzzy set membership (Burrough et al., 1992, Hall et al., 1992).

There are a variety of reasons why the application of fuzzy set membership in criteria standardization is highly appealing. First, it provides a very strong logic for the process of standardization. The process of criteria standardization can be seen as one of recasting values into a statement of set membership, the degree of membership in the final decision set. Compared with linear scaling, standardization using fuzzy set membership represents a specific relation between the criterion and decision set. This clearly opens the way for a broader family of set of membership functions than that of linear rescaling. For example, the commonly used sigmoidal function provides a simple logic for cases where a function is required that is asymptotic to 0 and 1. Second, the logic of fuzzy sets bridges a major gap between Boolean assessment and continuous scaling in weighted linear combination. Boolean overlay is a classical set problem and assumes a crisp boundary and certainty. By considering the process of criteria evaluation as one of fuzzy sets, the continuity and uncertainty in the relation between criteria and decision set are recognized. When set membership values are reduced to 0 and 1 (i.e. certainty), the set becomes crisp (a special case of fuzzy set) and the results will be identical to those of Boolean overlay (Jiang and Eastman, 2000).

In order to realize the standardization of the criteria using the membership functions and the fuzzy processing capabilities in the analysis “FuzzyCell” designed by Yanar and Akyürek (2006) is used.

Three equations (3.1 – 3.3) defined by Zeng and Zhou (2001) are used for representing the membership functions. The membership functions of the criterias are "linear" (3.1), "s" (3.2), and "logarithm" (3.3).

$$\mu_F(x) = \begin{cases} 1 & 0 \leqslant x \leqslant a \\ \dfrac{b-x}{b-a} & a < x \leqslant b \\ 0 & b < x \end{cases} \tag{3.1}$$

$$\mu_F(x) = \begin{cases} 1 & 0 \leqslant x \leqslant a \\ \dfrac{1}{2} - \dfrac{1}{2}\sin\left(\dfrac{\pi}{b-a}\right)\left(x - \dfrac{a+b}{2}\right) & a < x \leqslant b \\ 0 & b < x \end{cases} \tag{3.2}$$

$$\mu_F(x) = \begin{cases} 0 & 0 \leqslant x \leqslant 60 \\ Ln(kx^2) - 60 & 60 < x \leqslant 200 \\ 1 & 200 < x \end{cases} \tag{3.3}$$

Each criteria used in the study is represented by one of the functiions expressed above.

3.4 FuzzyCell

The capability of fuzzy sets to express gradual transitions from membership to nonmembership, and vice versa, has a broad utility not only for representing geographical entities with imprecise boundaries but also for GIS-based operations and analysis, including spatial decision analysis (Malczewski, 1999).

The introduction of Fuzzy Logic to GIS Software enables the user to model aspects of vagueness and ambiguity in linguistic categories (Benedikt et all. 2002).

In this study, the main aim is to select suitable sites for settlements and at this point the dominating argument is expressed as the 'good location'. However, the concept of good is not clearly defined and therefore the fuzzy set approach is used to codify experts' knowledge and the user's preference of good location. The FZ approach for site selection for settlements has two aspects. One is to handle the fuzziness in the spatial distribution of a physical or social factor (fuzzy boundary) and the other is to handle fuzziness in queries with a RBS (fuzzy inference) (Zeng and Zhou, 2001). Finally, in this study Fuzzycell is the tool for achieving our goal.

A fuzzy rule-based, expert like system for cell-based GIS analyses can be designed by setting up linguistic variables, defining fuzzy rules and specifying fuzzy model properties (i.e., selecting inference and aggregation methods, conjunction and disjunction operators and defuzzification method) using the interfaces of FuzzyCell (Yanar and Akyürek, 2006).

Figure 3.2. represents the general architecture design and workflow of the fuzzy inference system for cell-based information modeling.

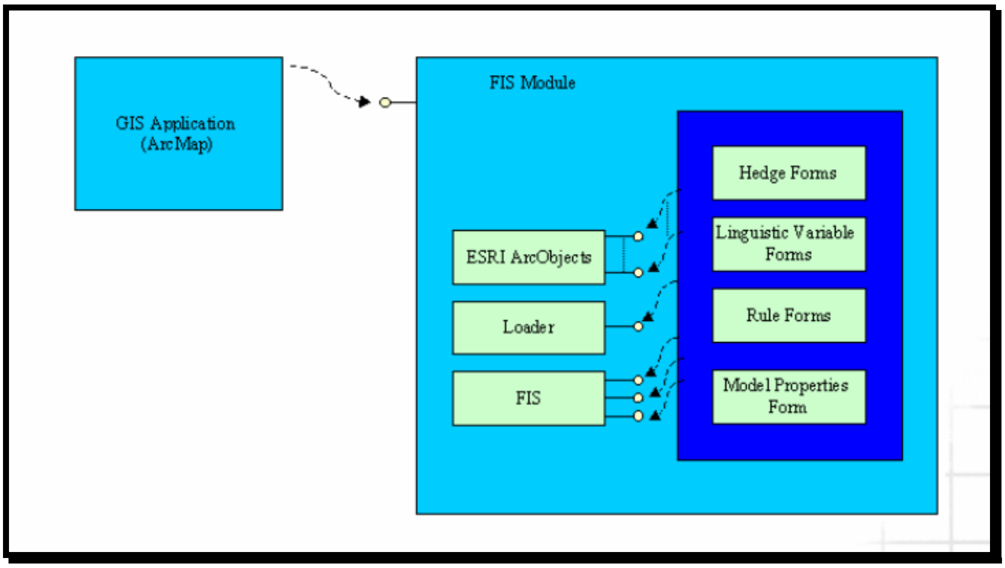

Figure 3.2 Architectural design and workflow of fuzzy inference system for GIS (Yanar and Akyürek, 2006).

The implementation of the fuzzy inference system tool for ArcMap is divided into two parts (Yanar and Akyürek, 2006):

(1) Fuzzy Inference Engine implementation(Figure 3.3.),

(2) Fuzzy Inference System Module implementation(Figure 3.4.).

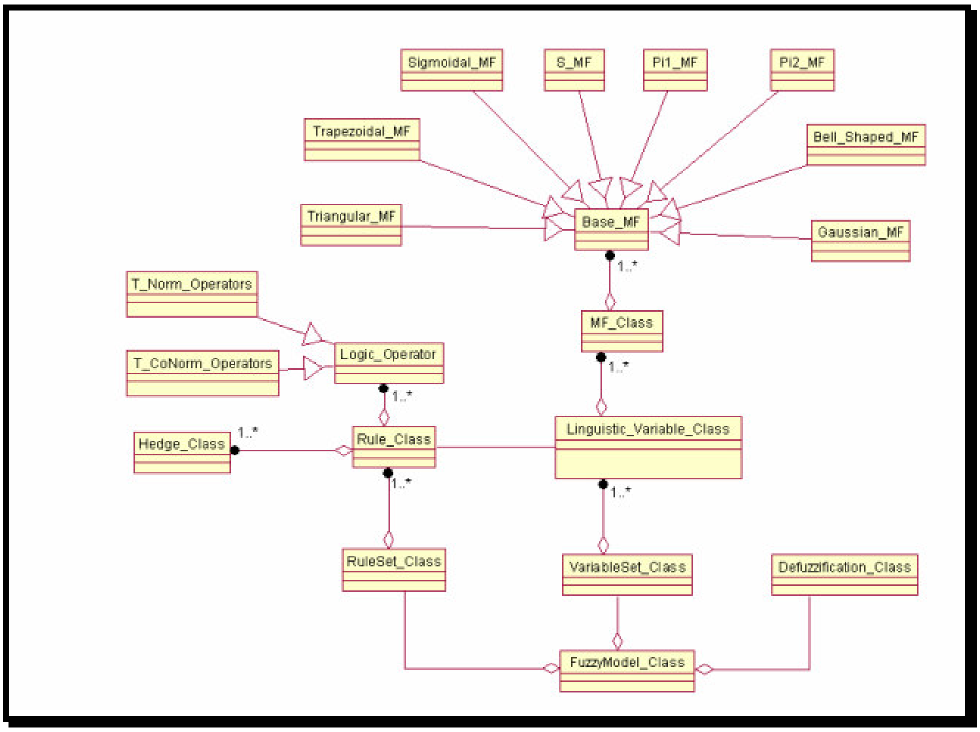

Figure 3.3 Design of Fuzzy Inference Engine (Yanar, 2003)

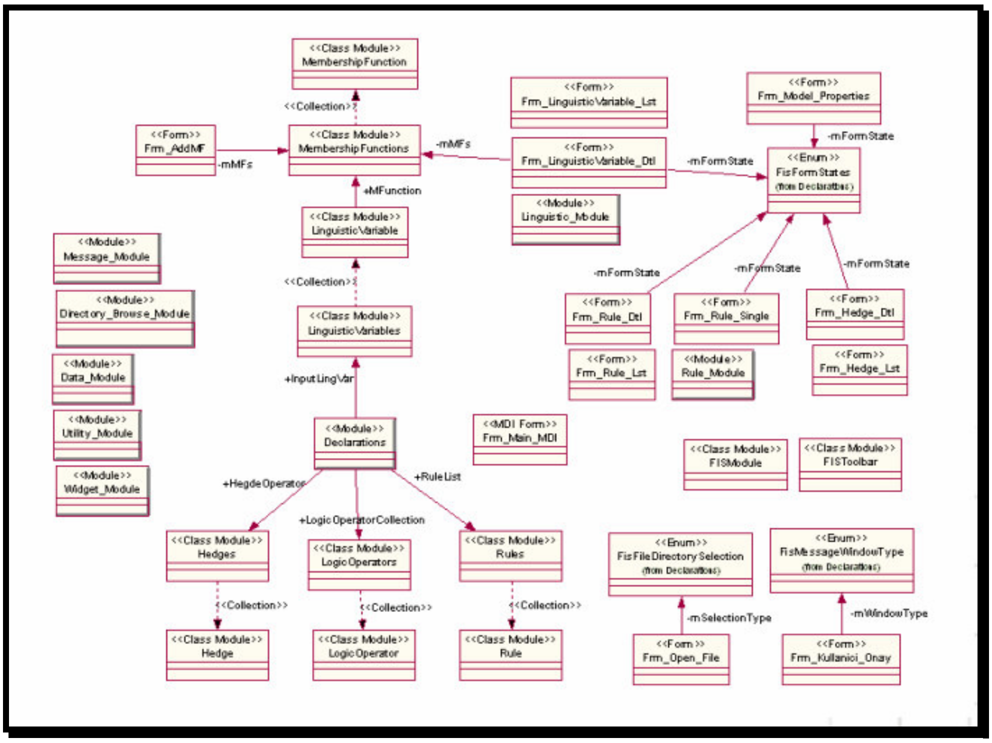

Figure 3.4 Design of Fuzzy Inference System Module (Yanar, 2003)

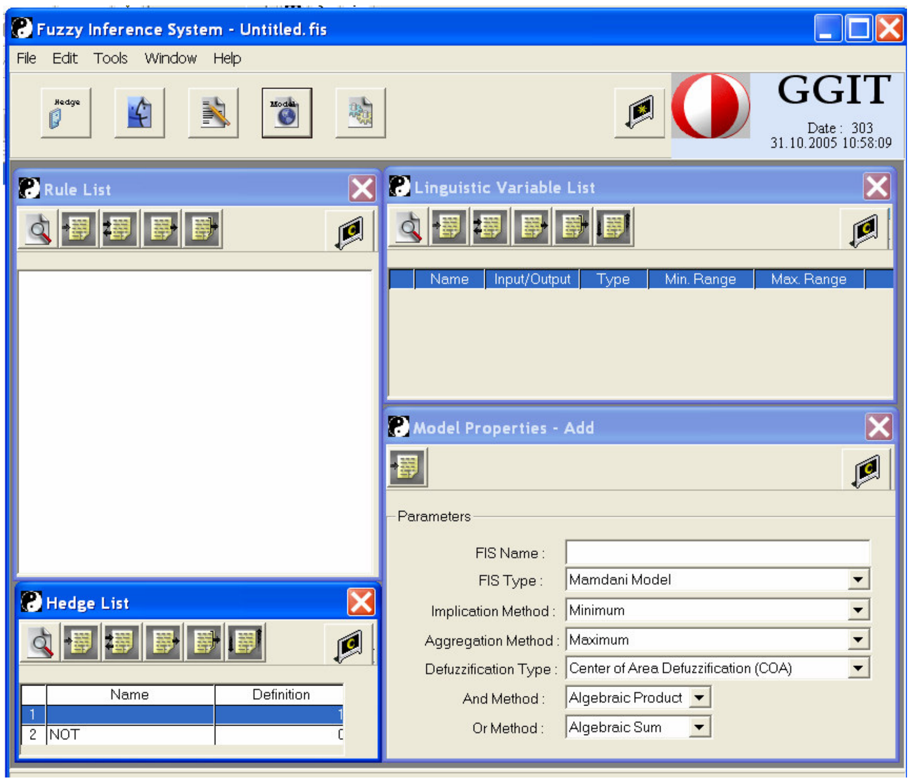

Figure 3.5 The Interface of the FuzzyCell (Yanar and Akyürek, 2006)

The Rule List, Hedge List, Linguistic Variable List, and the Model Properties windows from the interface of the FuzzyCell are seen in the Figure 3.5.

3.5 Fuzzy Rule Based system (FZRBS)

A fuzzy rule-based system (FRBS) is a RBS with a collection of fuzzy membership functions and rules that are used to reason about data (Zimmermann, 1991; Terano *et al*., 1992, Bezdek 1992, Kasabov 1996, Chen 1996, Zeng and Zhou, 2001).

The FZRBS for locational suitability of settlements is established in four main steps (Zeng and Zhou, 2001):

(*i*) define a rule system and its properties.

The rule system R is the set of rules.

If $A_{i,1}$ O $A_{i,2}$ O ... O $A_{ik-s,1}$ then $B_{i,s}$ for i=1,...,n

where O means AND, $A_{i,k-s}$ are fuzzy subsets of X_k and B_{i-s} are fuzzy subsets of Y.

The FRBS contains a set of rules, for example:

'IF the SLOPE is good OR excellent AND the ASPECT is good
AND it is close to school AND it is not too close to the main road
AND it is not very close to airport and not under the fly path
THEN it has an excellent location'

The suitability of a property is determinated by using a decision tree

(*ii*) State the necessary and sufficient conditions for a set of rules to encompass all possible 'if... then...' statements and put them into a fuzzy relation matrix,

(*iii*) select a resulting membership function, and

(*iv*) deffuzify.

Through these 4 steps of the fuzzy rule-based system, the suitable areas are obtained. Here all (9) criterias are executed together at the same time apart from the method used in the sensitivity analysis. After the suitable areas are gathered they are divided into five suitability groups by equal intervals.

3.6 Sensitivity Analysis

In decision making, it is usually the case that different attributes under consideration do not have the same level of importance (Nath et al., 2000).

Sensitivity analysis are employed as a means for achieving a deeper understanding of the structure of the problem by changing the inputs e.g. data, solver or evaluation model. This helps to learn how the various decision elements interact and allows the decision makers to determine the best solution (Gao et al., 2004).

Many methods are developed, such as Maximum likelihood, Chi-Square Test, Kolmogrov-Smirnov Test, and Weighting (Zeng and Zhou, 2001). In this study the weighting is selected as the sensitivity analysis method. Specifically to the locational suitability of settlements, the selected method is applied by the creation of different scenarios according to the different interest groups. Because the different age and work groups are the main determinants of the buyer profile in this study, the suitability of the sites also differs according to them.

The weighting function is defined as (Zeng and Zhou, 2001):

$$W = \sum_{i=1}^{n} w_i k_i \qquad (i = 1,\ 2,\ 3,\ ...,\ n;\ \sum w_i = 1)$$

where k is a factor, w is the weight, and i denotes the factor number.

Sensitivity analyses are applied to the three main groups (Physical Environment, Amenity & Transport, and Pollution and Noise) of the study explained in the first part of the chapter. Because the criteria are directly related to each other in the groups, they are assessed in the same weight category.

The scenarios produced by (Zeng and Zhou, 2001) are also used in this study. They are as follows:

(a) ‘No noise and pollution’ is a little more important than physical environment and amenity.

(b) ‘Amenity’ is most important. This case is more appropriate for a young family as they have a very busy routine. It shows that there are more areas to be selected.

(c) ‘Good physical environment’ and ‘no noise and pollution’ are preferred. This case may be preferred by retired people as most want a more relaxing environment. There are less areas to be chosen.

(d) ‘Good physical environment’ has a high priority with less concern about ‘noise and pollution’.

3.7 Classification

Classification is defined as identification of a set of features as belonging to a group (Aronoff, 1989). In the classical sense in order to test for belonging to a group, each group is separated from other groups with sharply defined intervals. For example, in a raster based GIS, a cell is assigned to a group if value of the cell is between the values describing that group. However, it is very difficult to work with vague concepts, which are easily comprehended by humans (Yanar and Akyürek, 2006).

Five different suitability maps are obtained after the analysis. First map is obtained by the FZRBS (Fuzzy Rule-Based System) method and the others are the results of the sensitivity analysis. Then each map representing the suitable sites is classified into 5 groups according to their suitability values. This is achieved by the cell values that are changing 0 to 100 and they are grouped as 0-20, 20,1-40, 40,1-60, 60,1-80, and 80,1-100.

CHAPTER 4

CASE STUDY: Odunpazarı-Eskişehir

4.1 Study Area and Data

4.1.1 Study Area

Eskişehir-Odunpazarı district is chosen as the study area to examine the proposed methodology. Because, Eskişehir is a developing city with its growing industry and trade. In addition, with its two universities that brings many students by the way many people to the city it has an active real-estate market and also it situated in the second degree fault zone that is important from the point of view of real estate selection.

Eskişehir is located on north-west of center Anatolia and it is surrounded by Afyon from south, Konya from south-east, Ankara from east and north-east, Bolu from north-west, Bilecik and Kütahya from west (Figure 4.1). It has an area about 13 652 sq kilometers.

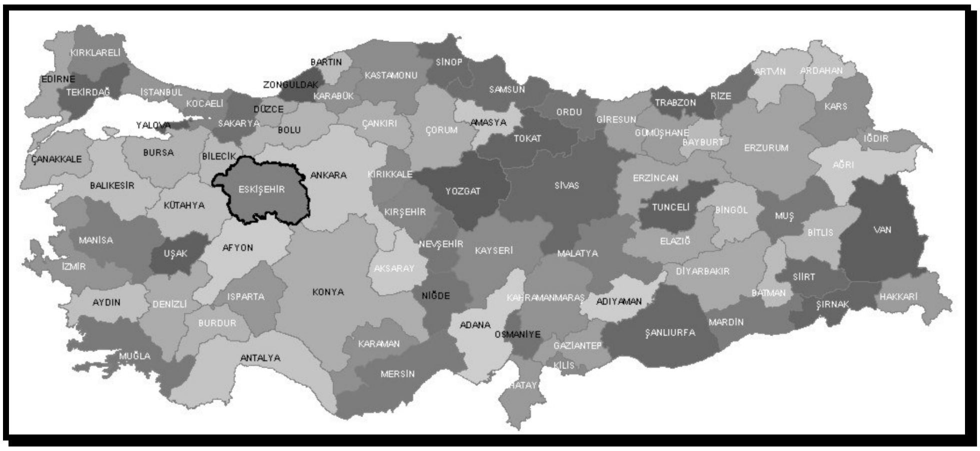

Figure 4.1 Location of Eskişehir in Turkey

Eskişehir's population is 706 009 according to the 2000 census data. There is an increase in the population between 1990 and 2000 (Figure 4.2). Nearly 80% of this population lives in urban areas.

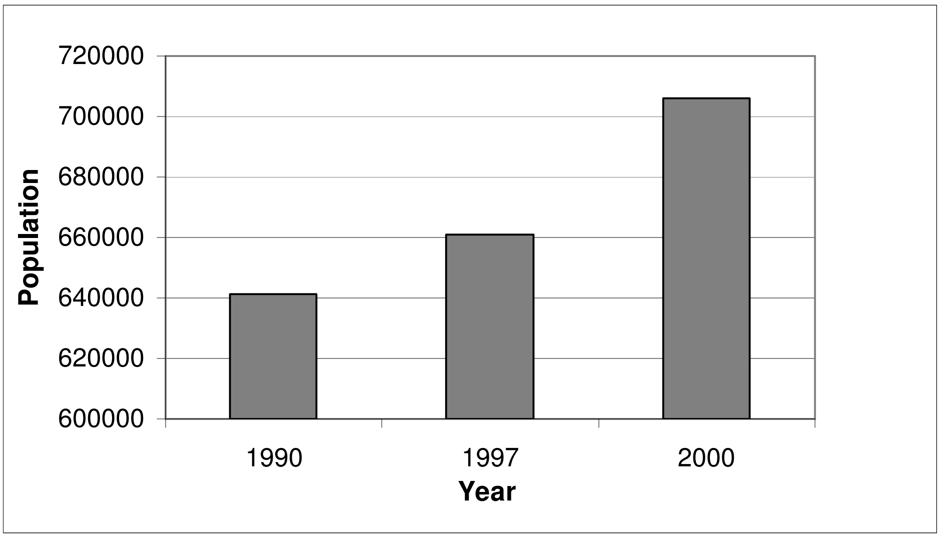

Figure 4.2 Eskişehir's population between 1990 and 2000

Eskişehir has 32 municipalities. Two of them named Tepebaşı and Odunpazarı are the districts of Eskişehir and also builds up the Greater Municipality. Odunpazarı is settled on the second-degree earthquake zone.

The population of Odunpazarı is about 274 000 according to data from the 2000 census and also there are nearly 28 000 buildings in Odunpazarı.

4.1.2 Urban Data

I-Raw Data

In this study many types of data were collected from different sources that can be named as *raw data.* The description of the *raw data* can be seen in Table 4.1.

Table 4.1 The description of raw data of Eskişehir

DATA	LOCATION	SOURCE
Topography Map	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Odunpazarı buildings and their physical structure database (Building type, Condition, Number of Storey, Age etc..)	Odunpazarı Municipality area	Eskişehir Greater Municipality.
Public buildings location and usage (Health center, hospital, police station, pharmacy, school etc..)	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Shop and Shopping Centers	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Hospitals capacity	Eskişehir Greater Municipality area	General Directorite of Civil Defense
Schools	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Road map of Eskişehir city center	Eskişehir Greater Municipality area	Eskişehir Greater Municipality
Ikonos satelite images of Eskişehir (about 770 ha)	Part of Eskişehir Greater Municipality area	Eskişehir Greater Municipality
Parks and Green Areas	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Railways in the city	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
Tramway and its stations	Eskişehir Greater Municipality area	Eskişehir Greater Municipality.
River(Porsuk) areas	Eskişehir Greater Municipality area	Eskişehir Greater Municipality

II- Processed Data

Raw data were processed in order to be used in the study. After that process, different types of data were obtained. They can be classified as:

- Graphical data
- Tabular data
- Prepared data (both tabular and graphical)

Graphical data are digital map layers about Odunpazarı. Graphic data are stored in ArcGIS Geodatabase format. Database file name is *Eskisehir.mdb* and it includes graphic and non-graphic data. The data stored in the database are composed of Parks, River (Porsuk), Tramway Stations, Railway, Highways, Markets. Schools in Odunpazarı. Each layer is stored in a different database table. In addition to these, there is topography data which is in raster format and stored separately in *topography.rrd* file.

All the data are projected in GCS_European_1950 projection system.

Parks is the first database table which includes parks and green areas geometry (the vector objects). They are stored as polygon object.

River (named Porsuk) is the second database table which includes the rivers and its branches areas geometry (the vector objects). They are also stored as polygon object.

Slope (Figure 4.5) is the third criterion which is obtained after processing the topography data (Figure 4.3). ***Topography*** is a kind of raster graphic-data composed of pixels and the value of the pixels changes between 763 and 1059 which represents the height in meters. In Figures 4.4 and 4.6 the histogram of the topography and the slope maps are represented.

For slope values (raster object) of each pixel of the study area, Surface Analysis – Slope function of the 3D Analyst module is used. The output cell size defined as 10 meters and the pixel values changes from 0 to 90% as a result.

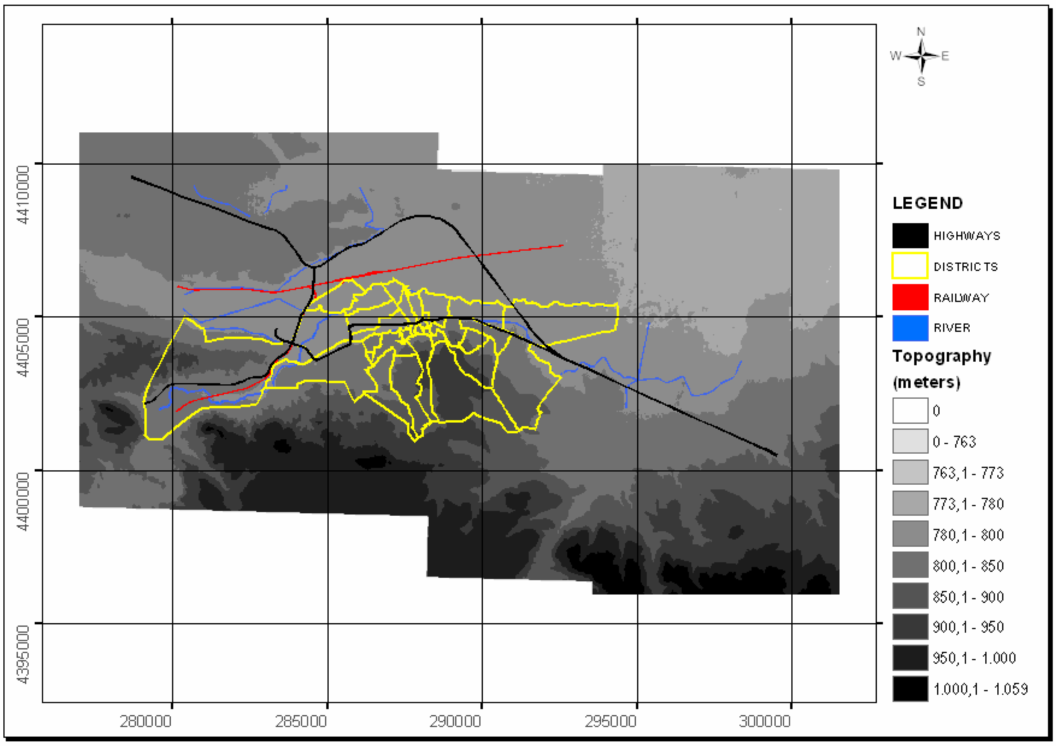

Figure 4.3 Topography map of the study area.

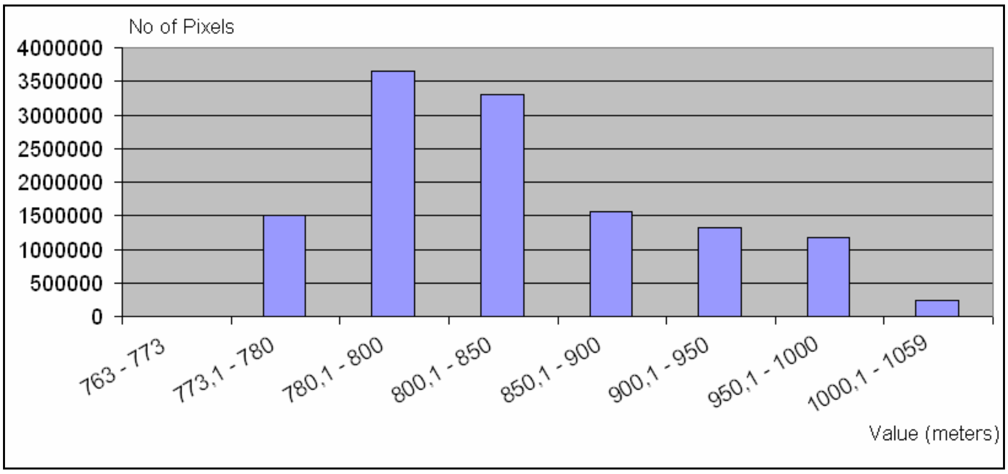

Figure 4.4 Histogram of the topography map

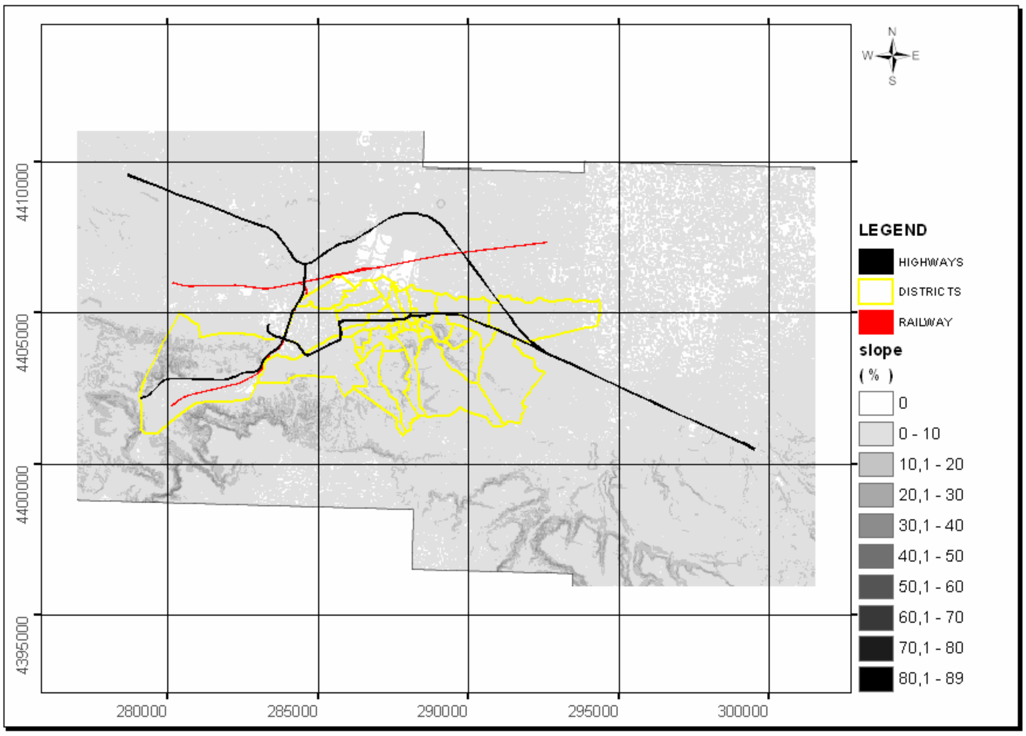

Figure 4.5 Slope map of the study area.

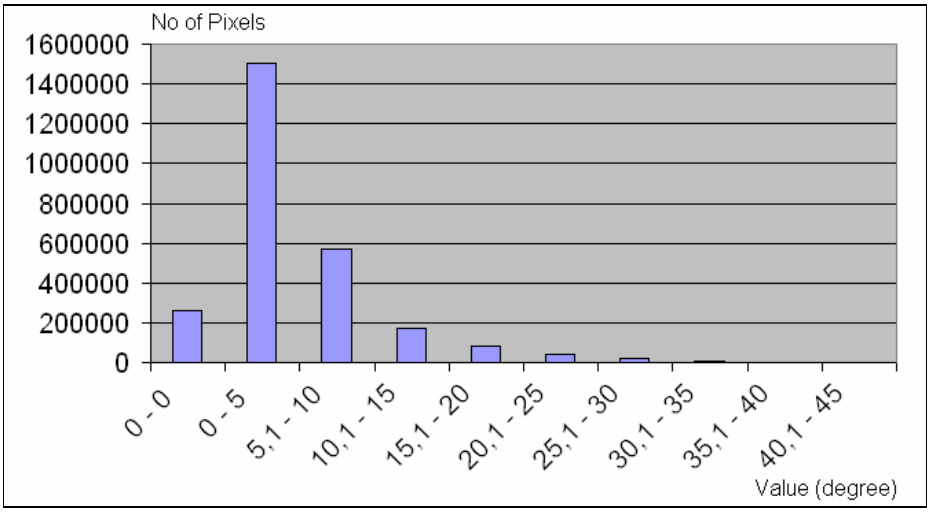

Figure 4.6 Histogram of the slope map

Aspect is the fourth criteria (Figure 4.7) which is again obtained after processing the topography map (Figure 4.3). The histogram of the aspect data can be seen in Figure 4.8.

For aspect map (raster objects) of the area, Surface Analysis – Aspect function of the 3D Analyst module is used. The output cell size for aspect defined as 10 meters, too. The aspect values of the pixels changes from 0 to 360.

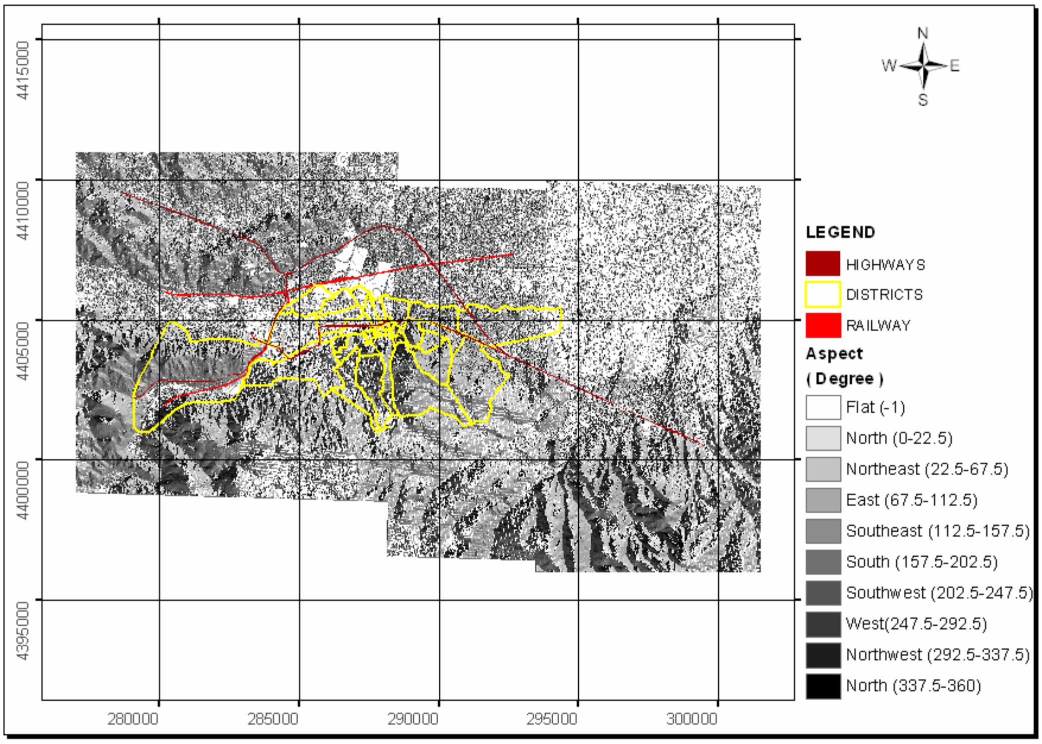

Figure 4.7 Aspect map of the study area.

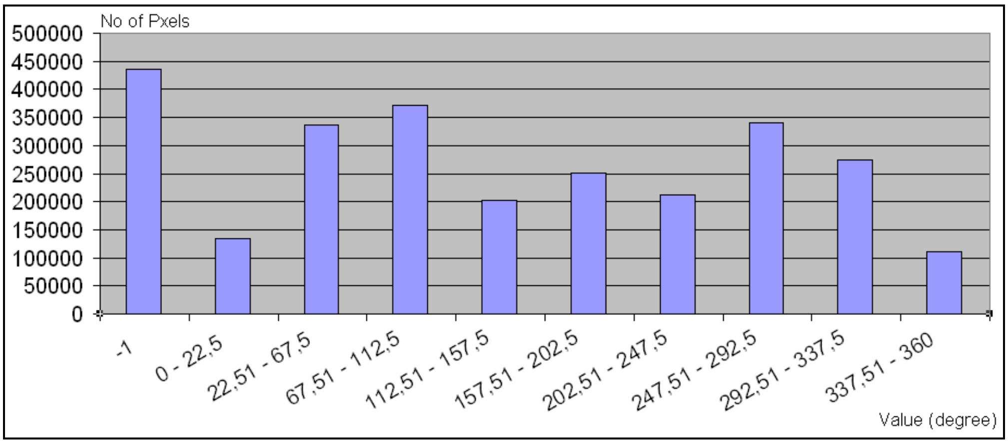

Figure 4.8 Histogram of the aspect map

Schools is the fifth database table which represents 158 schools (the vector objects) in Eskişehir including the all primary, elementary schools. They are stored as point object (Figure 4.10).

Markets, which includes the 11 markets and shopping centers geometry (the vector objects) is the sixth database table. They are also stored as point object (Figure 4.10).

TramwaySt including the 86 tramway stations in Eskişehir as point vector object forms the seventh database table (Figure 4.10).

Highways is the eighth database table including the main roads with heavy traffic. They are also vector objects as polygon features (Figure 4.10).

Railway is also the polygon features representing the vector objects which represent the railway path in Eskişehir (Figure 4.10).

The seven criteria can be seen in Figure 4.10. and also slope, and aspect criteria are processed for the determination of the site suitability. Apart from these criteria, “BUILDING” is the last table that is not processed for the analysis but used for the evaluation of the existing buildings (Figure 4.9) in Eskişehir from the point of view of suitability and vulnerability. It includes building geometry (the vector objects) stored as polygon object. There are 27 904 building objects in this table.

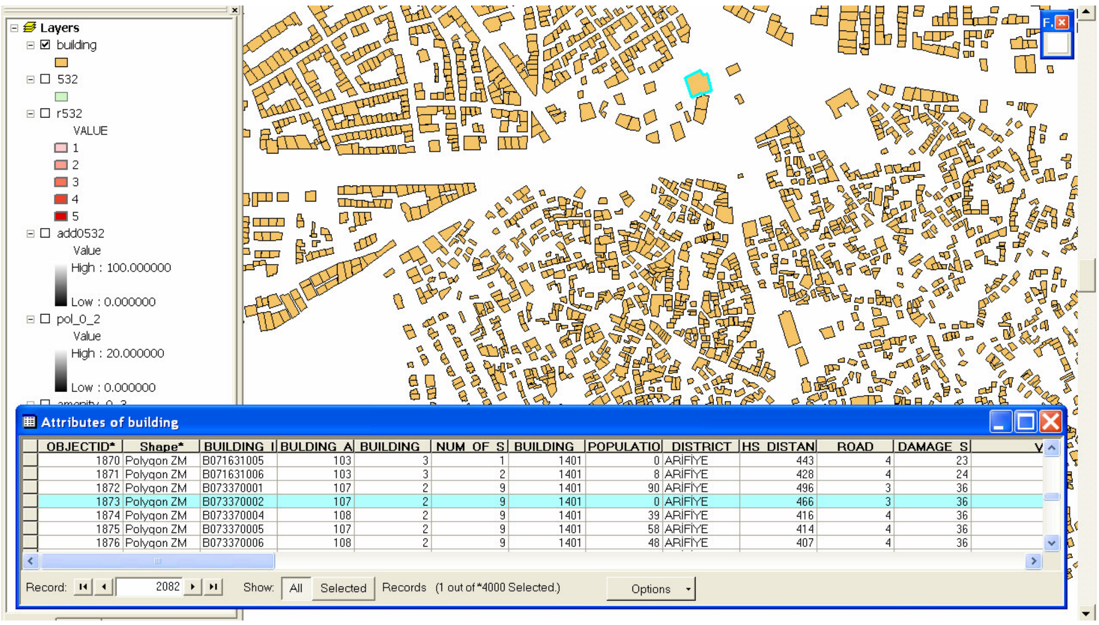

Figure 4.9 Graphic data of “BUILDING” table

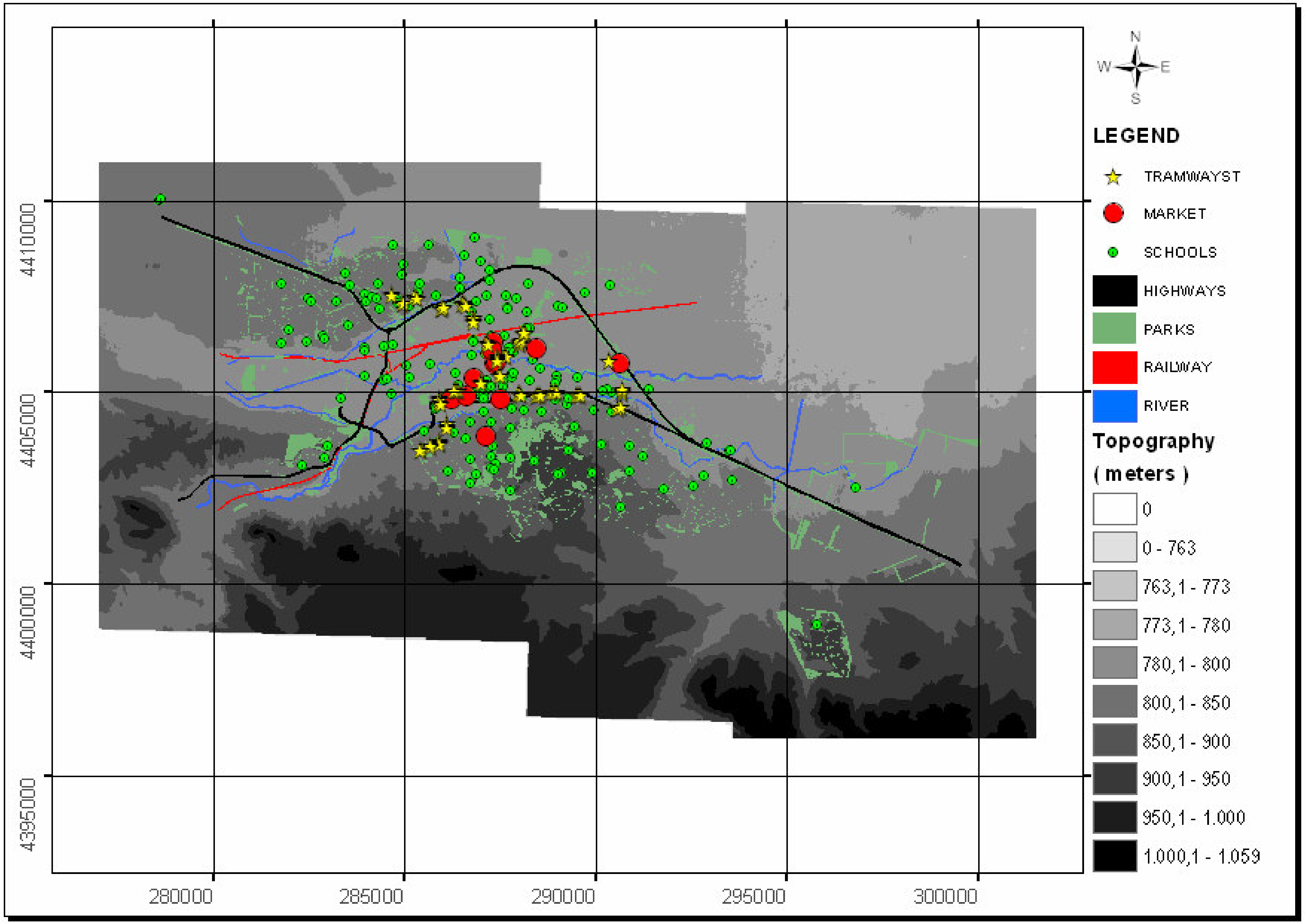

Figure 4.10 The seven of the criteria (topography map below) used in the study except for the slope and the aspect.

The “BUILDING” table (Table 4.2) also includes 17 columns. Some column values of the “BUILDING” table come from the “Code Tables” such as “BUILDING_AGE”, BUILDING_CONDITION”, “BUILDING_TYPE”, “NUMBEROFSTOREY”, and “ROAD_CODE”. They include look-up values coming from membership functions of the study (Servi, 2004). Also their tabular structures are given in Tables 4.3 - 4.7.

Table 4.2 BUILDING table structure

COLUMN NAME	COLUMN INFO	DATA SOURCE
BUILDING_ID	ID number of Buildings	CV
BUILDING_AGE	Construction Date Period	CT
BUILDING_TYPE	Structure Type	CT
NUM_OF_STOREY	Number Of Storeys	CT
BUILDING_COND	Building Condition	CT
POPULATION	Population of Building	CV
NEIGHBOURHOOD	Name of Neighbourhood	CV
HS_DISTANCE	Distance of Nearest Health Center	CV
ROAD	Type of Service Road	CT
SOIL STRUCTURE	Soil Structure Type of Building	CV
SUITABILTY	Suitability degree after site selection process	CV
VUL_SRAS1	Vulnerability value according to the earthquake scenario 1 (Servi,2004)	CV
VUL_SRAS3	Vulnerability value according to the earthquake scenario 3 (Servi,2004)	CV
MERKEZX	Center X Coordinate of Building	CV
MERKEZY	Center Y Coordinate of Building	CV
Shape_Length	Arcgis Geodatabase Column	CV
Shape_area	Arcgis Geodatabase Column	CV

**CV: Column Value, CT: Coming from Code Table*

Table 4.3 BUILDING_AGE table structure (Servi, 2004)

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
AGE	Age of Building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4.4 BUILDING_CONDITION table structure (Servi, 2004)

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
CONDITION	Building Condition
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4.5 BUILDING_TYPE table structure (Servi, 2004)

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
TYPE	Type of Building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4.6 NUMBEROFSTOREY table structure (Servi, 2004)

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table. Also referring number of storey of building
VALUE	Membership Functions Value which is coming from membership degree charts

Table 4.7 ROAD_CODE table structure (Servi, 2004)

COLUMN NAME	COLUMN INFO
CODE	Look-Up Code which is used in BUILDING table
TYPE	Type of Road
VALUE	Membership Functions Value which is coming from membership degree charts

4.2 Proximity Analysis

The FuzzCell is a raster-based software so in order to execute analysis on it, the data used must be in raster format. The slope and the aspect criteria are in raster format but the other seven criteria are in vector format. For both purposes which of first is to get the data in raster format and the second is to get suitable data for the site selection analysis. It is used Distance – Straight Line function of the Spatial Analyst module of Arcgis for getting the proximity values of study area for all the criteria except for the slope and the aspect. The Figures 4.11 – 4.17 show the proximity maps of the study area.

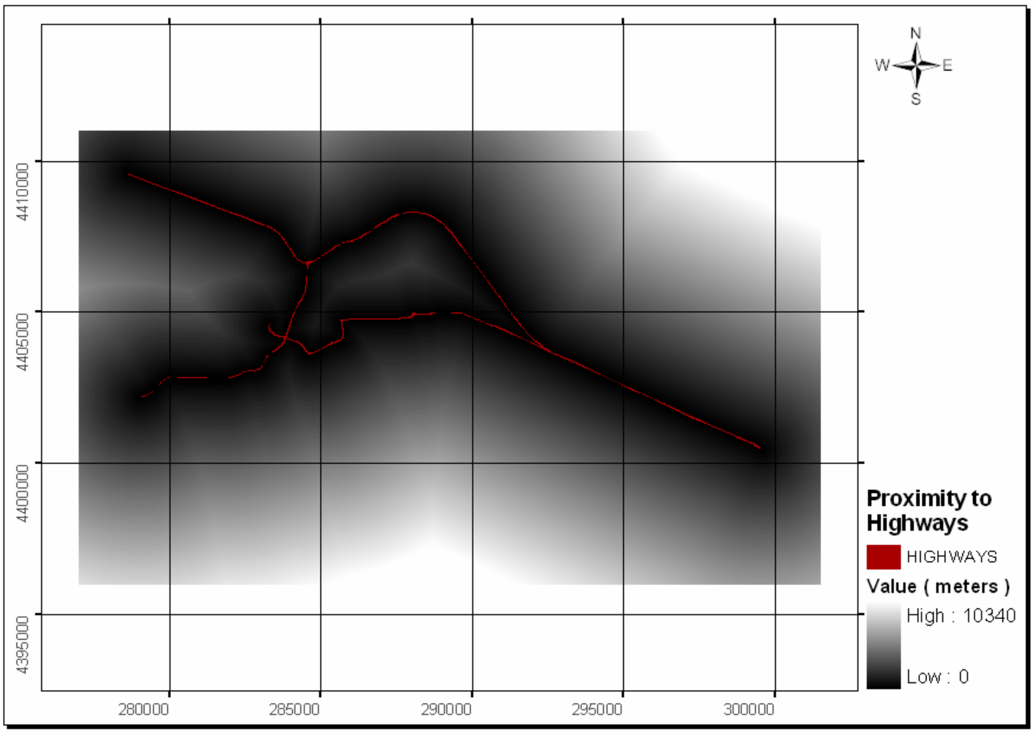

Figure 4.11 Proximity to Highways

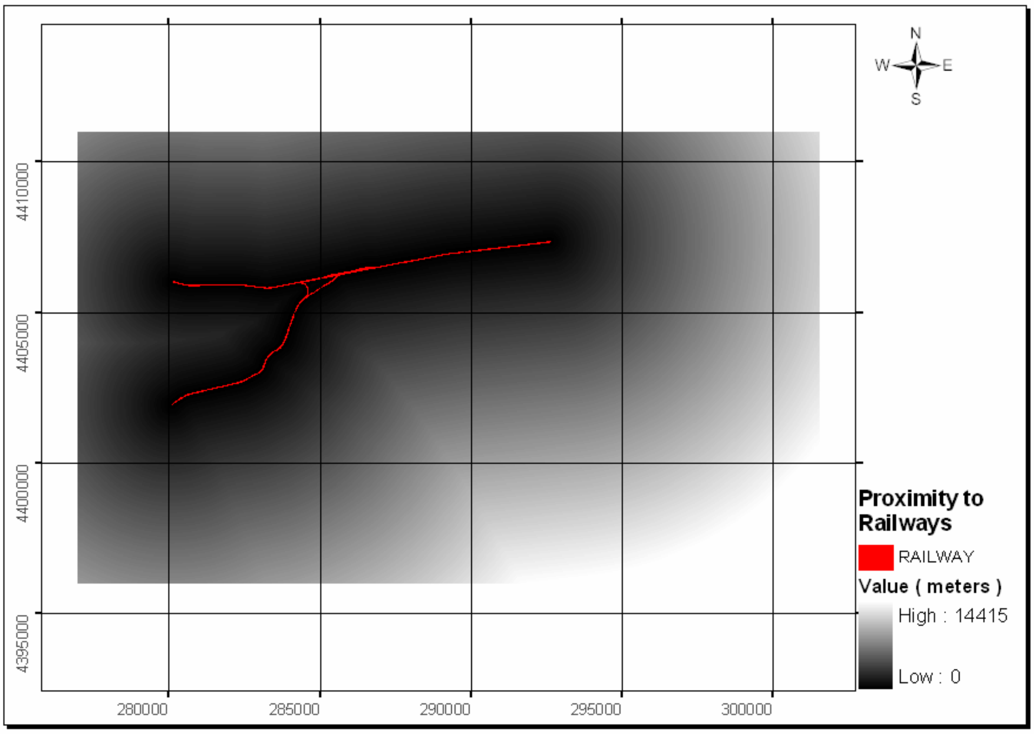

Figure 4.12 Proximity to Railways

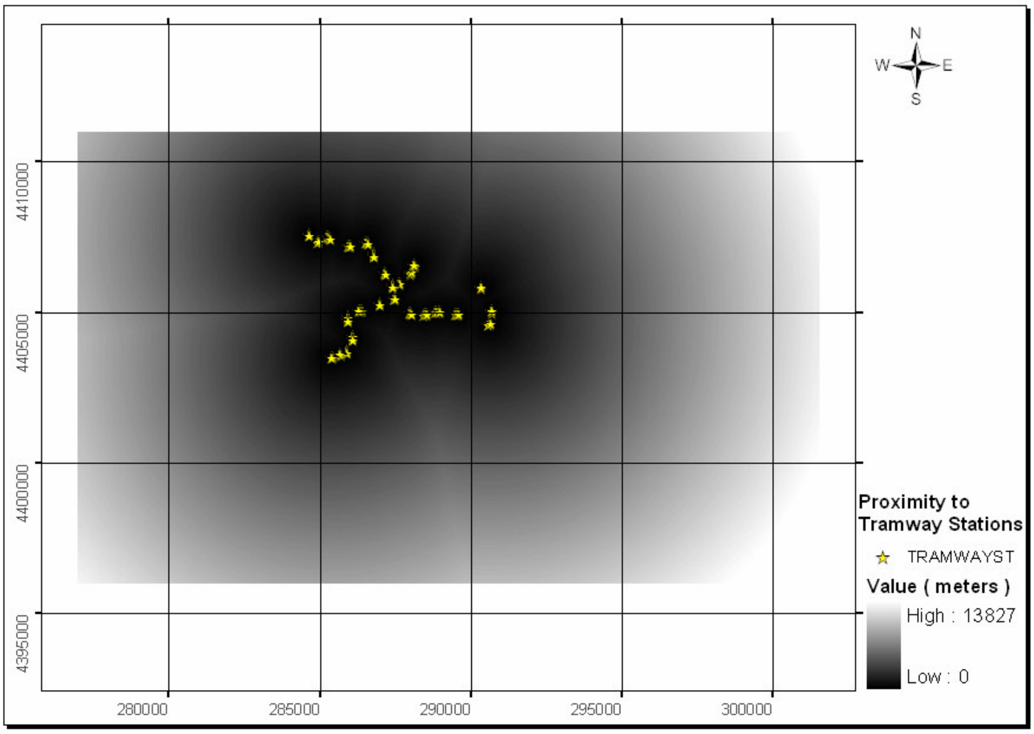

Figure 4.13 Proximity to Tramway Stations

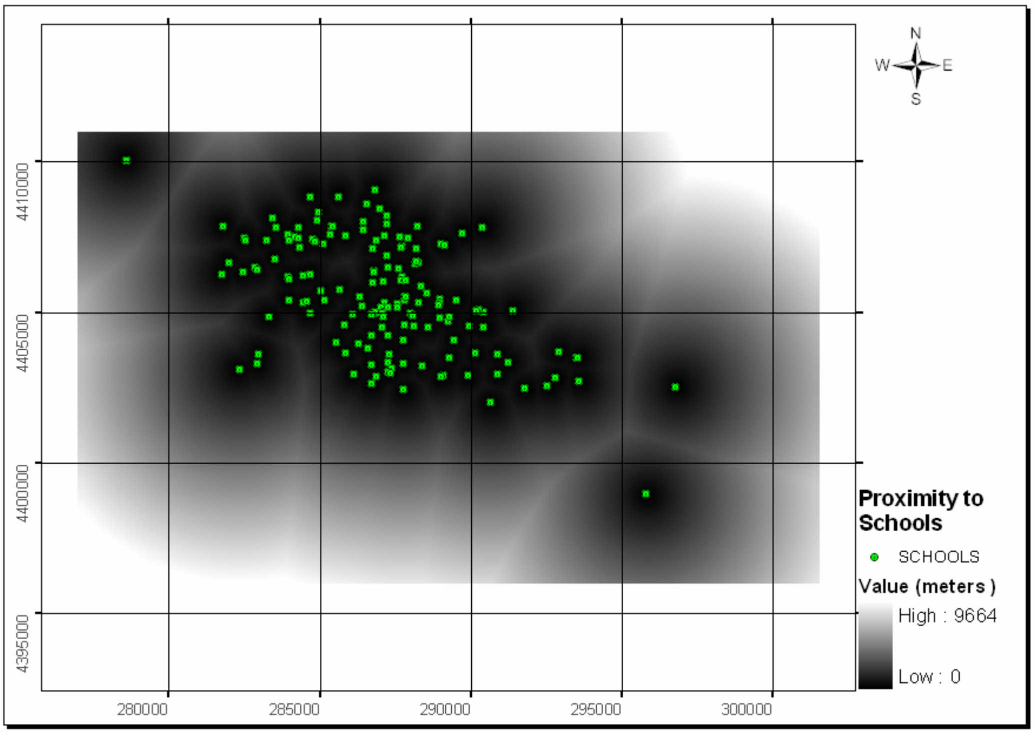

Figure 4.14 Proximity to Schools

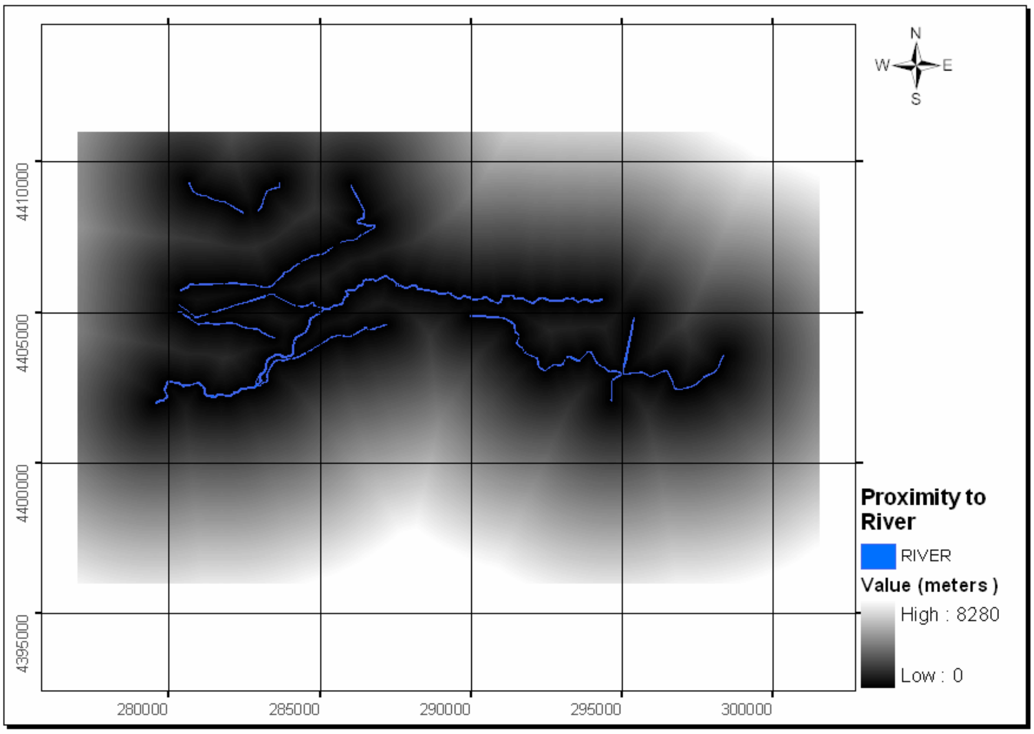

Figure 4.15 Proximity to River

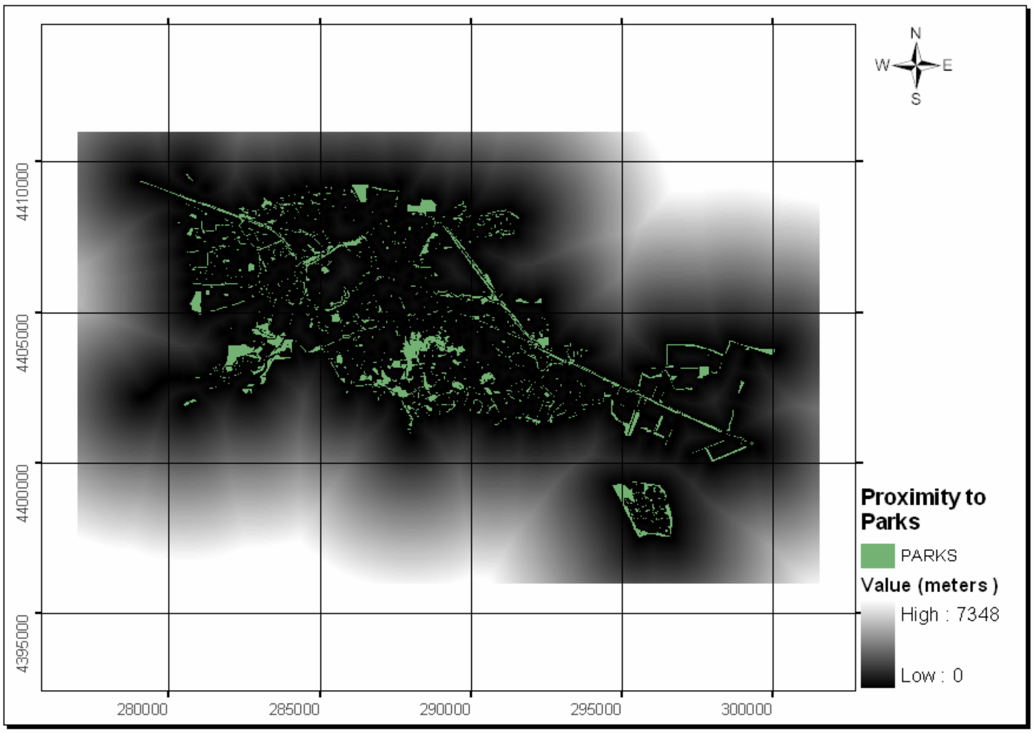

Figure 4.16 Proximity to Parks

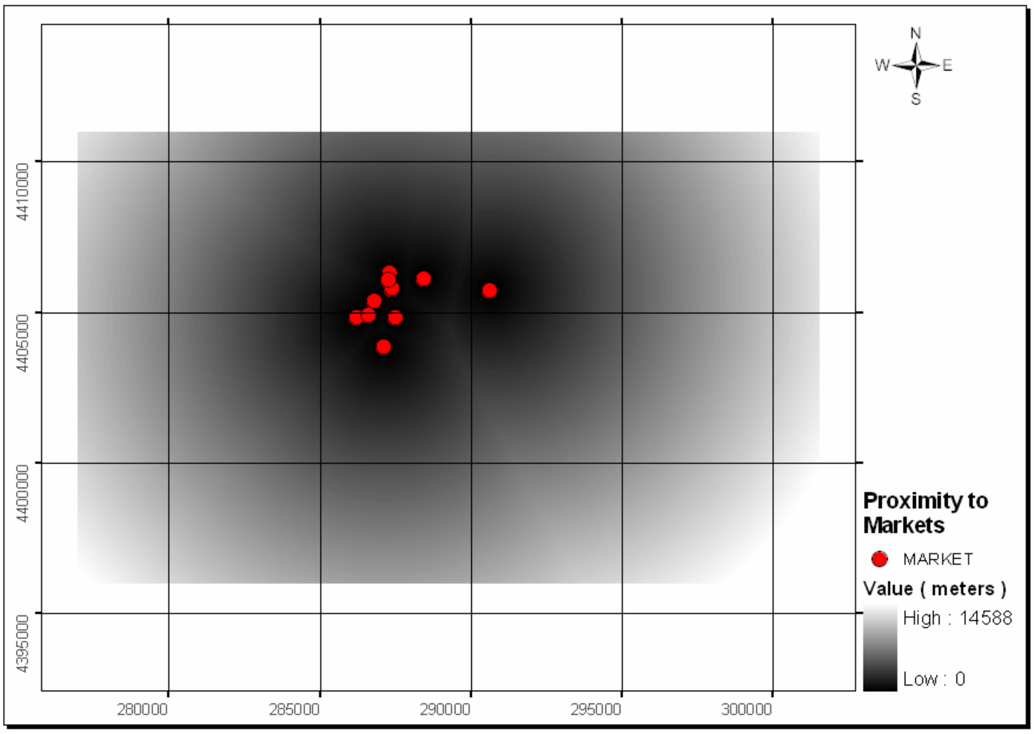

Figure 4.17 Proximity to Markets

4.3 Standardization of Criteria

Generally, the criteria used in the analysis are different in measurement scales. In order to run the processes it is necessary to standardize the criteria into a common scale. To achieve this, it is much more useful to identify membership functions.

In the study, for each criterion, one of the three equations (the linear function, the ‘s’ function, and the logarithm function) which are explained in the previous chapter is used. The linear function is used for the factors that are commonly considered to change in a linear form. For the functions whose value of “good” changes more rapidly with the changing distance the ‘s’ and the logarithm functions are used. Generally, the equations selected for the each criteria in the study of Zeng and Zhou (2001) are also chosen in this study, too. In addition to the equations, the variable values determined for the criteria of the same study are also implemented that are codified with FZ membership functions, based on ‘common sense’ as well as expert knowledge.

In the membership functions, degrees of membership (d.o.m) of the linguistic variables are represented in the “y” axis and the variable values are represented in the “x” axis.

The criteria “good slope” is defined by the “s” function (Figure 4.18) whose variables are a = 13 degrees and b = 25 degrees. This means that until 13 degrees of slope the sites are better for living with degreasing ideality, between 13 to 25 degrees it becomes harder and after 25 degrees it is not possible for normal urbanization and living.

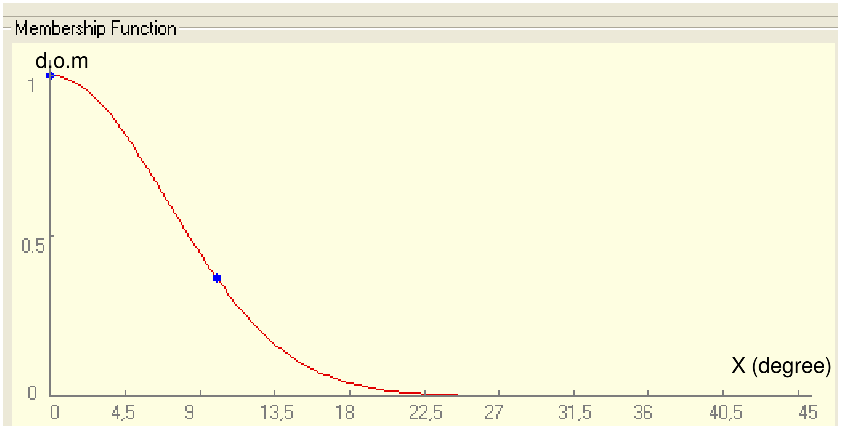

Figure 4.18 Membership function for “good slope”

Apart from the three equations, in addition to the trapezoidal (a kind of linear function) function, the “gaussian membership function” is used for the definition of ‘good’ aspect (Figure 4.19). By the trapezoidal function, the ‘flat’ areas whose aspect value is -1 are defined. Adding to the flat areas, the ‘southfacing’ aspect sites are defined.by the guassian membership function whose parameters are a = 30 and b = 180.

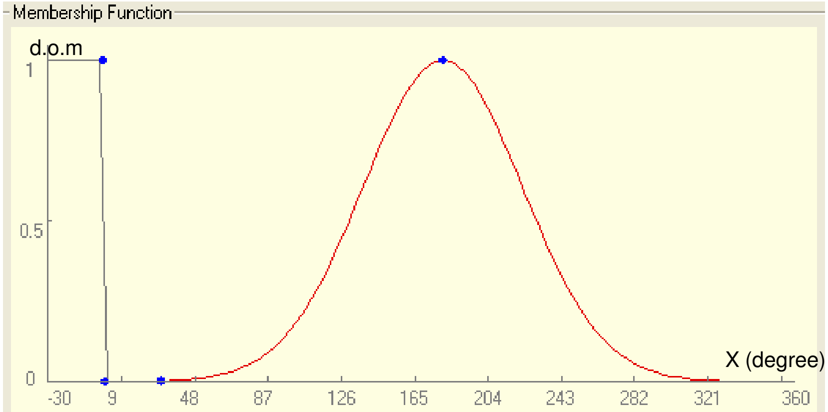

Figure 4.19 Membership function for “good aspect (flat OR southfacing)”

For the expression of the “close to parks” the “linear function” seen in Figure 4.20 is used with the parameters a = 60m. 0 and b = 700m. For this criterion, it is good to be in a 60 meters distance to a park or a green area. While the distance increases from 60 to 700 the the positive effect of the parks decreases and for more distant areas it has no effect.

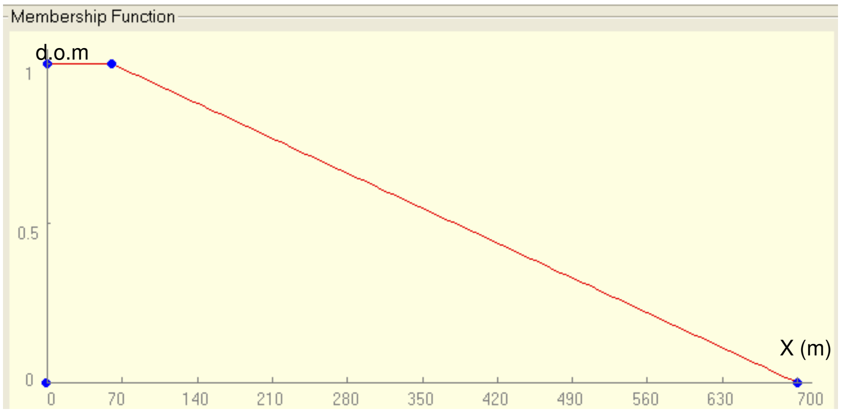

Figure 4.20 Membership function for “close to parks”

“close to river” is defined by the parameters a = 60m. and b = 500m. in the Figure 4.21 using the “linear function”. The sites more than 500 meters to a river does not get any positive effect from this river. It is best to be in first 60 meters and this positive effect decreases linearly from 60 meters to 500 meters.

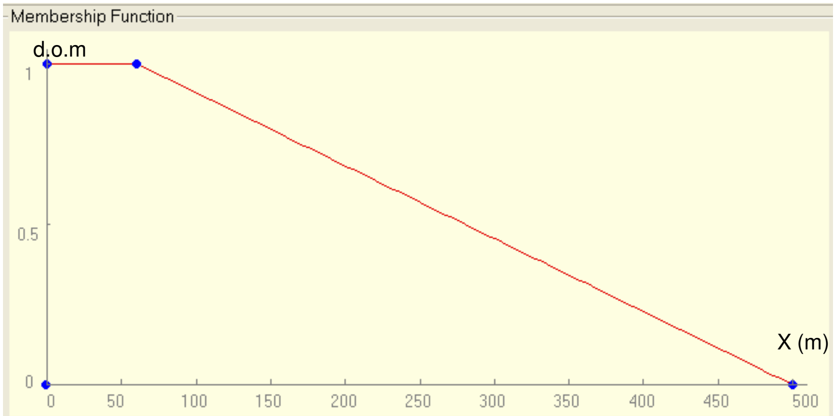

Figure 4.21 Membership function for “close to river”

Parameter a = 500 and b = 1500 for the definition of “close to schools” using the “linear function” can be seen in Figure 4.22. As 500 meters can be defined as the walking distance, it is better to be in this distance to a school as the children can go by walkig. Till 1500 meters it can be defined as near but after that distance it is better to use a vehicle.

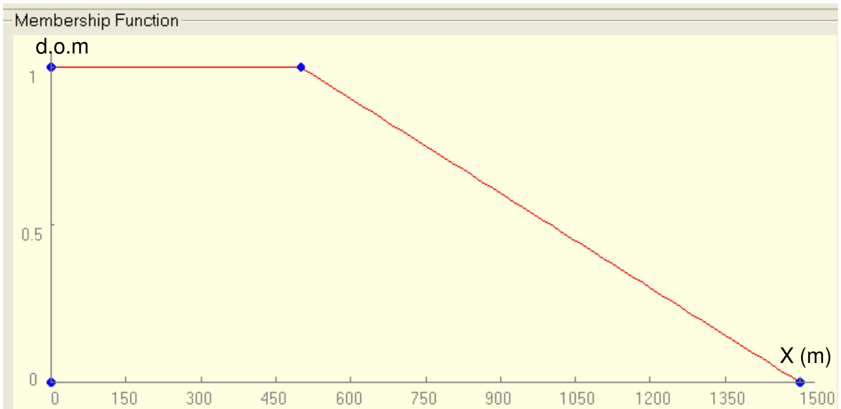

Figure 4.22 Membership function for “close to schools”

“close to markets” whose parameters are defined as a = 500m. and b = 3500m. use the “linear function” for the analysis (Figure 4.23). Similar to the “close to school” citeria, it is practical to walk 500 meters to a market. You can easily reach to a market easily till 3500 meters and it does not make you spend much time. But after that distance it takes long time to go for shopping.

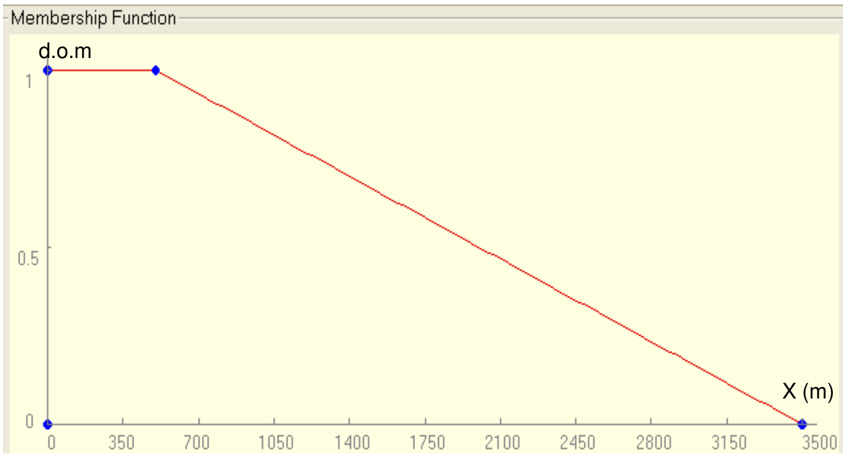

Figure 4.23 Membership function for “close to markets”

Using the “linear function” with parameters a = 500m. and b = 1500m., “close to tramway stations” which is the third criterion of the amenity and transport group is defined in Figure 4.24. You can walk to the station if it is in 500 meters distance. Between 500 and 1500 meters you may need a vehicle like a ring to reach to the station in addition to walking. After 1500 meters it becomes unpractical to walk to reach to the station and it takes long time.

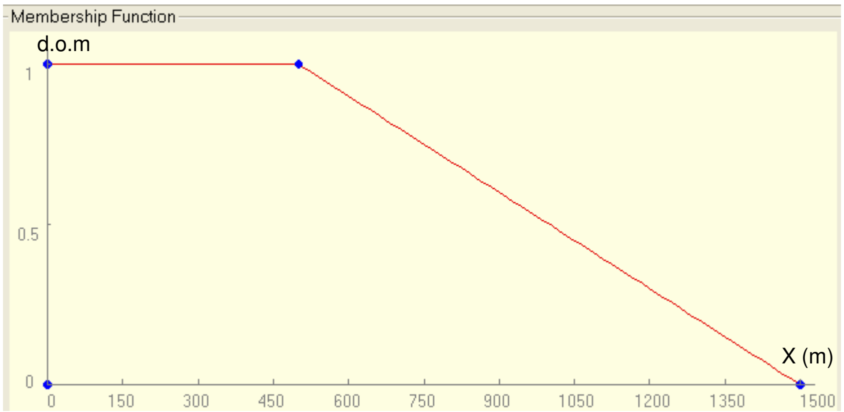

Figure 4.24 Membership function for “close to tramway stations”

“no railway noise” which is one of the two criteria of the pollution & noise group uses the parameters a = 30m. and b = 200m. through the “s” membership function seen in Figure 4.25. The first 30 meters’ zone is the place where you become uncomfortable because of the railway noise. This effect decrease going outside through the 30 – 200 meters zone and you do not feel the negative effect of the railway after 200 meters.

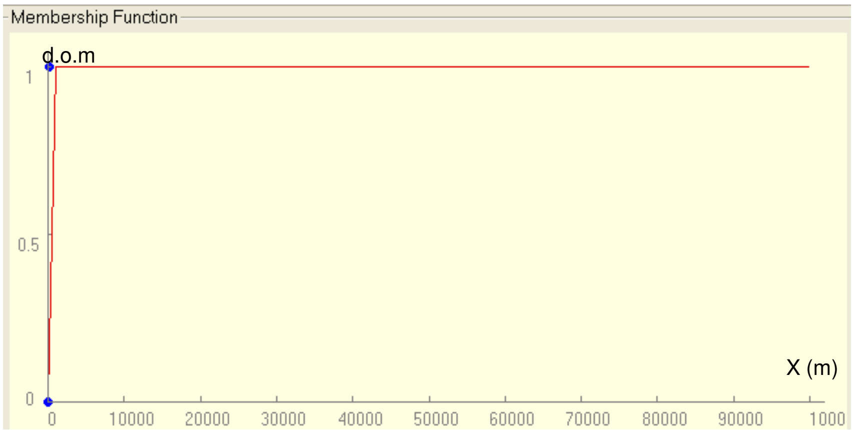

Figure 4.25 Membership function for “no railway noise”

The last criterion called “no highway noise” which is also the second and last criterion of the pollution & noise group is represented by the “s” membership function using the parameters a = 60m. and b = 200m. (Figure 4.26). Pollution and noise of motor vehicles from highways is felt too much in 60 meters zone. This negative effect decreases while going to the 200 meters distance and and after 200 meters it does not make any harmful effect.

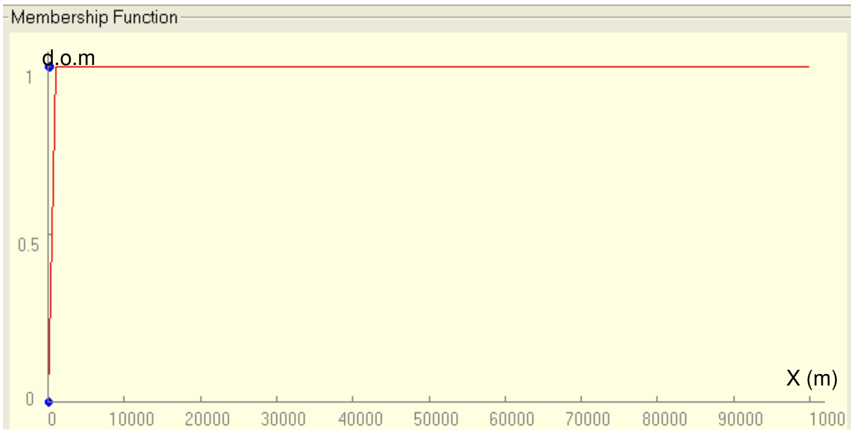

Figure 4.26 Membership function for “no highway noise”

In addition to the input data defined by the membership functions, the output data is also defined by a membership function in the linguistic variable list. This also means that the intervals for the cell values of the output raster image are described. In the description of the output MFs' the "linear function" is used and the output cell values changes between 0 and 100 as it is seen in Figure 4.27. where 0 means unsuitable and 100 means the most suitable sites.

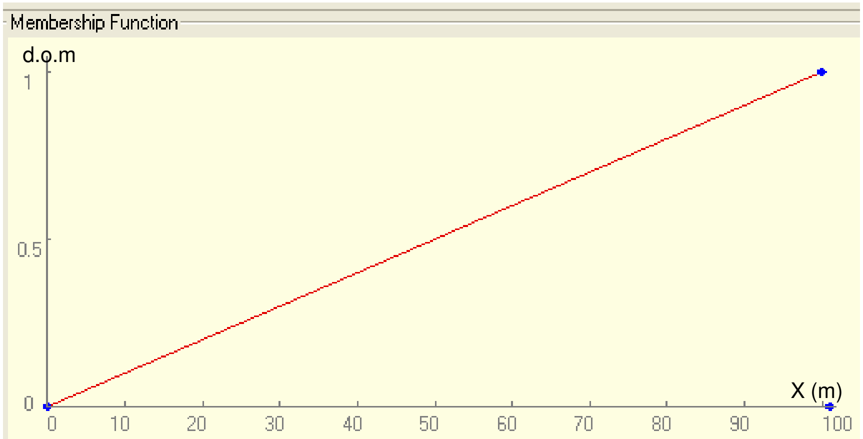

Figure 4.27 Membership function defined for the outputs

4.4 Site Selection

For the selection of suitable sites for the settlements two different methods are used. The first method is the fuzzy rule-based system (FZRBS) that integrates all the criteria together at the same time. The second is a kind of weighted overlay method that takes into consideration of the preferences of the different interest groups. Both methods use the FuzzyCell software.

4.5 Fuzzy Rule - Based System (FZRBS)

In this method, the methodology is the fuzzy rule-based system that uses Fuzzy "if … then…." rules and executes all the evaluation criteria together simultaneously.

Firstly, the nine criteria (linguistic variables) are defined by the help of membership functions expressed in the previous section. They are added to the "linguistic variable list" of Fuzzcell as input data. Then the output map is defined (Figure 4.27) again through the membership functions of FuzzyCell.

Then the Rule List is determined as;

'IF the SLOPE is good AND

the ASPECT is flat OR southfacing AND

it is close to PARKS AND

it is close to RIVER AND

it is close to SCHOOLS AND

it is close to MARKETS AND

it is close to TRAMWAY STATIONS AND

it is not close to RAILWAY AND

it is not close to HIGHWYS

THEN it has an excellent location'

After the rule list is defined, the parameters are determined for the model properties where the model properties window is seen in Figure 4.28. "Fis Type" is selected as Mamdani Model. Minimum is selected for the "Implication Method" and "And Method". Maximum is selected as the "Aggregation Method" and "Or Method" and lastly "Defuzzificaion Type" is determined as the Smallest of Maximum Defuzzification (SOM) for the analysis.

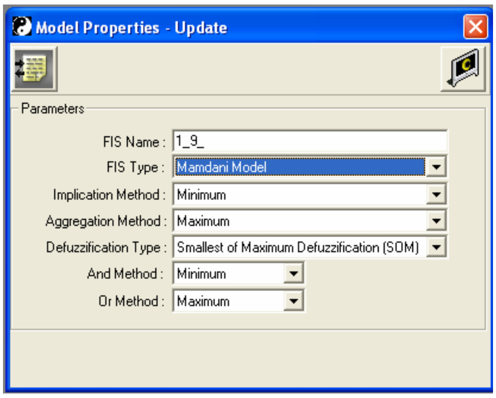

Figure 4.28 The Model properties of Fuzzy Inference System (FIS)

At the end of the implementation, the resultant map is obtained and presented in Figure 4.29 that shows the suitability sites in the study area.

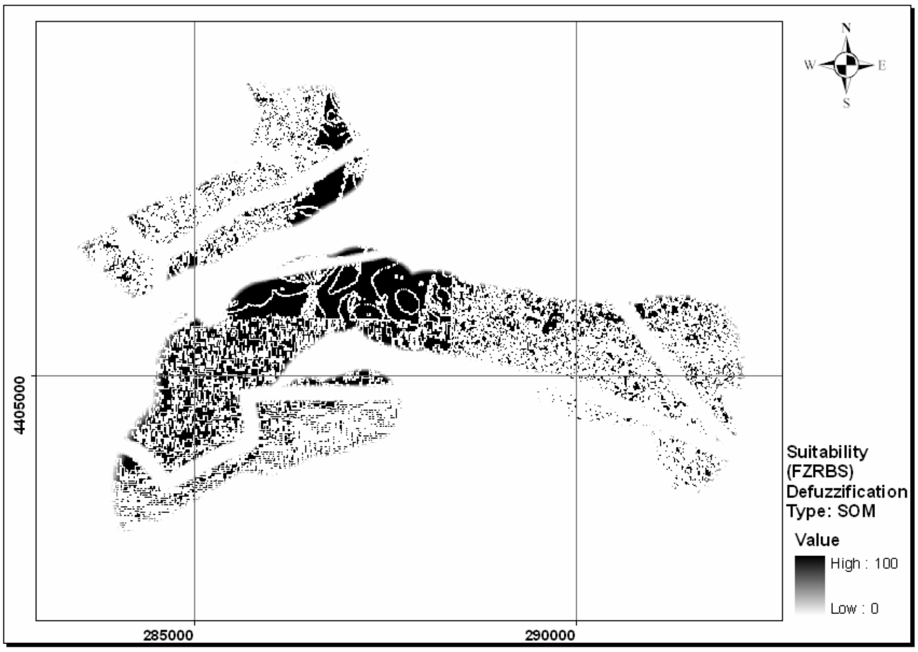

Figure 4.29 The final suitability map of 9 criteria according to FZRBS by using SOM (Smallest of Maximum) Defuzzification Type

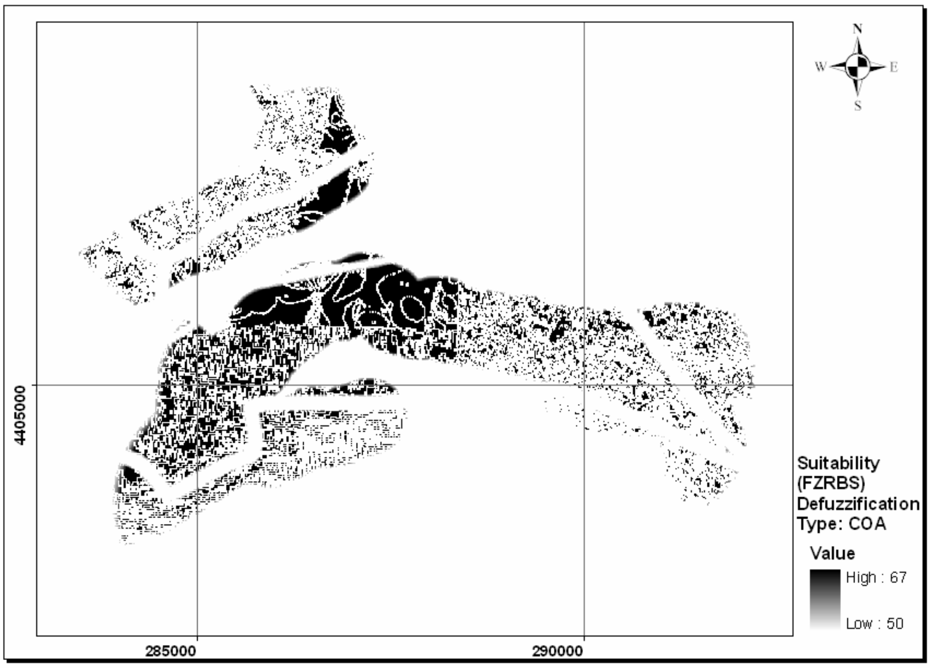

Figure 4.30 The final suitability map of 9 criteria according to FZRBS by using COA (Center of Area) Defuzzification Type

In addition to the resultant map obtained by using the SOM (Smallest of Maximum) defuzzification type, another map (Figure 4.30) is also gathered by executing the same operation using the COA (Centre of Area) defuzzification type. It is performed in order to observe the difference between the outcomes of the same operation using different defuzzification methods.

CHAPTER 5

SENSITIVITY ANALYSIS AND DISCUSSIONS

5.1 Sensitivity Analysis

Apart from the fuzzy rule-based methodology executed to the 9 criteria at the same time, a different way is followed in the site selection processes. It is the sensitivity analysis that takes into consideration of different people's profiles living in the city. Weighted overlay methodology is used to achieve this method. Here all the criteria are not weighted separately. Instead of giving weight to each criterion the similar criteria are put into the same group.

According to this idea the criteria are divided into 3 main groups named as Physical Environment, Amenity & Transport and Pollution & Noise.

Physical Environment criteria are: Close to Parks, Close to River, Good Aspect and Good Slope

Amenity & Transport criteria are: Close to Schools, Close to Markets and Close to Tramway Stations

Pollution & Noise criteria are: No highway pollution and no railway noise

After the criteria are grouped, the suitability map of each group is obtained. Here again the 'if… then…' rules of fuzzy rule-based system methodology are applied. The FIS is executed for each group separately. As a result of this 3 suitability maps for each group are obtained and they are presented in Figures 5.1. – 5.3.

For the suitability map of physical environment (Figure 5.1) the fuzzy 'if… the…' rule is created as;

'IF the SLOPE is good AND

the ASPECT is flat OR southfacing AND

it is close to PARKS AND

it is close to RIVER

THEN it has an excellent location'(from the point of view of physical environment)

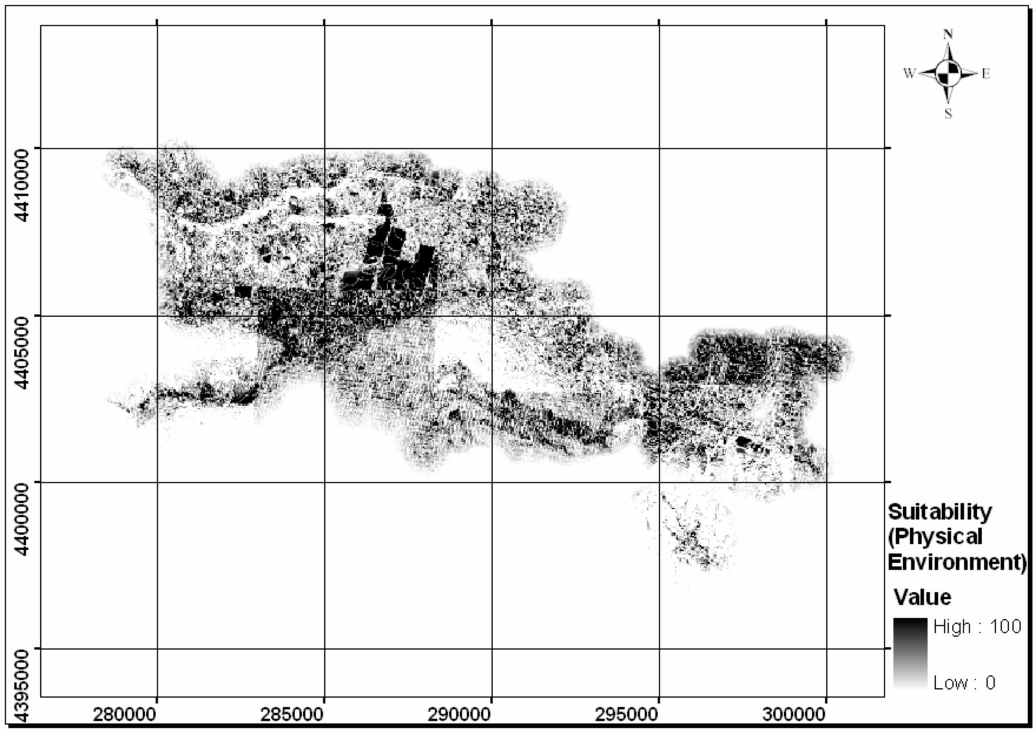

Figure 5.1 Suitability map according to "physical environment" criteria (Close to Parks, Close to River, Good Aspect and Good Slope)

For the suitability map of amenity & transport (Figure 5.2) the fuzzy 'if… the…' rule is created as;

'IF it is close to SCHOOLS AND

it is close to MARKETS AND

it is close to TRAMWAY STATIONS

THEN it has an excellent location' (from the point of view of amenity & transport)

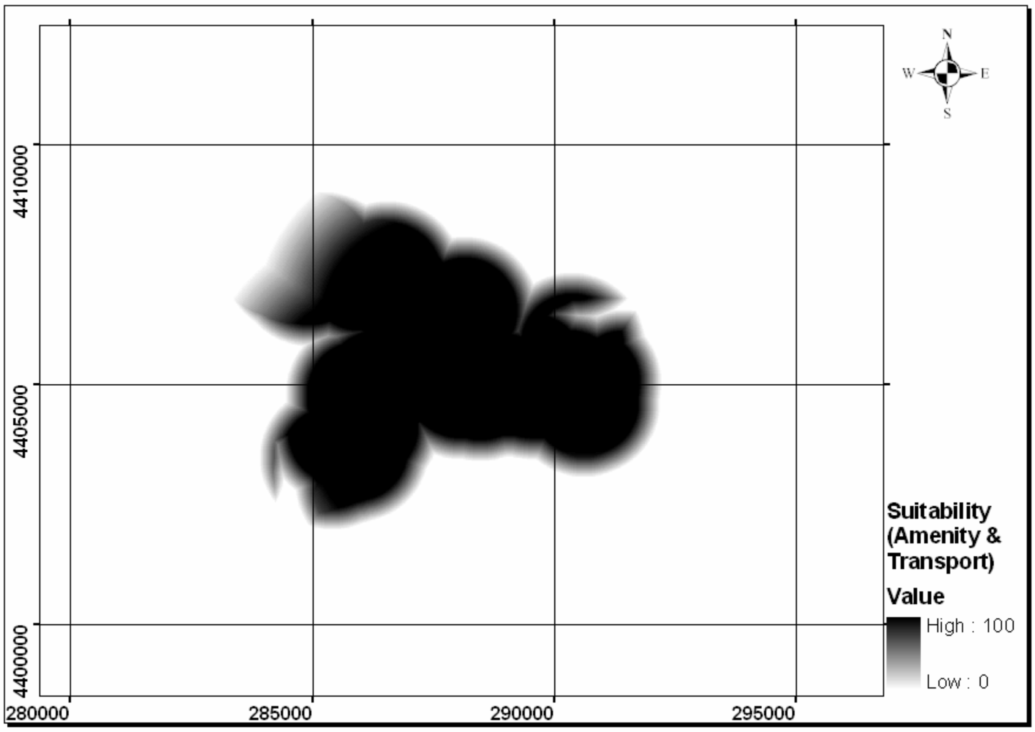

Figure 5.2 Suitability map according to "amenity & transport" criteria (Close to Schools, Close to Markets and Close to Tramway Stations)

For the suitability map of pollution & noise (Figure 5.3) the fuzzy 'if… then…' rule is created as;

'IF it is not close to RAILWAY AND

it is not close to HIGHWYS

THEN it has an excellent location' (from the point of view of pollution & noise)

Figure 5.3 Suitability map according to "pollution & noise" criteria (No highway pollution and no railway noise)

After the criteria are grouped and the suitability maps of each group are gathered, the four scenarios are executed. The aim of creating different scenarios is that the people have their own priorities as they are in different stages in their lives. Their age, work, child(ren) profiles, etc. are the main determinants of the scenarios.

The four scenarios used in the sensitivity analysis in the study are as follows:

(a) 'No noise and pollution' is a little more important than physical environment and amenity.

(b) 'Amenity' is most important. This case is more appropriate for a young family as they have a very busy routine. It shows that there are more areas to be selected.

(c) 'Good physical environment' and 'no noise and pollution' are preferred. This case may be preferred by retired people as most want a more relaxing environment. There are less areas to be chosen.

(d) ‘Good physical environment’ has a high priority with less concern about ‘noise and pollution’.

The implementation of the scenarios is achieved by the ‘weighted overlay approach’ that means the addition of map after they are multiplied by their given weights. The numerical weights are given in Table 5.1.

Table 5.1 The weights given to the criteria groups according to the four scenarios.

	(Physical Environment)	(Amenity & Transport)	(Pollution & Noise)
Scenario a	0,3	0,3	0,4
Scenario b	0,3	0,5	0,2
Scenario c	0,4	0,1	0,5
Scenario d	0,5	0,3	0,2

As a result, according to these four scenarios, the four different site suitability maps are obtained wich can be seen in Figures 5.4. – 5.7.

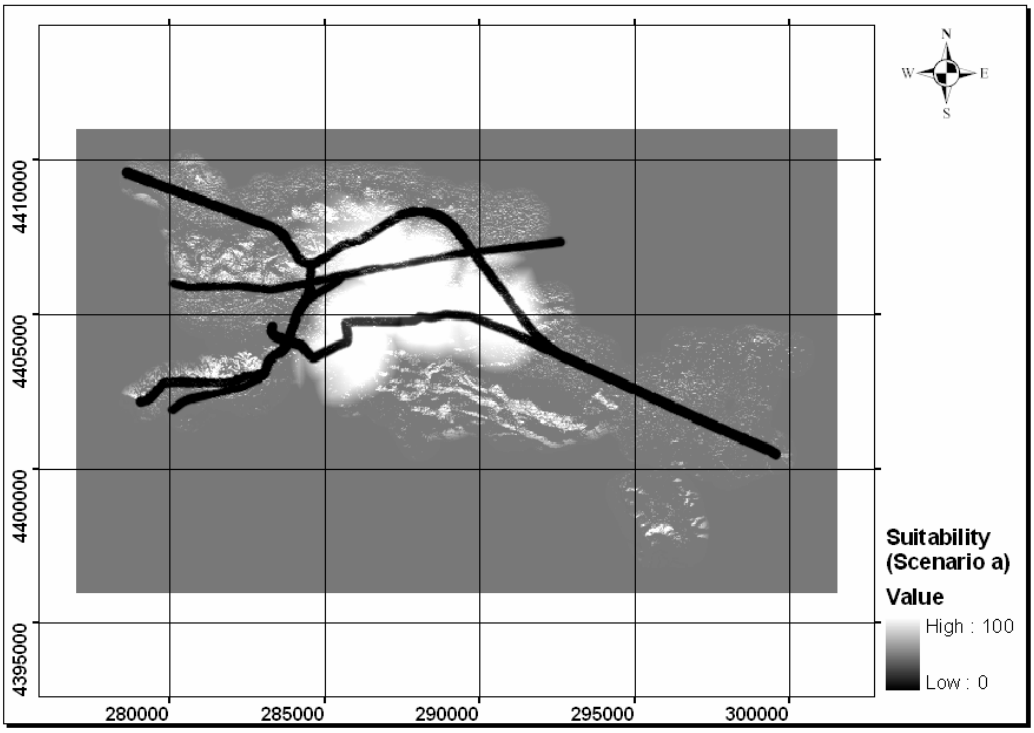

Figure 5.4 Site suitability map according to scenario (a)

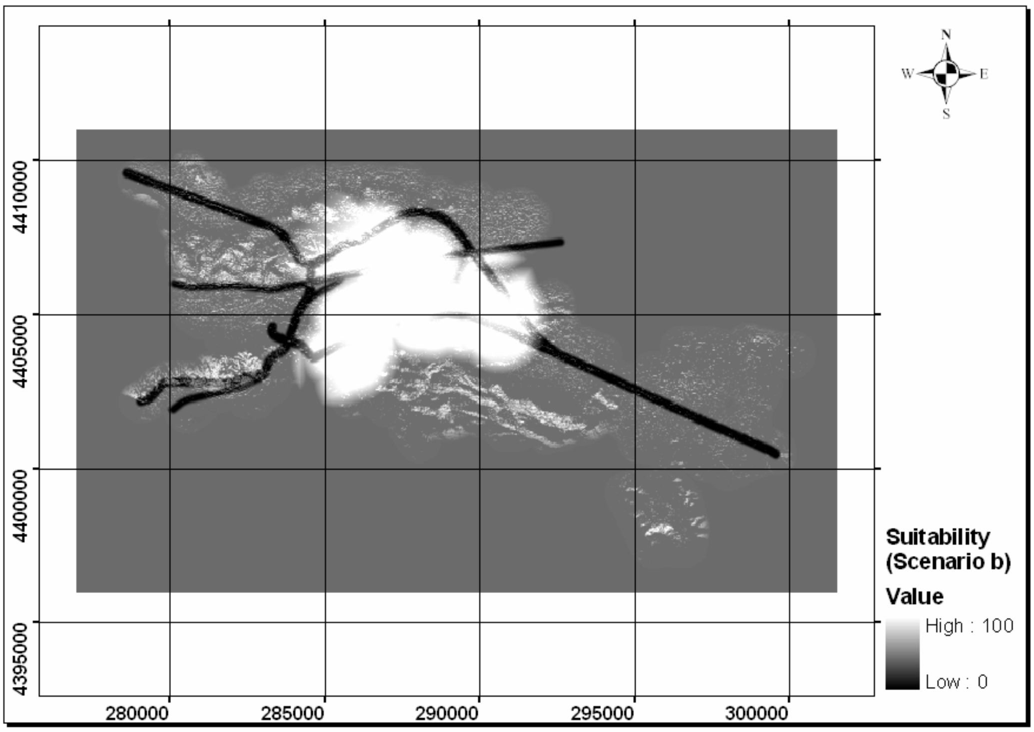

Figure 5.5 Site suitability map according to scenario (b)

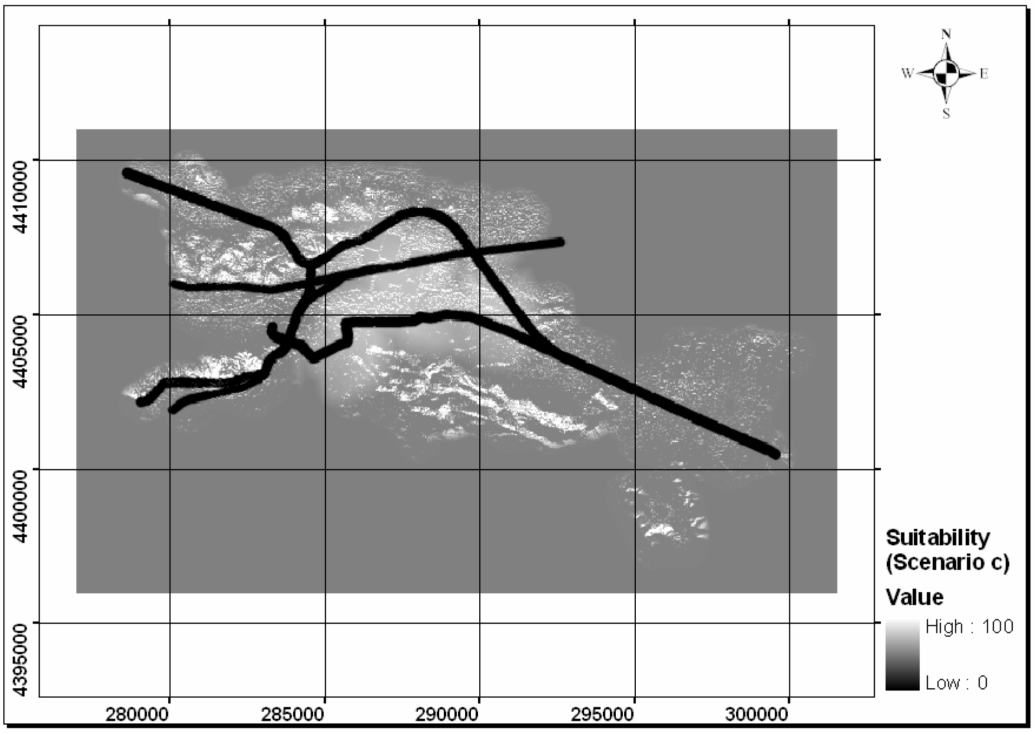

Figure 5.6 Site suitability map according to scenario (c)

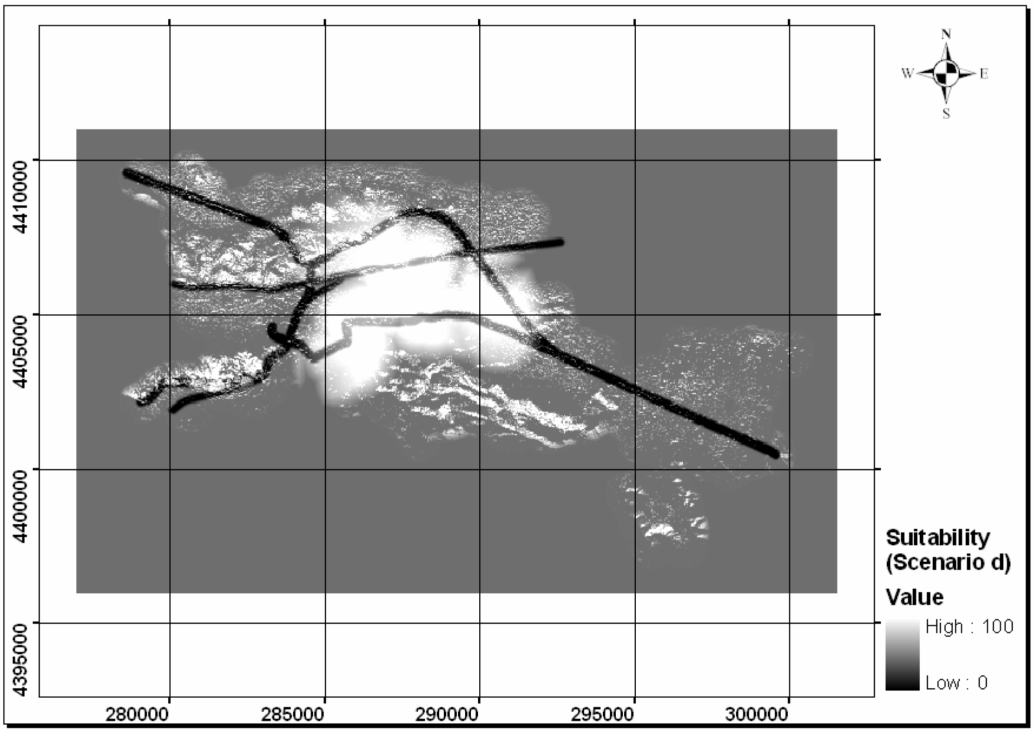

Figure 5.7 Site suitability map according to scenario (d)

5.1.1 Classification of the Suitability Maps

After the five site suitability maps (which of first is the result of FZRBS and the others are the results of weighted overlay approach) are obtained, the maps are classified into five suitability groups. It is because the cells of the output rasters have values between 0 and 100 and it is not meaningful to make interpretations on these maps.

The groups are classified in equal intervals as;

(1) % 0 – 20 = least suitable

(2) % 20.1 – 40 = less suitable

(3) % 40.1 – 60 = moderate

(4) % 60.1 – 80 = suitable

(5) % 80.1 – 100 = most suitable

Figures 5.8. – 5.12. are the resultant classified raster site suitability maps of the study are.

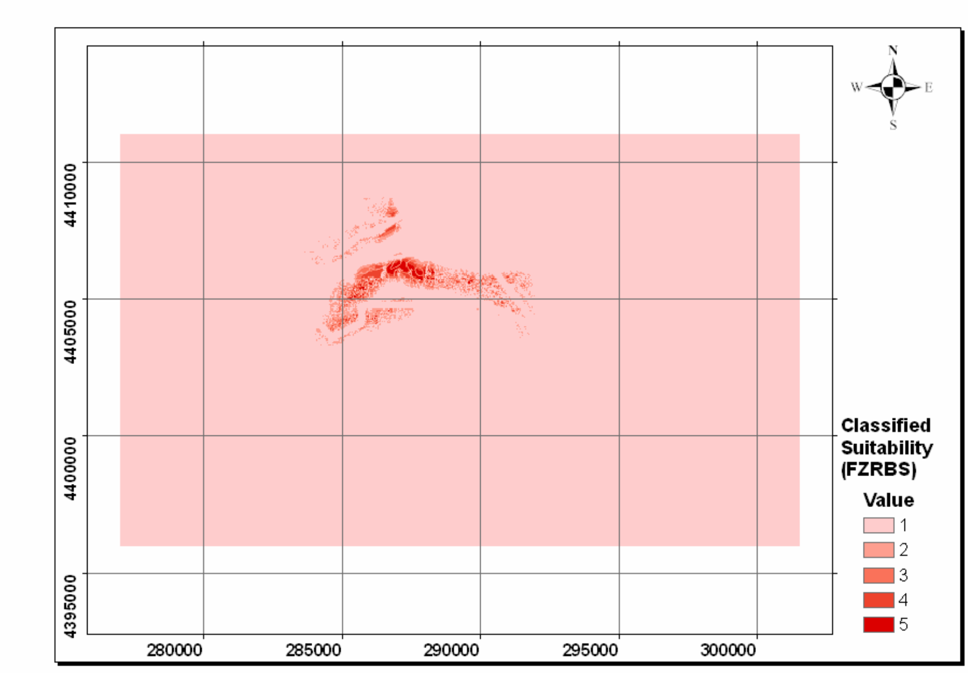

Figure 5.8 Classified site suitability map according to FZRBS using 9 criteria

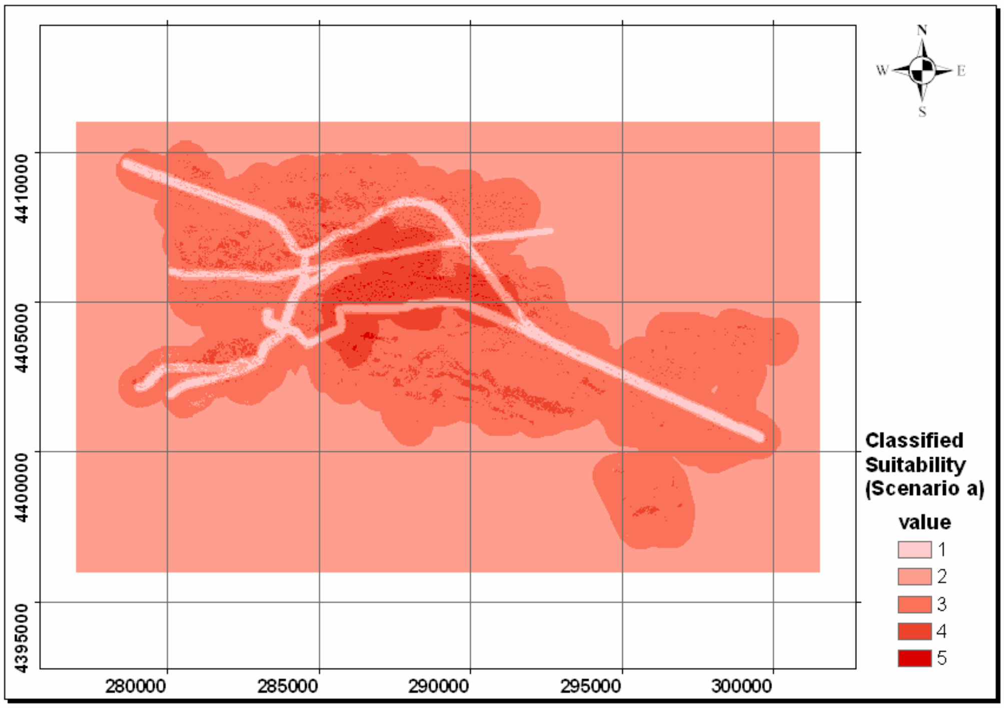

Figure 5.9 Classified site suitability map of scenario (a)

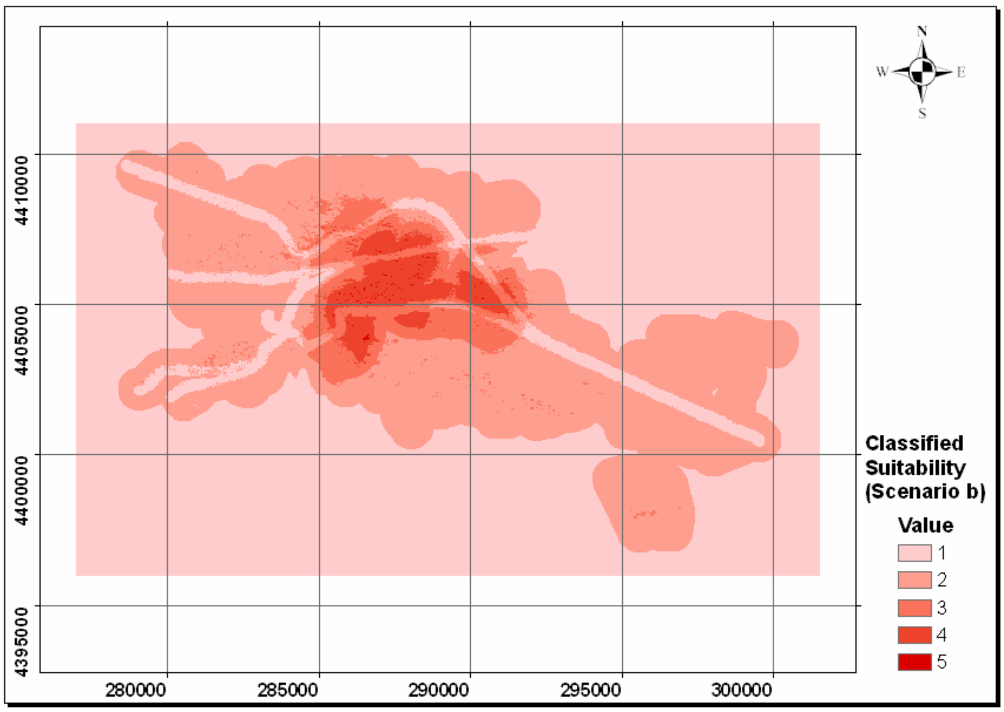

Figure 5.10 Classified site suitability map of scenario (b)

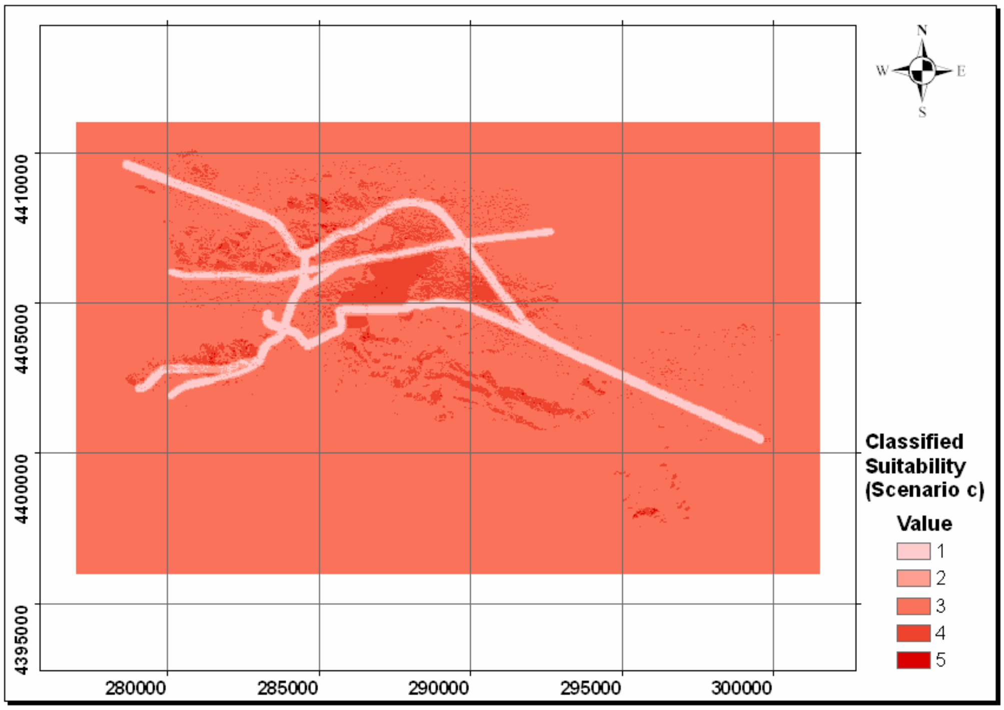

Figure 5.11 Classified site suitability map of scenario (c)

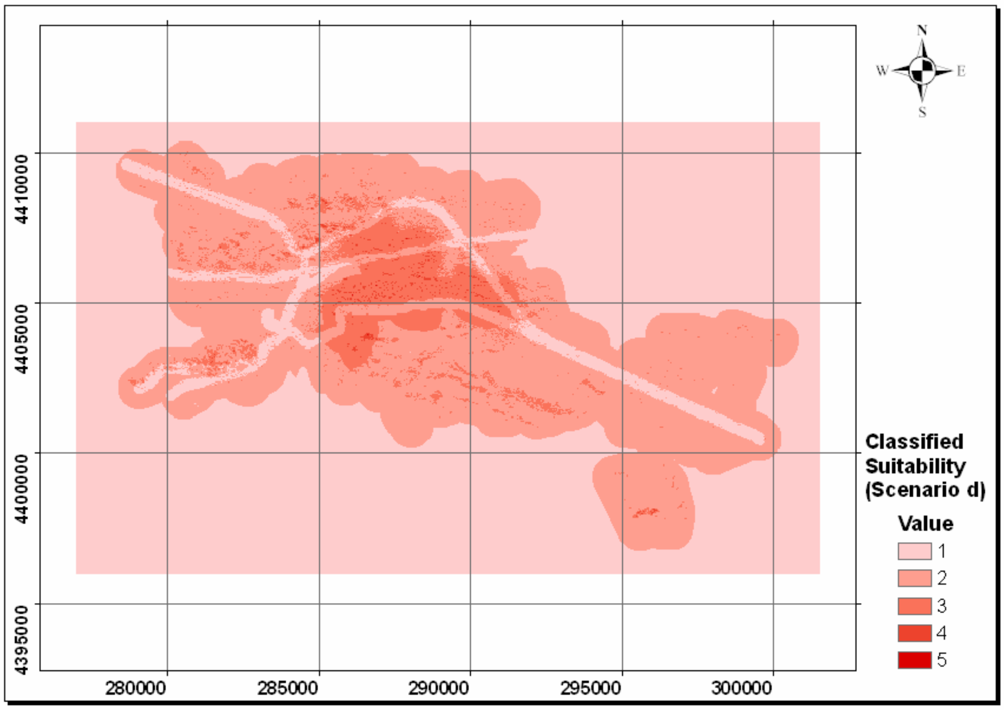

Figure 5.12 Classified site suitability map of scenario (d)

5.1.2 Converting the Raster Suitability Maps to Vector

As a result of the classification process the final raster site suitability maps are obtained. In order to make some analysis and interpretations about the Odunpazarı, Eskişehir area the site suitability maps must be in the same format with the building data. Because the building data are in vector format, the suitability maps must be converted to vector format.

For this target the “Convert – Raster to features…” functions of ArcGIS “Spatial Analyst” tool is used. After this process, the same five site suitability maps are obtained this time not in raster format but in vector format. Here the suitable areas on maps have their “GRIDVALUES” coming from the five classes on raster maps changing between 1 and 5.

Figures 5.13.– 5.17. below represent the vector suitability maps obtained by conversion process.

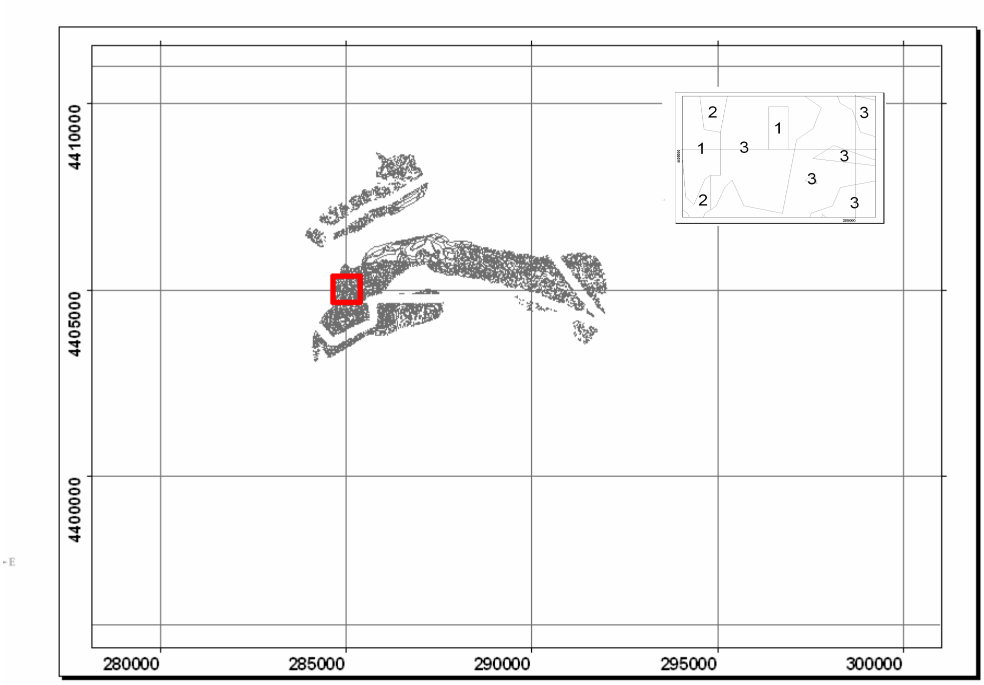

Figure 5.13 Vector suitability map showing the suitable sites’ areas that have their suitability value changing between 1 and 5 obtained by FZRBS method.

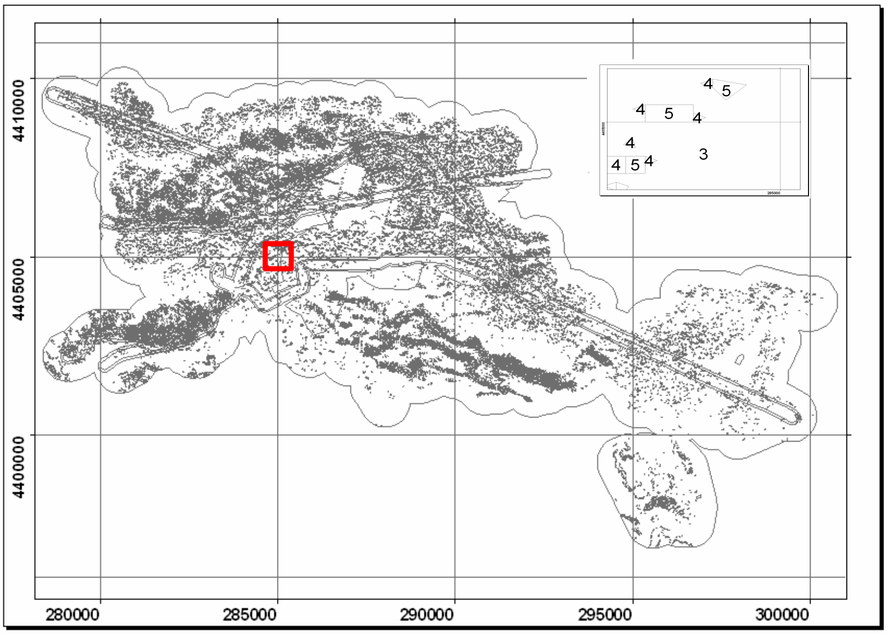

Figure 5.14 Vector suitability map showing the suitable sites' areas that have their suitability value changing between 1 and 5 obtained according to scenario (a).

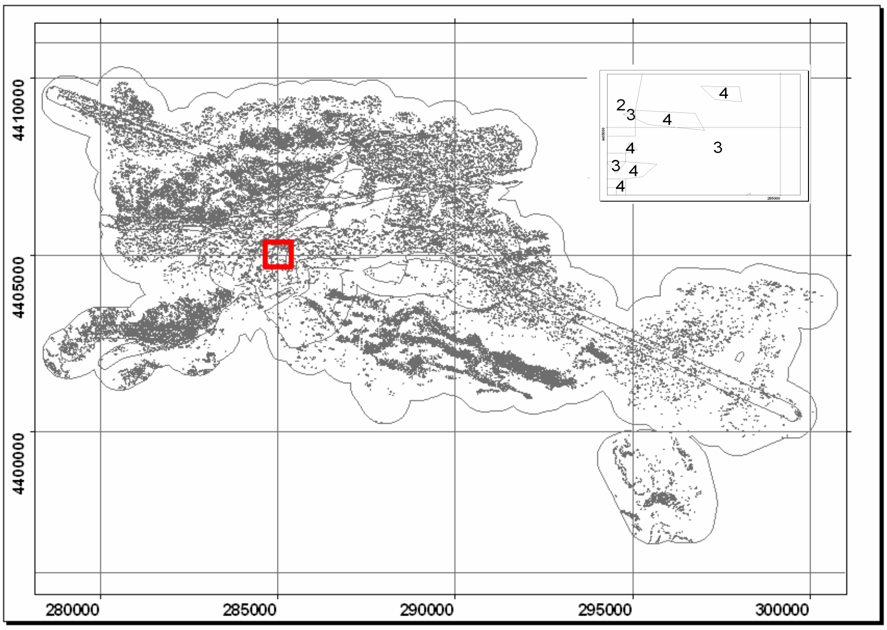

Figure 5.15 Vector suitability map showing the suitable sites' areas that have their suitability value changing between 1 and 5 obtained according to scenario (b).

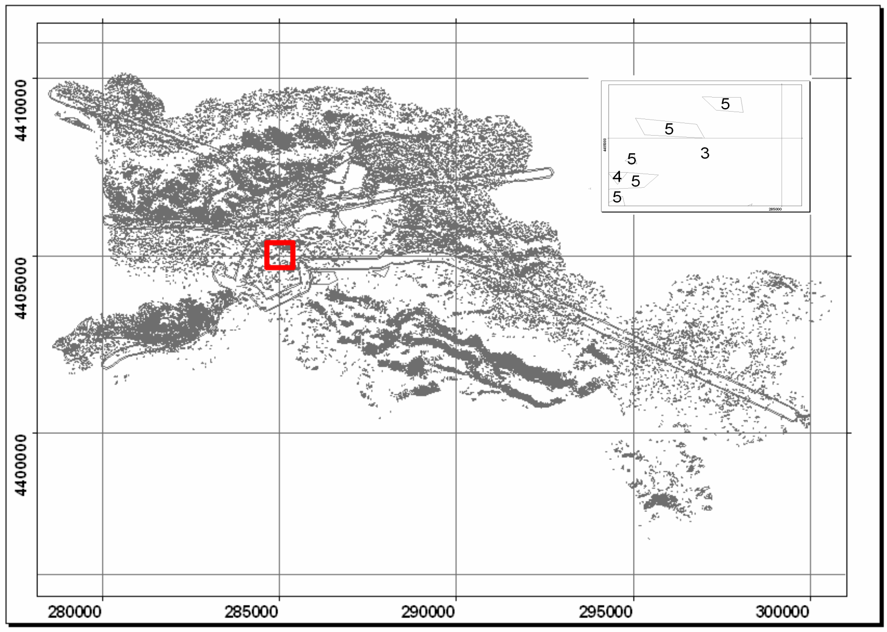

Figure 5.16 Vector suitability map showing the suitable sites' areas that have their suitability value changing between 1 and 5 obtained according to scenario (c).

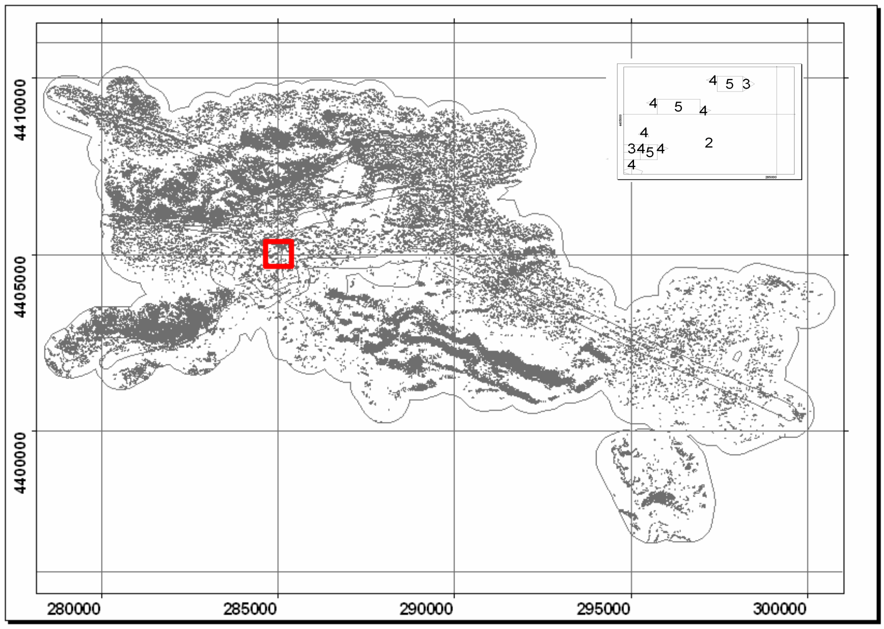

Figure 5.17 Vector suitability map showing the suitable sites' areas that have their suitability value changing between 1 and 5 obtained according to scenario (d).

5.1.3 Classification of the buildings

After the site suitability maps are converted to the vector format, the buildings in Odunpazarı area are classified by the vector operations. Each building in the area took part in one of the five suitability groups. This process is applied all of the five resultant (vector site suitability) maps. In this analysis if the building intersects more than one suitability area whose values changes 1 to 5, the bigger value is assigned to the building. This means that a building that is situated on more then one suitability site, the building is added to the better or best suitability class.

The five resultant building maps that are colored according to the 5 suitability groups are shown in the Figures 5.18. – 5.22. below. As a result, it can be concluded about the number of buildings and their related suitability classes according to FZRBS or different scenarios.

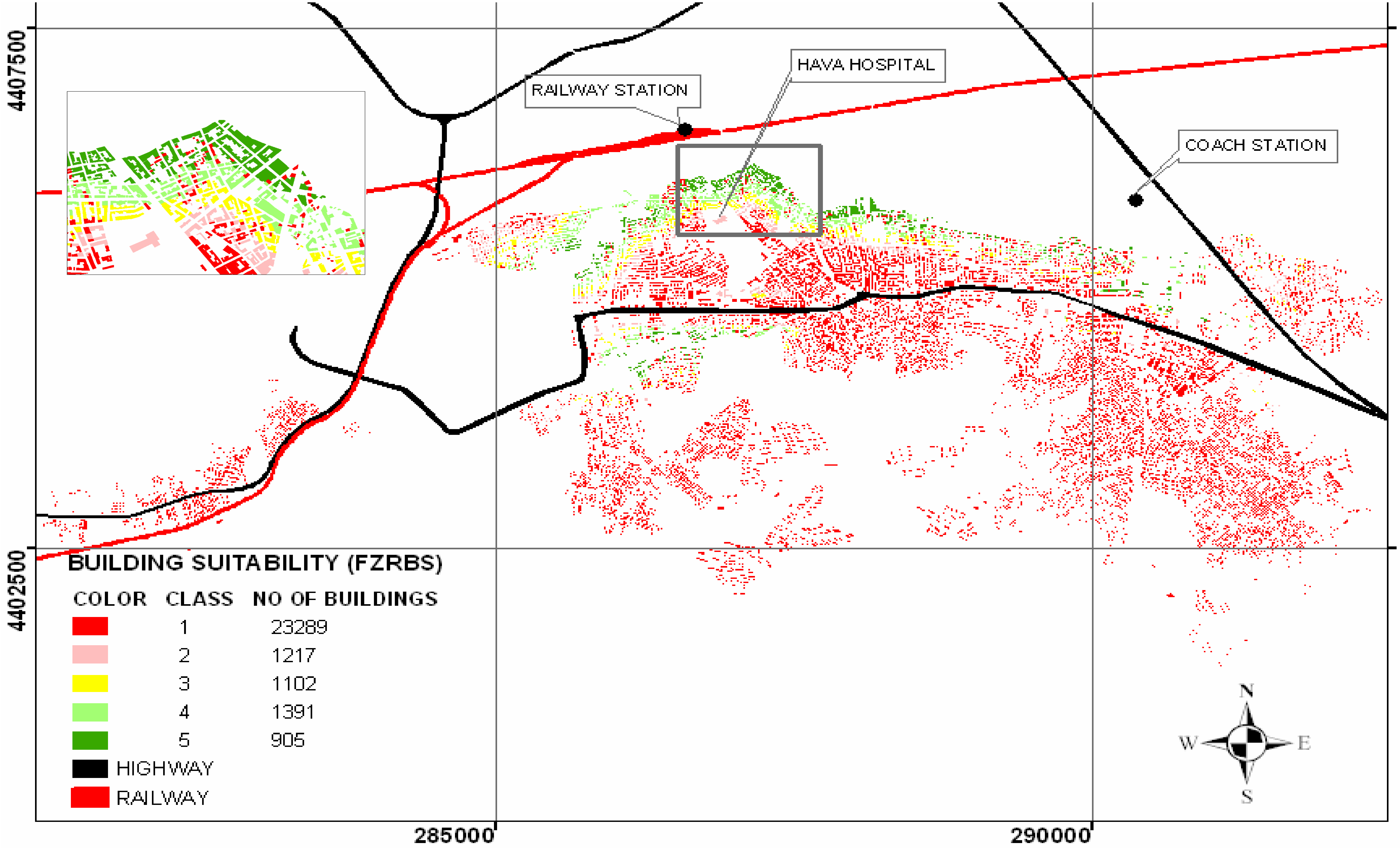

Figure 5.18 The building (polygon vector) map showing the five suitability classes of the buildings according to FZRBS.

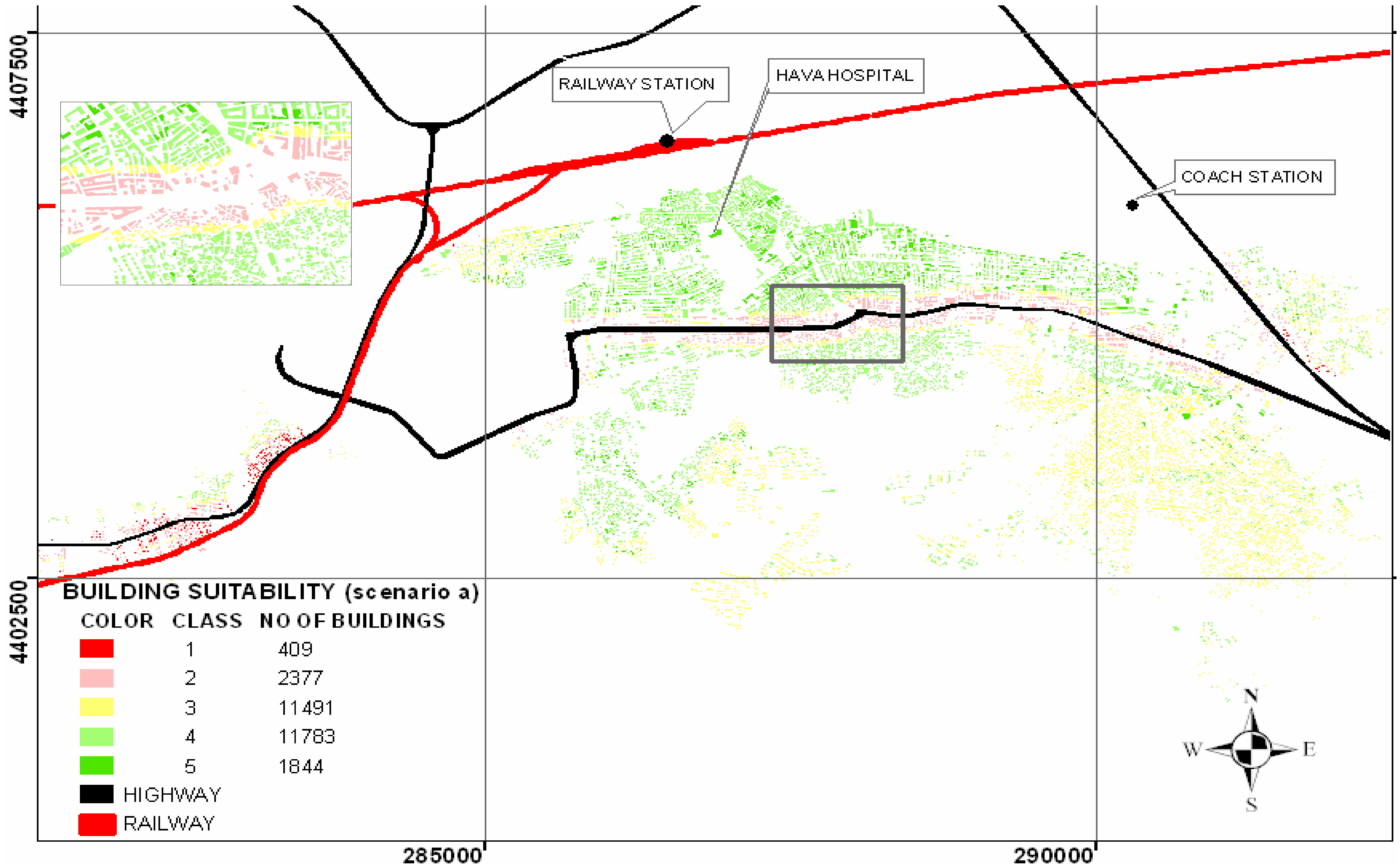

Figure 5.19 The building (polygon vector) map showing the five suitability classes of the buildings according to sensitivity (a) (physical environment 0,3 - amenity & transport 0,3 - pollution & noise 0,4)

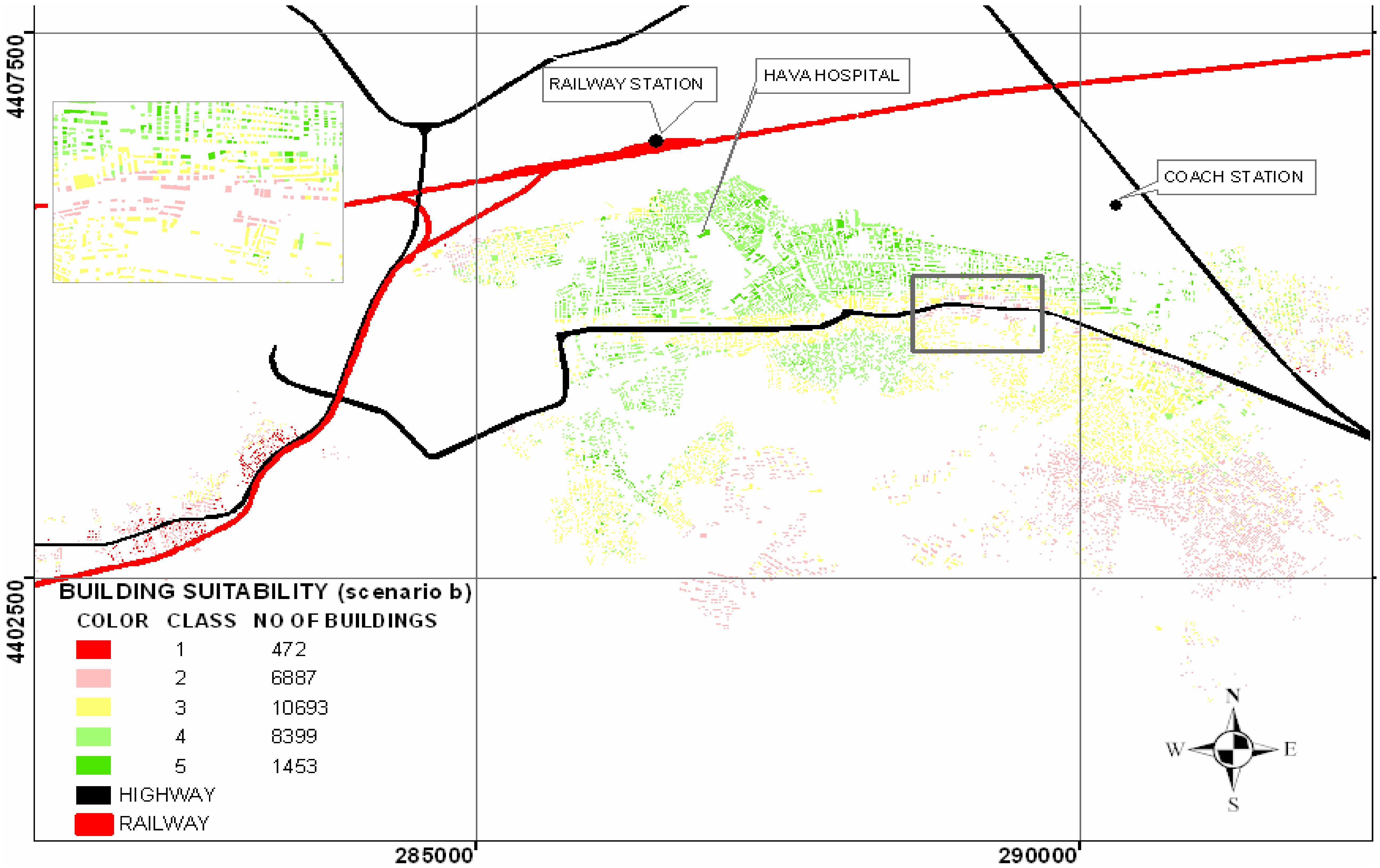

Figure 5.20 The building (polygon vector) map showing the five suitability classes of the buildings according to sensitivity (b) (physical environment 0,3 - amenity & transport 0,5 - pollution & noise 0,2)

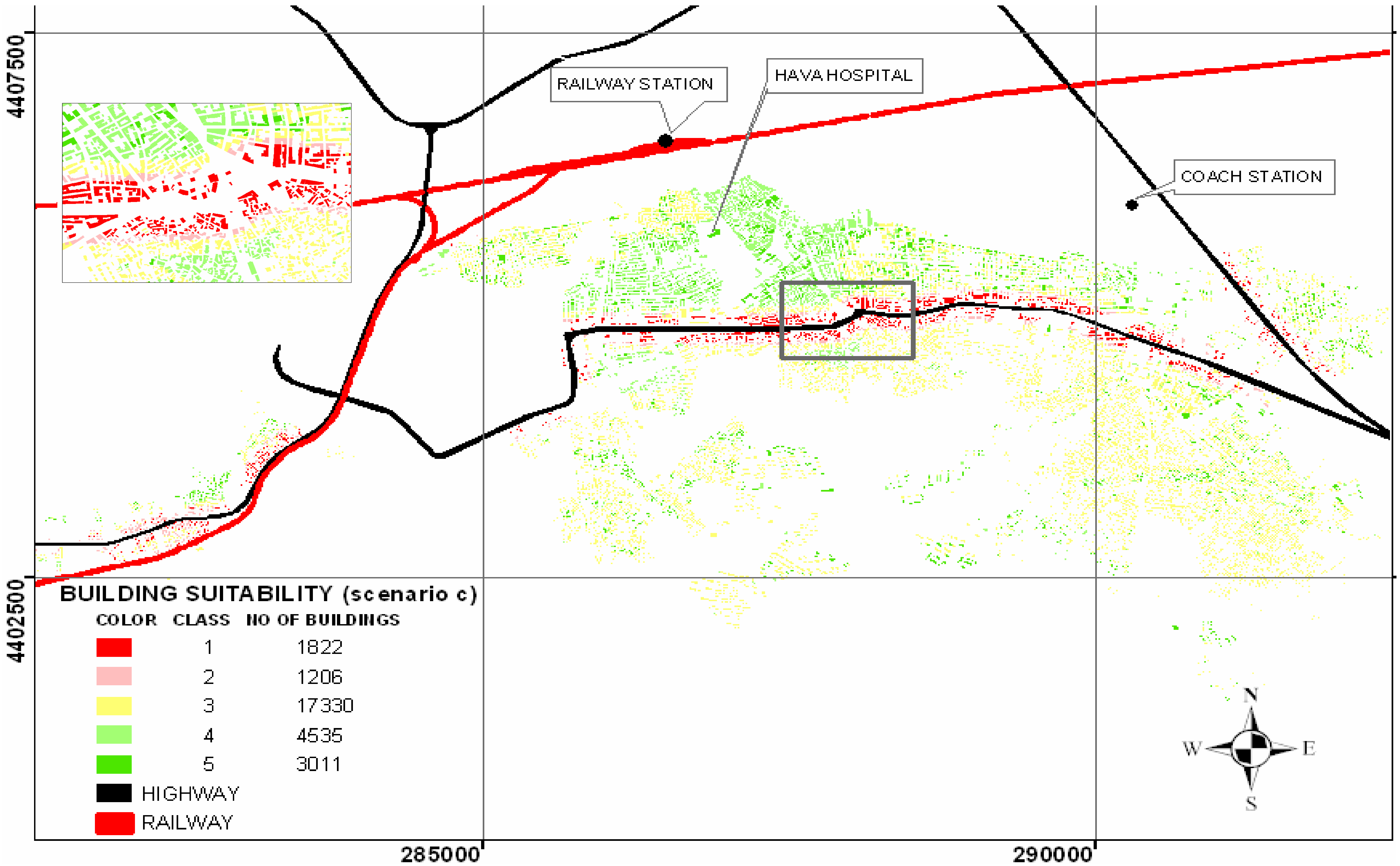

Figure 5.21 The building (polygon vector) map showing the five suitability classes of the buildings according to sensitivity (c) (physical environment 0,4 - amenity & transport 0,1 - pollution & noise 0,5)

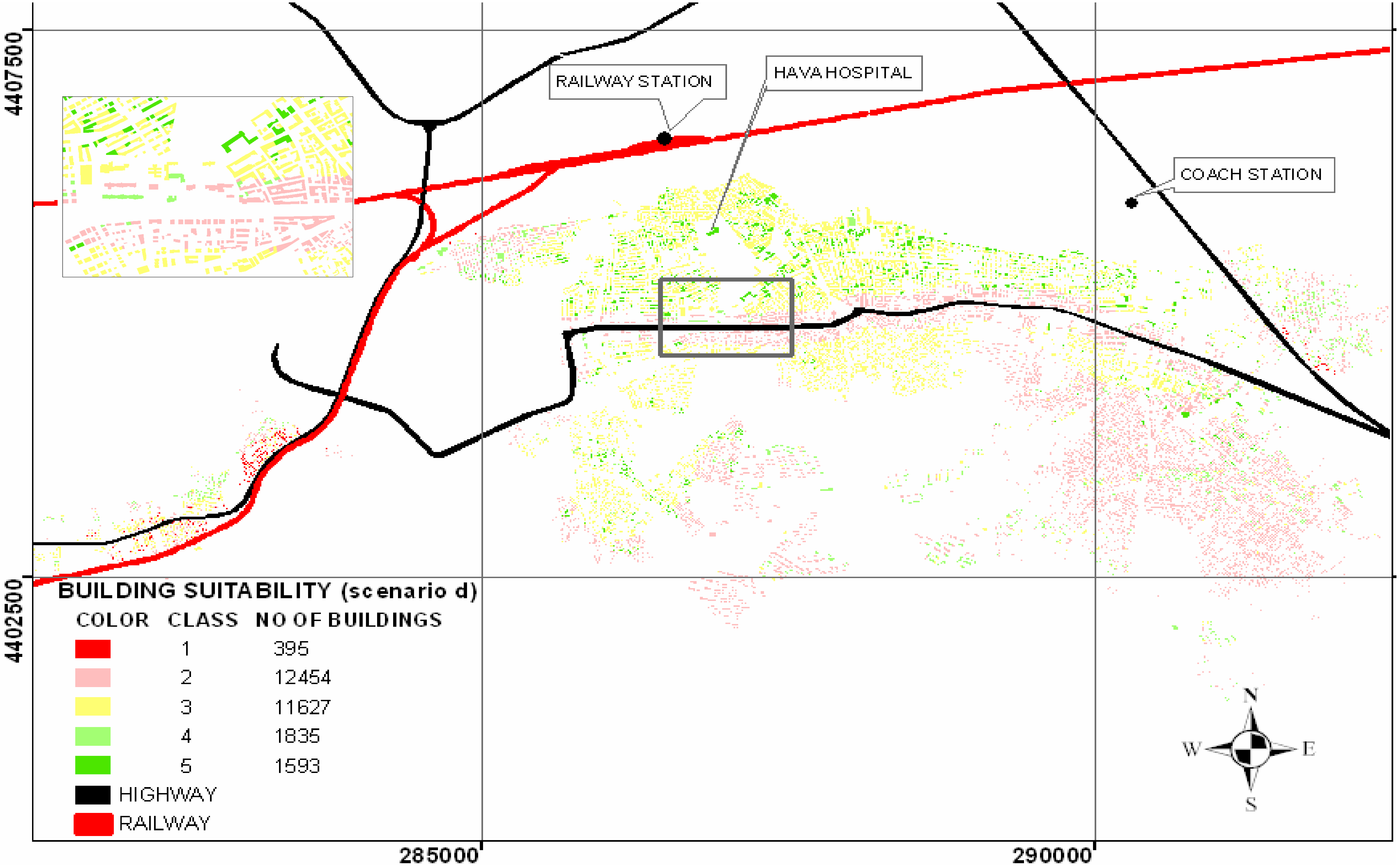

Figure 5.22 The building (polygon vector) map showing the five suitability classes of the buildings according to sensitivity (d) (physical environment 0,5 - amenity & transport 0,3 - pollution & noise 0,2)

5.2 Discussions

Searching for a property to purchase can be a very stressful process; this system can provide a buyer with a map of potential areas that best meet their requirements. This will significantly save time and travelling, thus reducing their stress. Also, most of the buyers do not have a great deal of knowledge about the influence of physical environment on property value. This system, by using expert knowledge, can help them to avoid potential pitfalls, providing a more objective opinion to assist their decision making. On the other hand, because each purchaser has his or her own particular criteria, the sequential orders of preference differ from one to another. From the point of view of real estate, this would be a very helpful tool for selling properties (Zeng and Zhou, 2001).

In the case study, a prototype of a locational suitability of settlements is developed by integrating fuzzy set theory. As a result of this, five different suitability maps are obtained. First the resultant maps are obtained by the FZRBS methodology and the other four site suitability maps are the results of four different scenarios created from the point of view of interest groups. After the suitability maps are gathered the results are combined with the results of the vulnerability results of the same area (Servi, 2004).

In the first (FZRBS) method, the site selection operation is defined through the fuzzy 'IF… THEN…' rules. In the case study, the rules determined as:

'IF the SLOPE is good AND the ASPECT is flat OR southfacing AND it is close to PARKS AND it is close to RIVER AND it is close to SCHOOLS AND it is close to MARKETS AND it is close to TRAMWAY STATIONS AND it is not very close to RAILWAY AND it is not very close to HIGHWYS THEN it has an excellent location'

When the rules are examined, it can be seen that the site searched must be the best one according to each criteria. So when we look at the Table 5.2 we see that a great deal (%83,5 - 23289 among 27904) of the buildings are in the %0 – 20 suitability interval. It means that it is very hard to find the excellent location that suits all the criteria together. 1391 (5%) of the buildings are in the %20 – 40, 1102 (%3,9) of the buildings are in the %40 – 60 and 1217 (% 4,4) of the buildings are in the %60 – 80 suitability interval.Only 905 (3,2%) of the buildings are really (80-100%) good located according to the criteria used in this study.

The FZRBS method mentioned above is executed using the SOM (Smallest of Maximum) defuzzification type. In addition to this, another FZRBS resultant map is obtained by implementing the COA (Center of Area) defuzzification type. It is aimed to see (Table 5.2) the probable different outcomes occurring because of the different execution types. When the table is examined it can be generally observed that when different types in model properties are used, different results are obtained. According to these two SOM and COA defuzzification types the numbers of most suitable buildings are 905 and 2123 respectively.

Table 5.2 Building suitabilities according to two different defuzzification types

BUILDING SUITABILITY - FZRBS				
Suitability Groups	No of Pixels		No of Buildings	
	Defuzzification Types		Defuzzification Types	
	SOM	COA	SOM	COA
% 0-20 (1)	3632829	362702	23289	22927
% 20-40 (2)	12352	10411	1217	886
% 40-60 (3)	11716	9256	1102	938
% 60-80 (4)	9904	10970	1391	1030
% 80-100 (5)	8199	16661	905	2123

In addition to the maps of FZRBS method, in the other four site suitability maps, firstly the 9 criteria are grouped. As a result of this three groups that are named “physical environment”, “amenity & transport”, and “pollution & noise” are constituted. First group is composed of good slope, good aspect, close to parks, and close to river criteria. Close to schools, close to markets, and close to tramway stations are the criteria of the second group and the last group is composed of the no railway noise and no highway pollution (noise). In the four scenarios, different weights are given to each criterion and they are combined according to the weighted overlay approach.

In the scenario a (Table 5.4), the weights are 0.3, 0.3, and 0,4 for the three criteria groups by order. When we examine the number of buildings for the 5 suitability groups, we see that there are 409 (% 1,5) buildings in the first (% 0–20) suitability group. There are 2377 (% 8,5) buildings in the % 20-40 interval, 11491 (%41,2) buildings in the % 40-60 interval, 11783 (% 42,2) buildings in the % 60-80 interval, and 1844 (% 6,6) buildings in the % 80-100 interval.

The weights are 0.3, 0.5, and 0.2 in the scenario b (Table 5.5). According to the results of the 5 suitability groups (Table 5.5), it is seen that % 38,3 of the buildings are in the %40 – 60 interval, that means it is the most crowded class. The second crowded suitability class is the %60 – 80 class with 8399 (% 30,1) buildings. The %0 – 20 interval has 472 (% 1,7), %20 – 40 suitability class has 6887 (% 24,7), and the %80 – 100 interval has 1453 (% 5,2) buildings.

In the scenario c (Table 5.6), 0.4, 0.1, 0.5 are weights by order. In this scenario % 6,5 (1822) of the buildings are in the % 0 - 20, % 4,3 (1206) of the buildings are in the %20 – 40, % 62,1 (17330) of the buildings are in the % 40 – 60, %16,3 (4535) of the buildings are in the % 60 – 80 interval. And the % 80 – 100 interval has 3011 buildings with 10,8 percentage among all of the buildings.

In the scenario d (Table 5.7), % 0 – 20 interval has 395 (%1,4), % 20 – 40 interval has 12454 (%44,6), % 40 – 60 interval has 11627 (%41,7), % 60 – 80 interval has 1835 (% 6,6), and the % 80 – 100 interval has 1593 (%5,7) buildings.

At the end of the suitability analysis of the buildings, each building has three kinds of resultant data which of first is the suitability values assessed at the end of this study and the other two are the vulnerability values of the same buildings. Here the first value changes according to five different analyses while the two are constant. Vulnerability values are the Seismic Risk Analysis Software (SRAS) (Küçükçoban, 2004) results of the buildings according to the two earthquake scenarios. The first scenario is the Gölcük (Mag: 7,4 Dept: 40 km.,Dist 140 km.) earthquake and the other is the İnönü Fault Zone (Mag: 5, Dept: 30 km.,Dist 18 km.) earthquake and they were assessed in a thesis study (Servi, 2004). Below, there is an example of a map (Figure 5.23) obtained according to the comparison of the suitability and the vulnerability values.

According to these three values metioned above, it is possible to make different kinds of interpretations about the value and the potential of the buildings. It gives idea to the people dealing with the real estates in Odunpazarı, Eskişehir area.

In the Tables 5. 3 – 5. 7, we see the number of buildings in each suitability group according to the four different suitability and two different earthquake scenarios in addition to the FZRBS results.

We can reach the results of ‘number of people’ in each suitability and vulnerability group. First of all we can not reach the same results according to these five suitability maps. In other words it is not possible to generalize the results of all scenarios. For example, according to the FZRBS results, 9093 people are living in the best located but higly vulnerable (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km. earthquake) areas whereas this number is 15256, 18612, 27040, and 18320 for the scenarios a,b,c, and d respectively.

When we examine the results it is seen that, places selected as the “good located (locationally suitable)” are mostly densed in the centre of the city, (beween river and the Hasan Polatkan Boulevard) near or around the markets and the tramway stations. Moreover, hospitals are the places where the locationally suitable settlements are aimed to dense around. Also in the results in which the ‘Pollution & Noise’ criteria is weighted more (scenarios a and c), the zone around the highway that is passing through the east – west direction (Hasan Polatkan and Adnan Menderes Boulevards), in the middle of the study area is dense with unsuitable buildings.

In further studies some other criteria of environmetal, social or personal factors such as power-lines, theatres, and income distribution may be added. Also in this study, the MFs are determined according to the studies in literature. And when the MFs selected for the slope and aspect are examined, it is observed that they are not unsuitable comparing to the histograms of the slope and aspect maps. However in the determination of the MFs of linguistic variables, it is better to make more detailed studies.

Table 5.3 No of buildings according to FZRBS and the vulnerability values of the two earthquake scenarios

Suitability Group	No of Buildings											
	FZRBS		Vulnerability (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km.)				FZRBS		Vulnerability (İnönü Fault Zone Mag: 5, Dept: 30 km.,Dist 18 km.)			
	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X
% 0-20	23289	83,5	0	9869	13091	329	27837	99,8	231	2079	9047	11932
% 20-40	1217	4,4	0	454	734	29	45	0,2	10	118	518	571
% 40-60	1102	3,9	0	433	645	24	22	0,1	9	117	483	493
% 60-80	1391	5,0	0	512	835	44	0	0,0	24	148	588	631
% 80-100	905	3,2	0	342	531	32	0	0,0	16	100	334	455
	27904	**100,0**	0	11610	15836	458	**27904**	**100,0**	290	2562	10970	14082

Table 5.4 No of buildings according to scenario (a) and the vulnerability values of the two earthquake scenarios

Suitability Group	No of Buildings											
	Scenario a		Vulnerability (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km.)				Scenario a		Vulnerability (İnönü Fault Zone Mag: 5, Dept: 30 km.,Dist 18 km.)			
	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X
% 0-20	**409**	**1,5**	0	53	355	1	**409**	**1,5**	2	17	151	239
% 20-40	**2377**	**8,5**	0	873	1449	55	**2377**	**8,5**	33	278	926	1140
% 40-60	**11491**	**41,2**	0	5253	6162	76	**11491**	**41,2**	78	880	4416	6117
% 60-80	**11783**	**42,2**	0	4715	6797	271	**11783**	**42,2**	158	1215	4712	5698
% 80-100	**1844**	**6,6**	0	716	1073	55	**1844**	**6,6**	19	172	765	888
	27904	**100,0**	0	11610	15836	458	**27904**	**100,0**	290	2562	10970	14082

Table 5.5 No of buildings according to scenario (b) and the vulnerability values of the two earthquake scenarios

Suitability Group	No of Buildings											
	Scenario b		Vulnerability (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km.)				Scenario b		Vulnerability (İnönü Fault Zone Mag: 5, Dept: 30 km.,Dist 18 km.)			
	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X
% 0-20	**472**	**1,7**	0	10	462	0	**472**	**1,7**	2	10	186	274
% 20-40	**6887**	**24,7**	0	2526	4314	47	**6887**	**24,7**	36	337	2631	3843
% 40-60	**10693**	**38,3**	0	5605	4940	148	**10693**	**38,3**	109	1113	4185	5286
% 60-80	**8399**	**30,1**	0	3046	5146	207	**8399**	**30,1**	130	933	3449	3887
% 80-100	**1453**	**5,2**	0	423	974	56	**1453**	**5,2**	13	129	519	792
	27904	**100,0**	0	11610	15836	458	**27904**	**100,0**	290	2522	10970	14082

Table 5.6 No of buildings according to scenario (c) and the vulnerability values of the two earthquake scenarios

Suitability Group	**No of Buildings**											
	Scenario c		Vulnerability (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km.)				Scenario c		Vulnerability (İnönü Fault Zone Mag: 5, Dept: 30 km.,Dist 18 km.)			
	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X
% 0-20	**1822**	**6,5**	0	573	1130	119	**1822**	**6,5**	45	193	698	886
% 20-40	**1206**	**4,3**	0	304	888	14	**1206**	**4,3**	10	95	492	609
% 40-60	**17330**	**62,1**	0	8364	8841	125	**17330**	**62,1**	148	1619	6920	8643
% 60-80	**4535**	**16,3**	0	1380	3013	142	**4535**	**16,3**	69	450	1723	2293
% 80-100	**3011**	**10,8**	0	989	1964	58	**3011**	**10,8**	18	205	1137	1651
	27904	**100,0**	0	11610	15836	458	**27904**	**100,0**	290	2562	10970	14082

Table 5.7 No of buildings according to scenario (d) and the vulnerability values of the two earthquake scenarios

Suitability Group	**No of Buildings**											
	Scenario d		Vulnerability (Gölcük Mag: 7,4 Dept: 40 km.,Dist 140 km.)				Scenario d		Vulnerability (İnönü Fault Zone Mag: 5, Dept: 30 km.,Dist 18 km.)			
	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X	Number	%	X <= 0,20	0,20 <= X < 0,40	0,40 <= X < 0,60	0,60 < = X
% 0-20	**395**	**1,4**	0	26	369	0	**395**	**1,4**	2	9	157	227
% 20-40	**12454**	**44,6**	0	5660	6637	157	**12454**	**44,6**	106	1034	4787	6527
% 40-60	**11627**	**41,7**	0	4783	6609	235	**11627**	**41,7**	161	1283	4726	5457
% 60-80	**1835**	**6,6**	0	635	1189	11	**1835**	**6,6**	8	102	727	998
% 80-100	**1593**	**5,7**	0	506	1032	55	**1593**	**5,7**	13	134	573	873
	27904	**100,0**	0	11610	15836	458	**27904**	**100,0**	290	2562	10970	14082

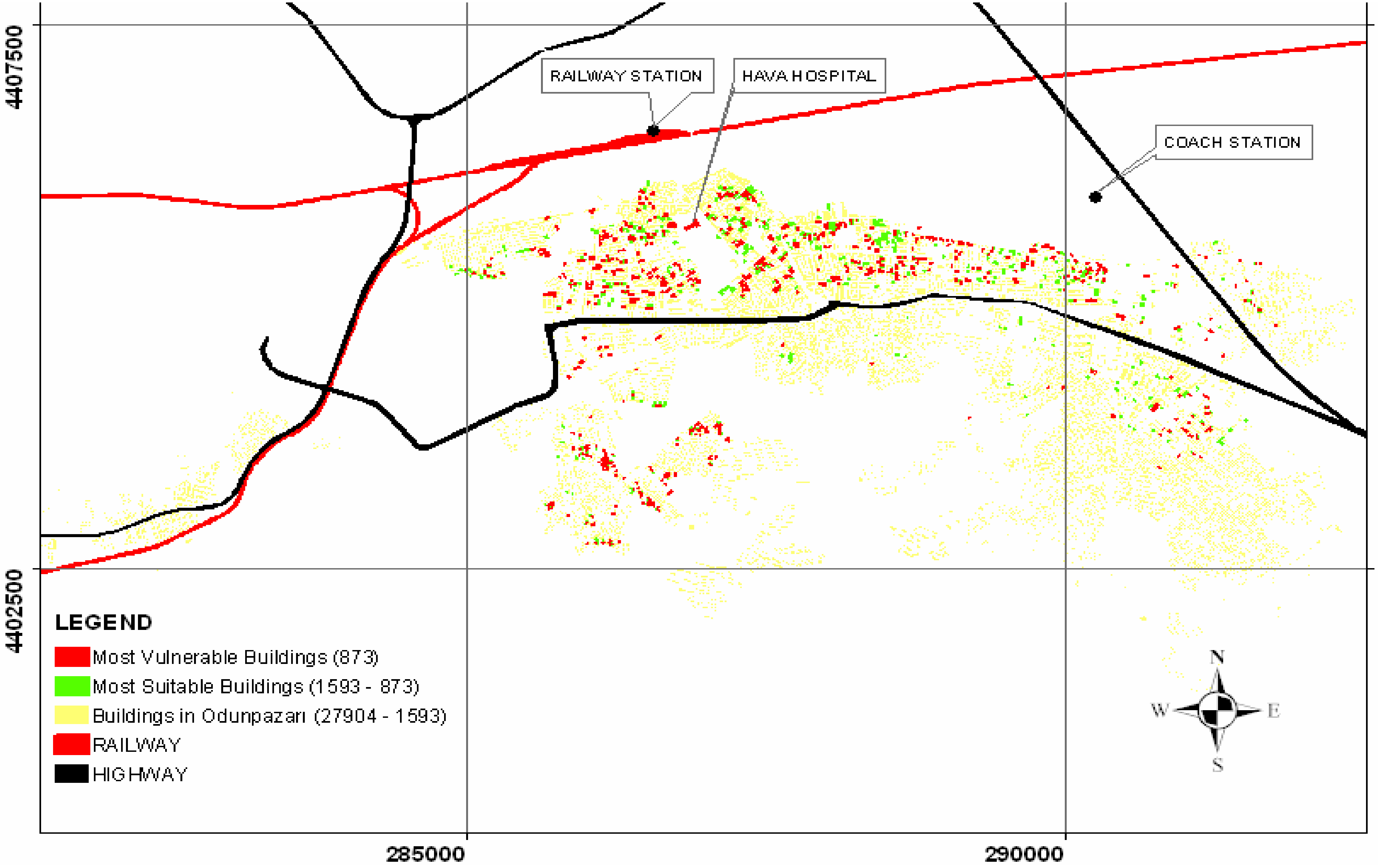

Figure 5.23 According to the İnönü Fault Zone; 873 most vulnerable buildings among the 1593 most suitable buildings according to the sensitivity scenario (d)

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Spatial decision making using GIS can handle many decision making problems. Selection of the locationally suitable sites for real estate is one of these issues. This study aims to develop a prototype of a real estate GIS. This prototype of a real estate GIS integrating fuzzy set theory is developed on a systematic basis as a spatial decision support tool where the traditional methods are based on the manual processes in the real estate industry. Uncertainty in defining selection criteria and the fuzzy boundaries of different factors are the problems that can be mitigated by the help of this system. In addition to this, rule-based system used to codify expert knowledge with fuzzy sets also mitigates the problem of data starvation. To summarize, integrating rule-based system, fuzzy set theory, and the GIS is too much useful for the spatial decision in real estate industry. In addition to these by integrating the vulnerability value with the site suitability values, this system gives detailed information about the value and the potential of the buildings. Here, as we live in a potential earthquake zone, it is useful for us also to have information about the vulnerability of the building we live in.

As the system has capabilities dealing with uncertainties, it can be used in different studies that are related with spatial decision making. In addition to the real estate industry, this prototype can be implemented to many other fields involving site selection such as city planning, locating social facilities etc. integrating the suitable and richer data.

Also in recent days, mortgage system is started to be discussed among people in Turkey. The government is working to legalize this system. This situation brought a great deal of action to the real estate market. The credit interest rates are falling down rapidly. People who do not have a house are trying to buy a house for themselves. So demand for the housing is increasing day by day. And this situation resulted in the increase in real estate values. So in this situation people who are planning to buy a house for repaying in 20 – 30 years must be more careful about this. Because they have not the chance of changing the real estate they bought before the time ends. Here, his prototype can help people in selecting the best property from the point of view of location and vulnerability to earthquake hazards.

In addition to the great market in built environment, the construction sector for creating new urban areas has a huge acceleration. This system can also help the investors of the public and private sector in site selection for new constructions.

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