GIS BASED MULTIPLE CRITERIA DECISION SUPPORT SYSTEM FOR URBAN PLANNING PROBLEMS IN GAZİANTEP

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ABSTRACT

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Finding new service facility location is one of the main applications of industrial engineering. Service facility location problem has multiple criteria and multiple alternatives. Therefore, the solutions of such problems are difficult. Geographic Information System (GIS) provides some easy ways to solve such difficult problems. In this thesis, a multiple criteria decision support system based on the Geographic Information Systems is developed facility location type urban planning problems. The developed system is applied to three different urban planning location problems in Gaziantep.

Three different urban planning problems are investigated in this study: *determination of locations for hospitals in Gaziantep*, *determination of locations for supermarkets in Gaziantep*, and *determination of locations and the numbers of the police stations in Gaziantep*. In the first case, Analytic Hierarchy Process (AHP) is integrated with GIS to determine alternative places in which hospitals can be established and to select the best place for the hospital. A computer program is developed for that purpose by using Visual Basic and MapBasic programming languages. In the second application supermarket location problem is studied by using simple additive weighting method (SAW) and GIS. In the third case, Set Covering Algorithm(SCA) is used with GIS for determination of locations and number of the police stations in Gaziantep. The problem is solved by means of a computer program developed by Visual Basic.

Keywords: Geographic Information Systems (GIS), Decision Support Systems, Multicriteria Decision Support System, Set Covering Algorithm, Buffer Analysis, Analytic Hierarchy Process (AHP), Simple Additive Weighting Method (SAW).

ÖZ

CBS TABANLI ÇOK KRİTERLİ KARAR DESTEK SİSTEMİ GELİŞTİRİLMESİ, GAZİANTEP İLİ ŞEHİR BÖLGE PLANLAMASINDA UYGULAMASI

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Yeni yerleşim yerinin bulunması endüstri mühendisliğinin ana uygulama alanlarından biridir. Servis yerleşim yeri problemi çok kriterli ve çok alternatiflidir. Bu nedenle bu tür problemlerin çözümleri zordur. Coğrafik bilgi sistemi(CBS) böyle zor problemlerin çözümünde bazı kolaylıklar sağlamaktadır. Bu tezde, şehir bölge planlama problemleri için coğrafik bilgi sistemi tabanlı çok kriterli bir karar destek sistemi geliştirilmiştir. Geliştirilen sistem Gaziantep ilinde üç örnek üzerinde uygulanmıştır.

Yapılan çalışmada, şehir bölge planlama problemlerinden olan kuruluş yerleşim yeri ve sayısının belirlenmesi ile ilgili olarak; hastane yerleşim yeri, supermarket yerleşim yeri ve polis istasyonlarının dağılım düzeyi problemleri incelenmiştir. Hastane yerleşim yeri problemi için çok kriterli karar destek sistemi araçlarından analitik hiyerarşi prosesi (AHP) CBS ile birlikte uygulanmıştır, bu amaçla Visual Basic ve MapBasic kullanılarak bir bilgisayar programı geliştirilmiştir. Supermarket yerleşim yeri belirleme problemin de ise basit ağırlıklandırma yöntemi (BAY) CBS'ne entegre edilmiş, geliştirilen yöntem Visual Basic kullanılarak yazılan bir bilgisayar programıyla desteklenmiştir. Son olarak, takım kapsama algoritması (KKA) ve CBS model alınarak Visual Basic'de bir bilgisayar programı geliştirilmiş ve polis istasyonlarının sayısı ve yeri bu programla belirlenmiştir.

Anahtar Kelimeler: Coğrafik Bilgi Sistemi, Küme Kapsama Algoritması, Analitik Hiyerarşi Prosesi, Çok kriterli Karar Destek Sistemleri, Tampon Analizi, Basit Ağırlıklandırma Yöntemi.

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ABBREVIATIONS

GIS: Geographic Information System

AHP: Analytic Hierarchy Process

SAW: Simple Additive Weighting Method

WLC: Weighted Linear Combination

SCA: Set Covering Algorithm

OLE: Object Linking and Embedding

ODBC: Open Database Connectivity

API: Applications Programming Interface

DSS: Decision Support System

MDSS: Multicriteria Decision Support System

MADM: Multi attribute Decision Making

MODM: Multiple Objective Decision Making

SDSS: Spatial Decision Support System

GPS: Global Positioning System

CR: Consistency Ratio

RCI: Random Consistency Index

x_{ij} : Scores of Criteria

w_j : Weighting of Criteria

CHAPTER I

INTRODUCTION

1.1. Introduction

From 1980 application of GIS has been largely expanded so that in the developed countries, most universities, commercial organizations and governments use these systems for different purposes. The different purposes help to develop GIS in different parts according to the needs of each region and country. GIS is revealed in many areas. This chapter briefly introduces the context of the thesis. In the first section, a literature review is given. The methodology and materials used in the solution procedure are explained in section 1.3. Objectives of the thesis are explained in section 1.4. In the final section the organization of the thesis is presented.

1.2. Literature Survey

Some of the applications concerning GIS are health, fire and location of services, etc… One of the applications concerning GIS is urban planning. These applications are usually related to government and municipalities. Therefore, many different applications concerned urban planning are being developed.

Many models have been developed for the facility location problems and allocation problems in urban planning. In the literature there are many studies. One of the studies was developed by Heung-Suk (2001). He explained public facility location based-on GIS using the stochastic set covering algorithm (Heung-Suk, 2001). Another application was developed by Eldrandaly who explained the problems about site selection for industry where integrated expert systems and ArcGIS program are used (Eldrandaly et al. 2003). Peter explored integrating GIS and Management Science as general (Keenan, 1998). Badri discussed the allocation problems for global facility location using AHP and goal programming (Badri, 1999). Malczewski has dealed with site selection problems theoretically (Malczewski, 1999b). Korpela and Tuominen discussed the solution of warehouse site location problem with spatial decision support system tools (Korpela, Tuominen 1996). Abu-Khater discussed GIS Applications in Urban Design which is related to the use of GIS in managing urban sprawl and urban growth, downtown revitalization (Abu-Khater, 2002). WOODAI CALS Co. developed a computer program for selecting the site by using overlapping method (WOODAI CALS Co, 2003).

In this thesis, first hospital facility location problem is explained in urban planning. Buffer analysis and grid method are used together to find alternative facility locations. The second application is concerned with supermarket facility location problem. Simple Additive Weighting Method (SAW) is used in this application. The last application is concerned with allocation problems which uses the Set Covering Algorithm for allocation of police stations.

In the literature, there are not enough studies concerning the hospital facility location problems in urban planning. In addition to this, tools used for selecting facility location are usually package programs such as expert systems. These programs perform less sensitivity and certainty because of relativity. The present thesis uses the grid method and buffer analysis. This application is also based on point level. It is not related to district or region level as coverage. Determined alternative facility locations are evaluated using AHP. Grid method means dividing the selected district with respect to specified dimensions. Both of them also perform consistency. Buffer analysis and grid method are appropriate for selecting hospital facility location. After identifying hospital facility locations, Analytic Hierarchy Process is applied to select the best location.

1.3. Methodology and Materials

In the thesis, all used data such as GIS maps etc… related to Gaziantep City from obtained Gaziantep TEDAS, Geyik and Velioğlu, (2005).

All applications in the thesis are carried out in Gaziantep which has two sub-municipalities and its population is nearly one million.

In the hospital facility location problem, the alternatives are first found and are enumerated respectively. While the alternatives are being found, a computer program called “new hospital” is used for finding the alternative hospital facility locations. Finding the best alternative is supplied by a computer program written in Visual Basic programming language. The computer program performs to user or decision maker using AHP method. The computer program written in Visual Basic is used to provide the shell for OLE-Automation between MapInfo and Visual Basic. MapInfo program provides the GIS platform to manage the spatial data and conduct the required spatial analysis operations.

Supermarket facility location problem in Gaziantep is solved by using a computer program. The computer program is written in Visual Basic. Simple Additive Weighting Method (SAW) is used for determining the best choice. In addition, the computer program performs to integrate between Visual Basic and MapInfo. Weighting values are obtained from questionnaire for AHP Approach for Supermarket Facility Location Problem Study in Gaziantep University, Baykasoğlu et al. (2003)

Police station allocation problem is solved by a computer program written in Visual Basic. The computer program is used to solve a Set Covering Algorithm (SCA) for police station locations.

Tools used for facility location problems and allocation problems, in this thesis, are MapInfo, MapBasic, Visual Basic, Multicriteria Decision Support Systems, Geographic Information Systems (GIS) and Spatial Multicriteria Decision Support Systems.

1.4. Objectives of the Thesis

Urban planning reflects the real life systems more realistically. Urban planning consists of many applications such as sewing system, water, fire, health, transportation and so on. In this thesis, it is aimed to solve facility location problems by using GIS.

This thesis mainly concentrates on the following themes;

- Identifying, operation and usage of GIS as a decision support tool

- An overview to GIS based multicriteria decision support system(MDSS)

- Investigation of the facility location problems according to MDSS tools

- Investigation of the allocation problem according to Set Covering Algorithm(SCA)

1.5. Organization of the Thesis

The brief content of the chapters in this thesis can be stated as follows:

- In Chapter 2, definition, operation and components of GIS are explained. Advantages and disadvantages of GIS are discussed.

- In Chapter 3, decision support systems and GIS-based decision support systems are presented. Some of the solution approaches for urban planning problems are examined in detail.

- In Chapter 4, the first case study, "hospital facility location problem" is explained.

- In Chapter 5, the second case study, "supermarket facility location problem" is explained.

- In Chapter 6, the third case study, "police station facility location problem" is explained.

- In Chapter 7, a brief summary of this thesis and the conclusions drawn from this study are presented.

CHAPTER II

AN OVERVIEW OF GEOGRAPHIC INFORMATION SYSTEM

2.1. Introduction

This chapter introduces the context of geographic information systems in detail. In Section 2.3. GIS components are presented, GIS operation is described in section 2.4. In section 2.5. advantages and disadvantages of GIS are explained. In section 2.6 GIS application areas are described. In section 2.7. recommendations to municipalities and government about GIS applications are presented. In section 2.8. and section 2.9 integrated mapping and OLE-Automation are explained. In the last section, conclusions obtained from this chapter are given.

2.2. Geographic Information System

GIS appeared in the literature in early 1960s Lo and Yeung (2002). GIS's use in siting analysis started in late 1970s, Jones and Barron (2002), (Quiambao, 2001), Wright et al. (1998), (Murta, 1996). The success of GIS in siting problems is attributed to its ability to perform deterministic overlay and buffer operations (Carver, 1991).

Geographic Information Systems are widely used nowadays. However, it has not been widely used in Turkey. In addition to this, usage of GIS is increasing gradually. Geographic Information System is a combination of skilled persons, spatial and descriptive data, analytic methods, and computer software and hardware all organized in a system to automate, manage and deliver information through geographic presentation. In other words, Geographic Information Systems (GIS) is a computer-based technology and methodology for collecting, managing, analyzing, modeling, and presenting geographic data for a wide range of applications.

Geographic information system permits the data sets to be linked spatially. This provides a powerful tool for processing and integration of large amounts of data from many different sources in their spatial context. GIS also significantly facilitates the manipulation of spatial data, enables spatial analysis capabilities, and enhances the visualization of analytical processes and results. The procedures related to GIS applications usually have to deal with rather complex multidisciplinary spatial databases and requires intensive processing and integration of the spatial information. Thus, the consensus is that GIS assessment is preferably conducted on a GIS software platform. A unique quality of a GIS is its ability to integrate diverse types of data into a common geographic framework models via software.

2.3. Components of GIS

A GIS can be divided into five components: People, Data, Hardware, Software, and Method (Figure 2.1). All of these components need to be in balance for the system to be successful. No one part can run without the other.

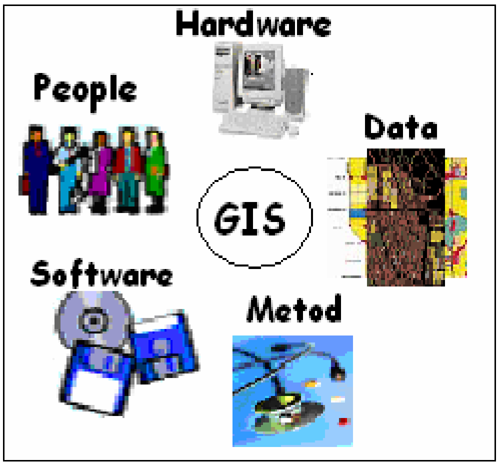


Figure 2.1 Components of GIS

People

People are the component who actually makes the GIS work. They include a plethora of positions including GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for maintenance of the geographic database and provide technical support. People also need to be educated to make decisions on what type of system to use. Continuity of

GIS depends on people component. People associated with a GIS can be categorized into: viewers, general users, and GIS specialists, Lo and Yeung (2002).

- Viewers are the public at large whose only need is to browse a geographic database for referential material. These constitute the largest class of users.

- General Users are people who use GIS to conducting business, performing professional services, and making decisions. They include facility managers, resource managers, planners, scientists, engineers, lawyers, business entrepreneurs, etc.

- GIS specialists are the people who make the GIS work. They include GIS managers, database administrators, application specialists, systems analysts, and programmers. They are responsible for the maintenance of the geographic database and the provision of technical support to the other two classes of users.

Data

Perhaps the most time consuming and costly aspect of initiating a GIS is creating a database. There are several things to consider before acquiring geographic data. It is crucial to check the quality of the data before obtaining it. Errors in the data set can add many unpleasant and costly hours to implementing a GIS and the results and conclusions of the GIS analysis most likely will be wrong. Several guidelines to look at include, Guptill (1995):

- Lineage – This is a description of the source material from which the data were derived, and the methods of derivation, including all transformations involved in producing the final digital files.

- Positional Accuracy – This is the closeness of an entity in an appropriate coordinate system to that entity's true position in the system.

- Attribute Accuracy – An attribute is a fact about some location, set of locations, or features on the surface of the earth. This information often includes measurements of some sort, such as temperature or elevation or a label of a place name. (Guptill, 1995)

• Logical Consistency - Deals with the logical rules of structure and attribute rules for spatial data and describes the compatibility of a datum with other data in a data set. There are several different mathematical theories and models used to test logical consistency such as metric and incidence tests, topological and order related tests. These consistency checks should be run at different stages in the handling of spatial data.

• Completeness – This is a check to see if relevant data is missing with regards to the features and the attributes. This could deal with either omission errors or spatial rules such as minimum width or area that may limit the information (Chrisman, 1999).

At the same time data can be divided into two parts. These are geographical or spatial and nonspatial data shortly described as follows.

Geographical data (Spatial data)

It is estimated that 80% of data used by managers and decision makers is related geographically (Worrall, 1991). Because of this, geographical data include all of raw information that are used by decision-maker. The kinds of these data are observation, map, image, statistics, location, census, volume etc. In addition to this decision-makers are usually used spatial data which referred to a location on the Earth's surface. That is, it can be considered as a form of geographical data. For example, in this thesis, the population and existing hospital places according to districts are data. But geographical data is raw material. Only data are not meaningful for decision-maker or user. It is necessary to process from raw materials to useful material. Data must be transformed into information. Information is meaningful for decision-maker. For becoming information of data, they are organized, gathered, presented, analyzed, interpreted and considered useful for a particular decision problem. Information is used by the decision-maker and is derived from original data. Becoming information of converting data adds extra values to the original data. Process converting data are progressively converted into information about the decision situation or decision problem. The situation determines the need and the nature of the information required. In other words that the situation is sub-target for reaching the main-target.

Geographic data save and display in two base data structure. Also a computer image can be represented in two formats (Figure 2.2). These are:

1. Vector data structure

2. Raster data structure

Vector Data Structure:

The location of a point feature, such as a bore hole, points, lines, polygons can be described by a single x, y coordinate. Linear features, such as roads and rivers, can be stored as a collection of point coordinates. Polygonal features, such as sales territories and river catchments, can be stored and encoded as a closed loop of coordinates. The vector model is extremely useful for describing discrete features, but less useful for describing continuously varying features such as soil type or accessibility costs for hospitals. That is these data structure are easy displaying on the screen. Also saving in the storage such as hard disk, do not cover much volume. Converting from vector to raster data structure it can cause missing the data structure, Batty et al. (1998).

Raster Data Structure

A type of computerized picture consists of row after row of tiny dots (pixels). This data structure is a kind of geographic data models. If solubility is increased, it needs more storage field. Raster images are sometimes known as bitmaps. Aerial photographs and satellite imagery are common types of raster data found in GIS. It is efficient to coincide two or more layers each other. In this data structure is important solubility (Goodchild, 2003).

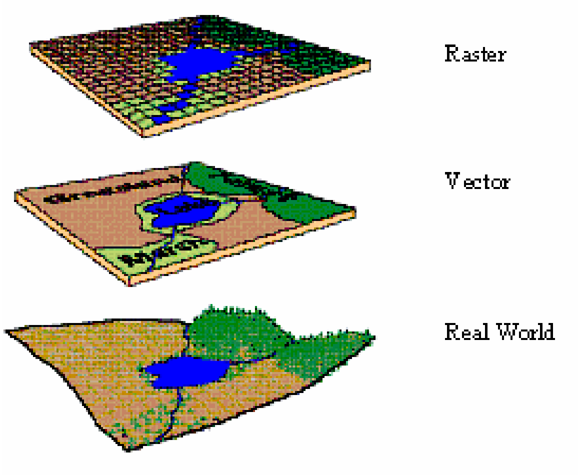


Figure 2.2 Raster and Vector Data Structures (Saab, 2005)

Both the vector and raster models for storing geographic data have unique advantages and disadvantages and modern GIS are able to handle both types.

Non-spatial Data

Non-spatial data has no specific location in space. It usually saves as a table and each qualitative data are defined by element of spatial data. It can however, have a geographic component and be linked to a geographic location. Tabular and attribute data are non-spatial but can be linked to location (Moon, 2003). For an example about non-spatial data, in this thesis, district maps is spatial feature and the associated information about the district name, population are non-spatial attributes which are linked to the park by its location.

Hardware

Hardware consists of the technical equipment needed to run a GIS including a computer system with enough power to run the software, enough memory to store large amounts of data, and input and output devices such as scanners, digitizers, GPS data loggers, media disks, and printers. In other words, it is to input data and they are managed and presented (Figure 2.3).

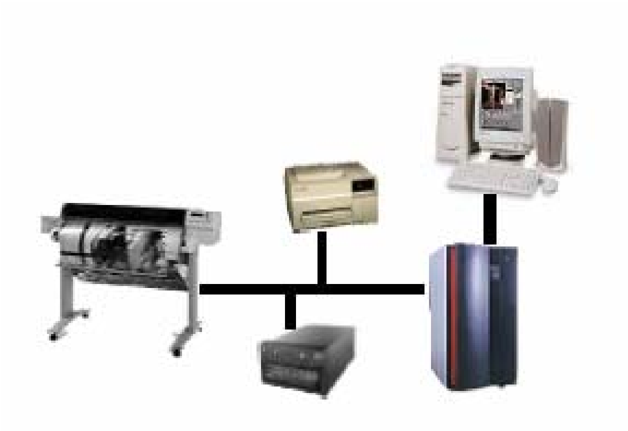


Figure 2.3 Hardware tools (Haithcoat, 1999)

Software

There are many different GIS software packages available today. All packages must be capable of data input, storage, processing, management, transformation, analysis, querying, output and providing relation between geographic coordinate and locations. The appearance, methods, resources, and ease of use of the various systems may be very different. Today's software packages are capable of allowing both graphical and descriptive data to be stored in a single database, known as the object-relational model. Before this innovation, the geo-relational model was used. In this model, graphical and descriptive data sets were handled separately. The modern packages usually come with a set of tools that can be customized to the users' needs (Spatial Information, 2005).

Some of the used software packages are Bentley GIS, AutoDesk, Esri, GE Smallworld, Intergraph, and MapInfo. In this study is used MapInfo Professional 6.0 which is considered the pioneer of desktop GIS. MapInfo Professional is a leading business mapping software capable of performing sophisticated and detailed data analysis. A few features of this package are (MapInfo, 2005):

- Ability to create detailed maps
- Locate patterns and trends
- Perform extensive data analysis
- Demographic analysis

- Remote database support
- Plug-ins to enhance functionality (Guptill,1995)

MapInfo have MapBasic which is capable of programming. It also integrates with the other computer programming language such as Visual Basic, Delphi, and C/C++. In this study Visual Basic is used to integrate MapInfo for developing applications

Method (Procedures)

Procedures include how the data will be retrieved, input into the system, stored, managed, transformed, analyzed, and finally presented in a final output. The procedures are the steps taken to answer the question need to be resolved. The ability of a GIS to perform spatial analysis and answer these questions is what differentiates this type of system from any other information systems.

The transformation processes includes such tasks as adjusting the coordinate system, setting a projection, correcting any digitized errors in a data set, and converting data from vector to raster or raster to vector (Carter, 1998).

2.4. GIS Operations

Geographic operations in GIS are converting map coordinate, combining maps, converting maps to variety form, raster and vector analyze, obtaining maps, buffer analyze, etc. The important side of GIS software must have geographic analyze features. Although many software are used spatial or geographic data, they are not called GIS software. GIS is different from such software. In GIS relation between spatial data and geographic coordinate are vital.

Querying: For obtaining required information is an operational asking question.

Combining Data Layers: Two or more data layer can be combined through the GIS (Figure 2.4).

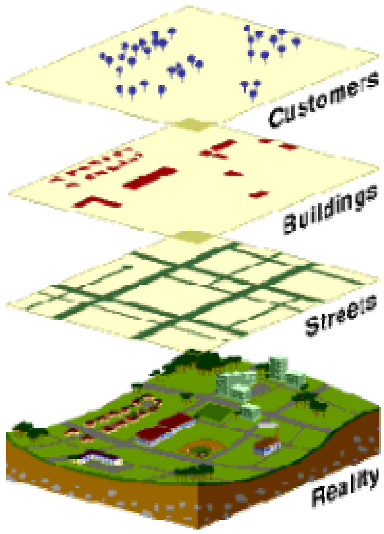


Figure 2.4 Combining Data Layers (Donnell, 2005)

Map Operations: This is performed by using digitizer obtaining the map.

Statistics Analyze: Embedding tools in GIS software are applied statistics analysis to manage data converting to the meaningful data. (Information)

Interpolation: From present state data are derived to new data.

Combining Data and Spatial Statistics: Two or more data layer are combined to expose for spatial statistics.

Buffer Analysis: It is to obtain data or information in specified distance from the determined object or point. This component takes a shapefile and outputs a new dataset that consists of the union of the buffers around each individual feature at the given distance. The output polygon feature will buffer in specified distance (Figure 2.5). This component falls into the category of GIS Vector Analysis functions. The arguments for this function are:

- Input File: Complete path to the dataset around which the buffer will be calculated.

- Distance: Buffer distance in the map's coordinate units (according to the coordinate system definition).

- Output File: Name of the output file that will contain the buffer.

This important feature is used in Hospital Facility Location.

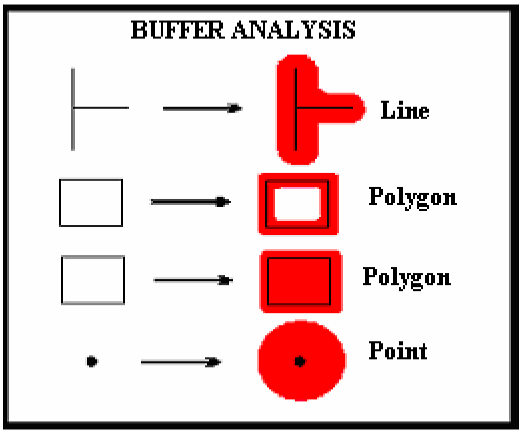


Figure 2.5 Buffer Analysis (Baykasoğlu et al. 2003)

2.5. Benefits of GIS

GIS supports the strategic planning process in all phases, by providing good and proper information patterns referring to the questions than has been asked, in a flexible way. On the other side, GIS cannot be supportive if problem definition is not valid – it is not a tool for overcoming the planning concept weaknesses. GIS enables permanent, efficient and valuable environmental data gathering, which is the one of the primary conditions for successful strategic planning model implementation. Spread network of data collecting units provide a significant time saving and than even more with ability of fast data overlapping. Than with inner validity control and generic capabilities provide effectiveness arise in sense of using more accurate and right information in specific problem solving. GIS provides appropriate problem identification information base. Its possibility to generate a wide range of data patterns related and understandable to all participants in a planning process makes possible accurate problem definition. GIS is substantive tool for providing information base for all necessary analysis methods witch has to be performed in strategic planning process (Introduction to GIS, 2004).

Information systems of older generation ware union of linear databases environment, which allowed search and processing of information. But, clear spatial visioning was missing. In that sense GIS made a significant progress. GIS technology has broadened the view of a map. Instead of a static entity, a map is now a dynamic presentation of geographic data. A map is the interface between geographic data and perception (Royal Town Planning Institute, 1992).

Benefits of GIS

- Links spatial data with geographic information about a particular feature on a map.
- GIS can use the stored attributes to compute new information about map feature.
- GIS performs exact matching, hierarchical matching, and fuzzy matching.
- Data stored in digital format, so physically more compact
- Large quantities of data can be maintained and retrieved at greater speeds
- Geospatial data are better maintained in a standard format
- Lower cost of maintaining and retrieving data
- Revision and updating are easier
- Data integration
- Maintaining data consistency
- Capability of data updating
- Capability of data processing and modeling
- Automated mapping
- Provision of complex spatial analysis
- Geospatial data and information are easier to search, analyze and represent
- Add more value to products
- Geospatial data can be shared and exchanged freely
- Productivity of the staff is improved and more efficient

- Time and money are saved
- Single source of data (eliminates duplication and redundancy)
- New capabilities (database queries, overlays for new information)
- Accurate, up-to-date accessible data
- Contiguous, consistent database
- Linked graphic and non-graphic data
- Better, quicker, and more accurate answers for the public
- A GIS is not simply a computer system for making pretty maps. More importantly a GIS is an analysis tools

Disadvantages of GIS

- GIS need skilled person
- GIS software is expensive
- GIS applications are complex
- Process leads to long term

2.6. GIS Application Areas

- Archaeology
- Agriculture
- Defence and intelligence
- Electric and Gas
- Engineering Pipeline
- Engineering Surveying

- Government
- Fire/Disaster Homeland Security
- Forestry
- Health and Human Services
- Insurance
- Education
- Landscape Architecture
- Law Enforcement and Criminal Justice
- Libraries and Museums
- Location Services
- Marine, Coast and Oceans
- Media
- Mining and Earth Sciences
- Natural Resources
- Petroleum
- Real Estate
- Retail Business
- Telecommunications
- Transportation
- Water and wastewater
- Universities (Esri, 2002)

Guidelines for Initializing the GIS on the Municipality Government Level and Private Sector Level

In many areas of business, such as manufacturing and banking, organizations must meet government regulations regarding pollution and interstate trade. GIS provides tools to help companies comply with local, state, and national regulations. In forestry, military, floods, hurricanes, telecommunication, transportation, sewing systems, water systems, fire department and etc. can be used GIS. Geographic Information Systems (GIS) provide an electronic representation of information—spatial data—about the earth's natural and man-made landscape. A GIS system stores each category of information in a separate "layer" for ease of maintenance, analysis and visualization. Layers can represent terrain characteristics, roadways, census data, demographics information, environmental and ecological data. The systems use real-time data from many diverse sources such as satellite imagery, aerial photos, maps, ground surveys and global positioning systems (GPS). As results GIS are absolutely added the value to applications of government, municipalities and business (Laloviç, 2004).

Recommendations to the Government, Municipalities and Business

Designing GIS takes time and intensive work among all institutions, public and private sector/services and their employees. Here are some word experiences to ease the designing process and ensure success shortly.

Involve users. GIS applications in private or public sector includes user. It is essential for design.

Take it one step at a time. It is not necessary to create a complete detailed design all at once; design is an interactive and iterative process. That can progress in stages as appropriate for the needs of organization.

Build a GIS team. A wide range of information, skills, and decision making is required during this process. At different stages, team will comprise various experts throughout enterprise.

Be creative. The initiation of a new project is a good opportunity to survey new technology and processes.

There is considerable potential to enhance how GIS serves organization’s goals and objectives.

Create deliverables. It is best to divide a large project into discrete and identifiable units of work. Project milestones must be defined to be no less frequent than two months or so. This will keep project focused and earn management support.

Keep organizational goals and objectives in focus. It is essential that the design and implementation process always be focused on the real requirements of organization and its customers.

Do not add detail prematurely. Detail must be added at the appropriate step. For example, do not try to define all of the validation rules for feature classes before geodatabases are constructed. Selectively introduce implementation details throughout the project so that the team can progress to the next step.

Document carefully. The more complex the environment greater is the benefit from documenting design. The use of business diagramming software is especially useful to communicate design.

Be flexible. The initial design will not be the final design as implemented. The design will evolve as organization changes, new technology is introduced, and people become more adept with the technology.

Plan from model. Create an implementation plan that addresses organization’s key priorities in a manageable fashion. If new datasets are needed, build the data management applications first.

The present age is still in the beginning of a new e-government(municipality, business) era. But its importance is reflected in an international community decision to proclaim this field of work as a strategically important task.

GIS tools are public sector product as generally. In fact only 30% of GIS and DSS tools users are private companies whose business is related to spatial recourses. Their development is a result of all governmental levels needs to increase work efficiency and effectiveness. Nowadays development of these tools is a global activity, developers of GIS tools, although they are competitive, especially consider compatibility and adaptability of its products.

2.7. Conceptual Overview of Integrated Mapping

GIS is not to obtain information from data only. Also it is to support multicriteria decision analysis. GIS allows decision-makers incorporate a spatial dimension in their decision making. The spatial dimension means that applications include routing or location analysis, or assignment problem. GIS includes complex software system. Comprehensive decision support will require the effective integration of GIS and modeling techniques. This can be achieved by building systems using a GIS as a decision support system (DSS) generator. The building by recent technical developments both within GIS software and in programming tools generally.

The ability to integrate GIS software and models is being facilitated by renewable software techniques which allow a variety of forms of interaction between the GIS software and the modeling software. The simplest from of software interaction is the exchange of data. In its most basic form, this might be achieved by a program preparing a file which is then used by other software. This inquires a common file format for use by both pieces of software. Current trends favour the use of integrated databases (ODBC), API and OLE. This has led to the use of common standards that allow a wide range of programs interchange data. In this thesis, OLE Automation is used. MapInfo is manipulated by constructing strings that represent MapBasic statements from Visual Basic, using OLE Automation to send the strings to MapInfo. Here string means that functions, method or control statements. When from Visual Basic send to MapInfo program by calling a command, MapInfo launches silently in the background without display a splash screen. When MapInfo map window place into application, do not embed it; instead, “reparent” the window by sending MapInfo a series of command strings. The end result is that MapInfo windows appear to the user as child windows of application. Because of this, OLE will be explained shortly.

2.8. OLE-Automation in Visual Basic as Integrated Tool

OLE has been developed by Microsoft. It focuses on integrating between two programs. It has components. Each component has its own data and some documented operations on that data commands can be sent to that component from other programs to perform those operations. Therefore, a program can be written in one of several programming languages. This provides a degree of flexibility not found with the API approach. The main advantage of this approach is the flexibility and it allows in the integration of different types of software (Keenan, 1998).

In this thesis, a distinct feature of the present work is to implement GIS between MapInfo and Visual Basic as a GIS platform. The integrated system analyses data extracted from the GIS and returns results to the GIS. In this way, the large amount of spatial data analyzed by the developed a computer program in Visual Basic and the results produced can be manipulated fully with the capabilities of the GIS technology. At the same time, this application increases the set of possible applications of GIS. The major advantages of using GIS-based methodology for public and private sector are as follows:

1. A GIS-based system as integrated the other computer programming language has the ability to objectively explore relationships. This is not supported with GIS a software tool only that is performed by using integrated mapping between relevant environmental factors and developed methods properly.

2. It accepts different types of mathematical parameters (e.g. class, ordinal, continuous and Boolean) as input or output values. Therefore, it is well suited for consolidating all multidisciplinary supplied optimizing-related factors, which are integrated into a model as completion.

3. All the spatial data can be easily edited, converted, rescaled, re-projected in a GIS Platform. The system is extremely flexible, capable of incorporating any improved new data set. As new information is entered, the final results will automatically be updated.

4. A GIS-based system is suitable for integrating required information with the other data such as remote sensing data, satellite imaginary which is of great importance in the present work.

2.9. Conclusions

In this chapter, GIS and GIS components are presented in detail. GIS operations are described. Advantages and disadvantages of GIS are determined. Recommendations are informed to the municipalities and government. The integrated mapping tools are described in detail. OLE-Automation, one of the integrated mapping methods between MapInfo and Visual Basic, is determined.

CHAPTER III

GIS BASED MULTIPLE CRITERIA DECISION SUPPORT SYSTEM

3.1. Introduction

In this chapter, a brief overview of GIS-based Multicriteria decision support systems is given. In section 3.1. decision support system is described with its components. Multicriteria decision support systems and some of the Multicriteria support systems tools are presented in section 3.2. In section 3.3. set covering algorithm is described. In the last section, spatial decision support system is explained.

3.2. Decision Support Systems

In the early 1980s, extensive research in DSS was made. These systems integrate data and models to help to solve unstructured problems (Sprague, 1980). These models consist of tools that take data as inputs, perform processing on the data, and create specific outputs of use to the decision maker. Models, for example, can be familiar analytical techniques such as set covering analysis, simple additive weighting method, regressions, forecasts, etc. In all cases, the analytical procedures are embedded in software and the data on which the analysis acts is provided through anything from manual input to automatic retrieval. These systems can be temporary. DSS using spreadsheets or other end-user oriented tools or formal systems cost hundreds of thousands of dollars. It is determined that a particular course of action/alternative from existing alternatives is selecting process, Hess at el. (2002).

The ultimate aim of GIS is to provide support for making spatial decisions. The GIS capabilities for supporting spatial decisions can be analyzed in the context of the decision process. Simon (1960) determined DSS into three elements. These are intelligence, design and choice (Malczewski, 1999a).

Intelligence: Any decision-making process begins with recognition of the decision problem. A spatial decision problem is the difference between the desired and existing state of a real-world geographical system. It is a “gap” between the desired and existing states as viewed by a decision maker. The intelligence phase involves searching or scanning the decision environment for conditions calling for decisions. During the intelligence phase raw data are obtained, processed, and examined for clues that may identify opportunities or problem. The data acquisition, storage, retrieval, and management functions convert the real world decision situation into the GIS. That is the intelligence try to find an answer of that question “is there a problem or an opportunity for chance?”

Design: This phase involves inventing, developing, and analyzing a set of possible solutions to problem identified in the intelligence phase. Alternatives may involve actions such as “close an existing plant,” “choose the best site location.” Typically, a formal model is used to support a decision maker in determining the set of alternatives. A model is a simplified representation or abstraction of reality. Because the real is complex. Also many of the complexity are actually irrelevant to the specific problem. It represents the decision situation by structuring and formalizing the available data and information about the decision problem. In that way about the decision problem for generating a set of alternative decisions are mainly based on the spatial relationship principles of connectivity, contiguity, proximity, and the overlay methods. It tries to find an answer of that question “What are the alternatives”?

Choice: While the generation of alternative decisions is purely part of the design stage, the evaluation of alternatives in mainly part of the choice phase. It involves selecting a particular course of action/alternative from those available. Each alternative is evaluated and analyzed in relation to others in term of a specified decision rule. It tries to find an answer of that question: “which alternatives are best?”

3.3. Multicriteria Decision Support System

These methods were developed to evaluate alternatives based on the decision maker’s subjective values and priorities, Mollaghasemi and Pet-Edwards (1997), Jankowski and Richard (1994). It is quite difficult to define precisely MCDS.

However, various definitions appear in literature. One common definition is that of Roy (1996). Roy (1996) postulates that MCDS is a decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often contradictory, in order to guide the decision maker(s) towards a judicious choice. Whatever the definition, it is generally assumed in MCDS that the decision maker has to choose among several options or alternatives. The set of alternatives is the collection of all alternatives. Selecting an alternative among this set depends on many characteristics, often contradictory, called criteria. Accordingly, the decision maker will generally have to be contented with a compromising solution.

Briefly Multi-Criteria Decision Making (MCDM) is related to the solution of problems that involve multiple attributes, objectives and goals. The Multicriteria problems are commonly categorized as continuous or discrete, depending on the domain of alternatives classify them as multiple attribute decision-making (MADM), and multiple objective decision-making (MODM). According to Zanakis et al. (1998), the former deals with discrete, usually limited, number of pre-specified alternatives. In this thesis, different MCDM techniques are used. These are analytic hierarchy process (AHP), simple additive weighting method (SAW). Set covering algorithm (SCA) is also used with GIS. They will be explained briefly.

3.3.1. Analytic Hierarchy Process

AHP is developed by Satty (1980) to help the decision maker to arrive at the best decision in a case of multiple conflicting objectives (criteria). Analytic hierarchy process (AHP), which is a flexible decision making tool for multi criteria problems, AHP is used in this study to determine relative importance of hospital facility location criteria. AHP helps decision makers to organize and evaluate the relative importance of selected objectives and the relative importance of alternative solutions. AHP contains multi level hierarchical structure: objective (goal), criteria (and sub-criteria), and alternatives. Decision maker provides judgments about relative importance of each criterion and then state a preference on each criterion for each decision alternative. Output of the process is ranked alternatives according to the preferences, Triantaphyllou and Mann (1995).

3.3.1.1. AHP Structure

AHP can be applied to a decision making problem after structured hierarchically at different levels: objective, criteria, and alternatives. The first level is the goal of the decision maker, several different factors combine the second level, and the last level of the hierarchy contains all the alternatives (Figure 3.1).

1. Goal – the goal of the decision

2. Criteria/objectives – elements that comprise the goal

3. Sub criteria – elements that comprise a given criteria or sub criteria

4. Alternatives – different solutions or choices that are available

Mathematically, Analytic Hierarchy Process is a simple matrix-based technique (Saaty, 1980). This matrix (Table 3.1) is formed by alternatives, decision criteria, and performance values of alternatives and weights of criteria.

If A_1, A_2, A_3, …, A_m and C_1, C_2, C_3, …, C_n indicate alternatives and criteria respectively. Then x_{ij} is the performance value of *i-th* alternative in terms of *j-th* criterion, and w_j is the weight of the criterion C_j:

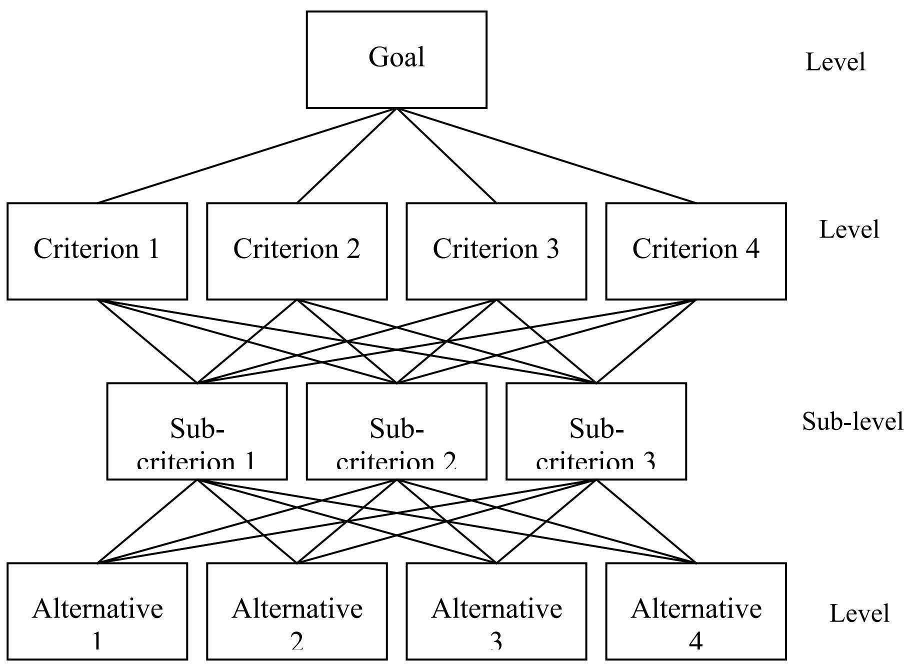


Figure 3.1 Hierarchical Structure of AHP

Table 3.1 Analytic Hierarchy Process Matrix

	C_1	C_2	…	C_j	…	C_n
	w_1	w_2	…	w_j	…	w_n
A_1	X_{11}	x_{12}	…	x_{1j}	…	x_{1n}
A_2	X_{21}	x_{22}	…	x_{2j}	…	x_{2n}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_i	x_{i1}	x_{i2}	…	x_{ij}	…	x_{in}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
A_m	x_{m1}	x_{m2}	…	x_{mj}	…	x_{mn}

3.3.1.2. Process of the AHP

The AHP divides the decision problem into the following main steps (Saaty, 1994):

1. Problem structuring.
2. Assessment of the local priorities.
3. Calculation of global priorities.

Decision problem is structured by defining the overall goal, decision criteria and sub-criteria, all possible alternatives, and putting them into the different levels of hierarchy (Figure 3.1).

The weights of the criteria and scores of the alternatives, which are called local priorities, are considered as decision elements in the second step of the decision process. The last step of the AHP aggregates all local priorities to obtain the global priorities used for ranking of the alternatives and selection of the best one (Mikhailov, 2002).

3.3.1.3. Pairwise Comparison

Analytic Hierarchy Process, like other decision making methods, needs to quantify qualitative data, and it uses pairwise comparison matrix for that purpose. AHP takes pairwise comparisons as inputs and converts them into relative weights as outputs. Pairwise comparisons are quantified by using a scale, with values from 1 to 9 to rate the relative preferences, proposed by Saaty (Saaty, 1994). There are some other 1-5, 1-7, 1-15, and 1-20 scales in the literature, however the most accepted and used one is Saaty's scale depicted in Table 3.2 Triantaphyllou and Mann (1995).

According to the scale, decision maker can use the values for the pairwise comparison from the set: {9, 8, 7, 6, 5, 4, 3, 2, 1, 1/2, 1/3, 1/4, 1/5, 1/6, 1/7, 1/8, 1/9}.

After constitution of the pairwise comparison matrixes for criteria and alternatives in terms of each criterion, decision maker has to extract the relative importance of criteria and scores of the alternatives from those judgment matrixes. The next step is to estimate the right principal eigenvector of the judgment matrix. Corresponding maximum left eigenvector is approximated by using the squaring matrix. That is, the matrix is to square and then the elements in each row are added, finally added each number is normalized by dividing the row sum by the row totals. Hence eigenvector for a judgment matrix is obtained (Saaty, 1990). This process must be iterated until the eigenvector solution does not change from the previous iteration. Unfortunately it is reality that achieving perfect consistency in pairwise comparison for real life situations is unusual. If decision maker evaluates that element *A* is much more important than element *B*, *B* slightly more important than element *C*, and *C* slightly more important than *A*, then judgments are inconsistent and decisions made by decision maker are distrustfully.

Consistency of comparison in a judgment matrix can be controlled by consistency ratio (*CR*) and comparison is considered to be sufficiently consistent if corresponding *CR* is less than %10 (Saaty, 1980). Consistency ratio (*CR*) is calculated by dividing consistency index (*CI*) by random consistency index (*RCI*).

$$CR = \frac{CI}{RCI} \tag{3.1}$$

To solve the above equation consistency index (CI) should be obtained first by using the formula:

$$CI = \frac{(\lambda_{\max} - N)}{(N-1)} \tag{3.2}$$

λ_{max} and N represent the maximum eigenvalue and number of elements compared respectively. The maximum eigenvalue λ_{max} is calculated by multiplying the original judgment matrix by priority vector and then summing these values over the rows. The next step is done by dividing the weighted sum vector by elements of the priority vector. The average value of this resultant vector is λ_{max} Zaim et al. (2004). Random consistency index (*RCI*) values are given in Table 3.3.

Table 3.2 Scale of Relative Importance (Triantaphyllou and Mann, 1995)

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	An activity is strongly favoured and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with *i*.	

Table 3.3 RCI values for different values of N.

N	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

3.3.1.4. Computing the Final Ranking

After the pairwise comparisons of criteria and alternatives in terms of each decision criterion, decision maker obtains relative importance of criteria (weight vector) and scores of the alternatives (priority vectors). Then the final step is the calculation of the overall scores (global priorities) of the alternatives to be used for ranking them. Final priority for alternative i can be calculated with the formula:

$$\sum_{j=1}^{n} x_{ij} w_j , \quad for\, i = 1,2,3,...m \tag{3.3}$$

This formula is used for each alternative at the third level of the hierarchy. Another representation of calculation of final priorities is possible with matrixes:

$$\begin{vmatrix} x_{11} & x_{12} & \cdots & x_{1j} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2j} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mj} & \cdots & x_{mn} \end{vmatrix} \quad \text{X} \quad \begin{vmatrix} w_1 \\ w_2 \\ \vdots \\ w_j \\ \vdots \\ w_n \end{vmatrix} \tag{3.4}$$

First matrix is combined with priority vectors; each column shows priority of alternatives for criterion j. Second matrix is weight vector of criteria. Multiplication these two matrixes yields a decision matrix containing final priorities of all alternatives. Decision maker uses these priorities for a final selection or combining with another decision making method for further applications.

Analytic hierarchy process (AHP) is a method designed to solve complex problems involving multi criteria. The process is based on the judgments of decision maker about the relative importance of each criterion and then specifying a preference on each criterion for each decision alternative.

Overall analytic hierarchy process is not used in this study, it is only processed to obtain relative importance of hospital facility location criteria; the relative importance for each criterion is not same for each position applied. Because each position/job has different characteristics and requirements to be performed by individuals, level of these characteristics and requirements should be determined particularly for each selection problem. Finally, AHP pairwise comparison is suitable for that purpose in the study.

3.3.2. Simple Additive Weighting Method

This method is the most often used technique for tackling spatial Multicriteria decision making. The technique is also referred to as weighted linear combination (WLC) or scoring method. They are based on the concept of a weighted average. The decision maker directly assigns weights of "relative importance" to each attribute. A total score is then obtained for each alternative by multiplying the importance weight assigned for each attribute by the scaled value given to the alternative on that attribute, and summing the products over all attributes. When the overall scores are calculated for all the alternatives, the alternative with the highest overall score is chosen. Formally, the decision rule evaluates each alternative, A_i, by the following formula:

$$A_i = \sum_j w_j x_{ij} \tag{3.5}$$

Where x_{ij} is the score of the ith alternative with respect to the jth attribute, and the weight w_j is a normalized weight, so that $\sum w_j = 1$. The weights represent the relative importance of the attributes. The most preferred alternative is selected by identifying the maximum value of A_i (i = 1,2,…..,m).

The GIS-based SAW method involves the following steps Malczewski (1999b):

1. Define the set of evolution criteria (map layer) and the set of feasible alternatives.

2. Standardize each criterion map layer.

3. Define the criterion weights; that is, a weight of "relative importance" is directly assigned to each criterion map.

4. Construct the weighted standardized map layer; that is, multiply standardized map layers by the corresponding weights.

5. Generate the overall score for each alternative using the add overlay operation on the weighted standardized map layers

6. Rank the alternatives according to the overall performance score; the alternative with the highest score (rank) is the best alternative.

The SAW methods can be operationalized using by GIS system having overlay capabilities. The overlay techniques allow the evaluation criterion map layers (input maps) to be aggregated to determine the composite map layer (output maps). The methods can be implemented in both raster and vector GIS environments, Eastman at el. (1995).

3.3.2.1. The Normalized (Standardized) Value

Generally, different attributes have different scales of measurement; all the attributes often conflict with each other and are incomparable. Normalization aims at obtaining comparable scales. The linear scale transformation methods convert the raw data into standardized criterion scores. A number of linear scale transformations exist. The simple formula is used for standardizing the row data is the following equations:

For a given attainment level of x_{ij} , the normalized value, y_{ij} , will be

$$y_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}} \qquad (3.6)$$

3.4. Set Covering Method

The set covering problem (SCP) is a well-known combinatorial optimization problem. Given a set of points P = {p1, p2… pm} indicates m row and a collection of subsets of P, {S1, S2…… Sn} indicate n column. Find the smallest number of subsets, S_i, such that the union of the S_i contains all points in P. 0-1 incidence matrix with m-row, n-column, and the problem is to select the minimum weight subset of columns while ensuring every row is covered, Kinney and Barnes (2004).

This problem can be formulated as a constrained optimization problem below:

Decision variables:

$$Xi = \begin{cases} 1 \text{ if } S_i \text{Subset is used} \\ 0 \text{ otherwise} \end{cases} \quad (3.7)$$

(i = 1… n. Hence there are n variables)

Constraints

$$\sum_{i \in I_k} x_i \geq 1 \qquad \text{For each } k = 1 \ldots m \text{ define} \quad (3.8)$$

$I_k = \{i\text{: } S_i \text{ contains } p_k\}$.

Objective Function:

$$\text{Minimize} \quad \sum_{i \in I_k} x_i \quad (\text{for k=1… m}) \quad (3.9)$$

3.5. Spatial Decision Support Systems

Spatial Decision Support System is the particular nature of the geographic data considered in different spatial problems. In addition, traditional DSS are designed primarily for solving structured and simple problems which make them non practicable for complex spatial problems. This requires adding to conventional DSS a range of specific techniques and functionalities used especially to manage spatial data. These additional capacities enable the SDSS to:

- Acquire and manage the spatial data,
- Represent the structure of geographical objects and their spatial relations,

- Diffuse the results of the user queries and SDSS analysis according to different spatial forms

- Including maps, graphs, etc., and

- Perform an effective spatial analysis by the use of specific techniques (Densham, 1991).

3.6. Conclusions

In this chapter, GIS-based multicriteria decision support tools are briefly presented. These are analytic hierarchy process, simple additive weighting method. Set covering algorithm is also presented in this chapter. Spatial decision support system (SDSS) is explained.

CHAPTER IV

GIS BASED DECISION SUPPORT SYSTEM FOR HOSPITAL FACILITY LOCATION

4.1. Introduction

In this chapter, GIS based hospital location problem is presented. In section 4.2 general knowledge is given about this application, in section 4.3 a computer program that is written in MapBasic programming language with using grid method and buffer analysis is explained.

In this application, a two-phase approach is used:

Phase1: Finding candidate hospital locations by taking into consideration the available hospitals. A computer program is developed in MapBasic for this purpose.

Phase 2: Evaluation of candidates found for the best hospital facility location using AHP. A computer program (called AHP Program) is developed in Visual Basic which is integrated MapInfo Program.

4.2. Hospital Facility Location

The overall structure of the proposed system is shown in Figure 4.1. The aim of the application is to find the best possible hospital locations using GIS and MCSS. For finding the hospital location problem is developed a computer program in MapBasic. After alternative hospital facility locations are found, the best possible hospital location is found using a computer program again. This program is developed in Visual Basic. Data used in this application are districts and hospital data (Figure 4.2).

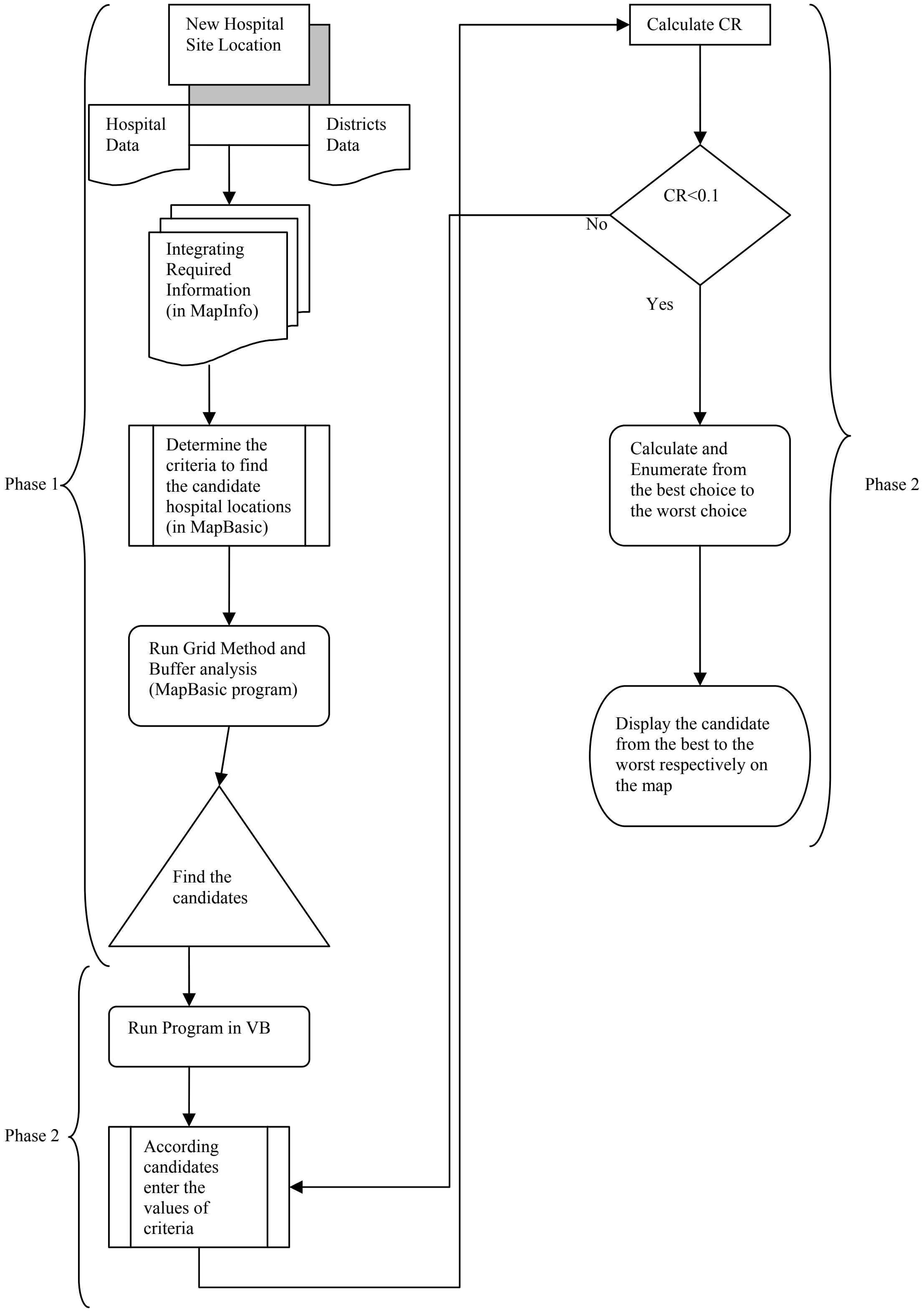


Figure 4.1 Structure of the Proposed Hospital Facility Location System

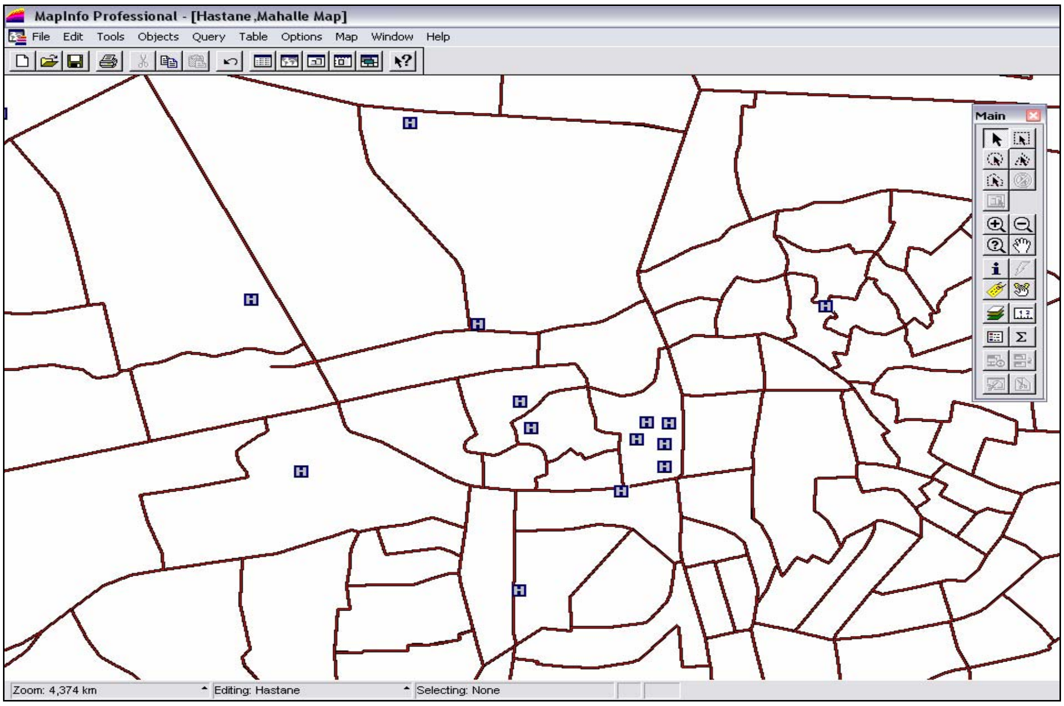
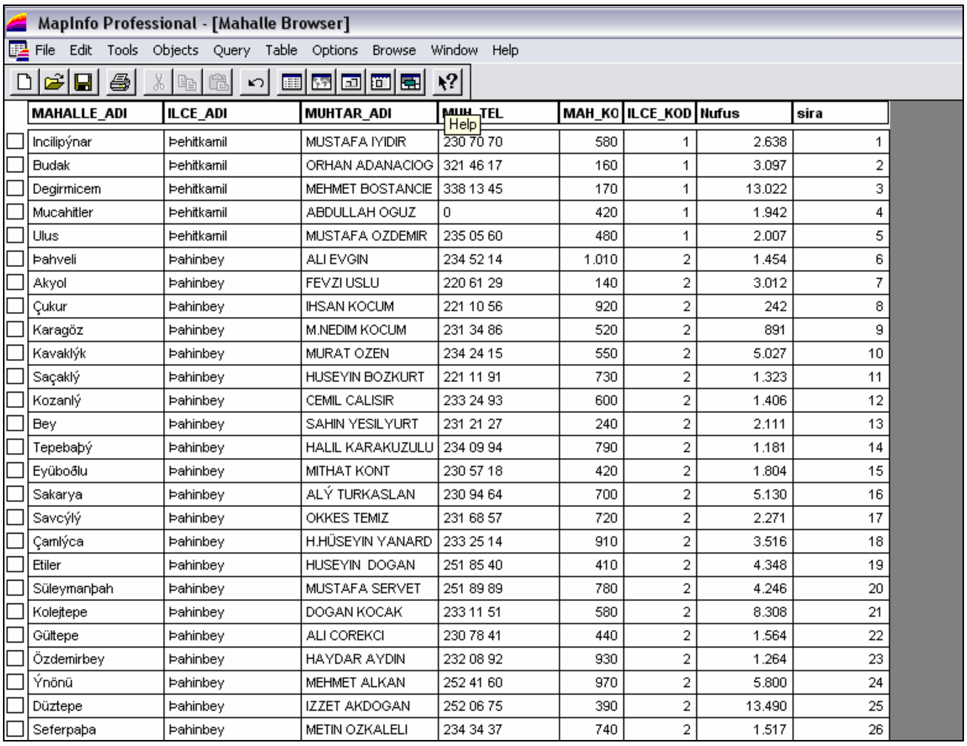


Figure 4.2 Displaying Districts and Hospital Data as Mapped

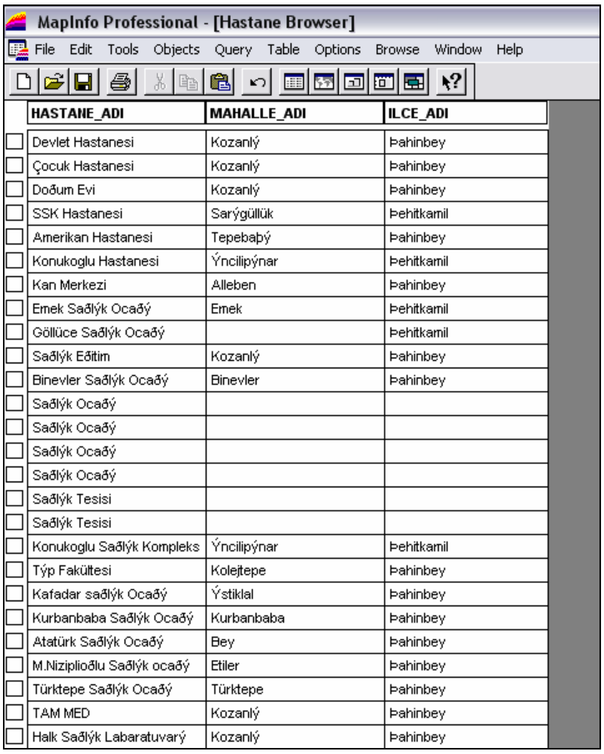
District data are MAHALLE_ADI, ILCE_ADI, MUHTAR_ADI, MUH_TEL, MAH_KODU, ILCE_KODU, Nufus and sira. (Figure 4.3) "Nufus" and "sira" data added to use later. Population data are quoted from 2001 year (Appendix A).



MAHALLE_ADI	ILCE_ADI	MUHTAR_ADI	MUH_TEL	MAH_KO	ILCE_KOD	Nufus	sira
Incilipýnar	Þehitkamil	MUSTAFA IYIDIR	230 70 70	580	1	2.638	1
Budak	Þehitkamil	ORHAN ADANACIOG	321 46 17	160	1	3.097	2
Degirmicem	Þehitkamil	MEHMET BOSTANCIE	338 13 45	170	1	13.022	3
Mucahitler	Þehitkamil	ABDULLAH OGUZ	0	420	1	1.942	4
Ulus	Þehitkamil	MUSTAFA OZDEMIR	235 05 60	480	1	2.007	5
Þahveli	Þahinbey	ALI EVGIN	234 52 14	1.010	2	1.454	6
Akyol	Þahinbey	FEVZI USLU	220 61 29	140	2	3.012	7
Çukur	Þahinbey	IHSAN KOCUM	221 10 56	920	2	242	8
Karagöz	Þahinbey	M.NEDIM KOCUM	231 34 86	520	2	891	9
Kavaklýk	Þahinbey	MURAT OZEN	234 24 15	550	2	5.027	10
Saçaklý	Þahinbey	HUSEYIN BOZKURT	221 11 91	730	2	1.323	11
Kozanlý	Þahinbey	CEMIL CALISIR	233 24 93	600	2	1.406	12
Bey	Þahinbey	SAHIN YESILYURT	231 21 27	240	2	2.111	13
Tepebaþý	Þahinbey	HALIL KARAKUZULU	234 09 94	790	2	1.181	14
Eyüboðlu	Þahinbey	MITHAT KONT	230 57 18	420	2	1.804	15
Sakarya	Þahinbey	ALÝ TURKASLAN	230 94 64	700	2	5.130	16
Savcýlý	Þahinbey	OKKES TEMIZ	231 68 57	720	2	2.271	17
Çamlýca	Þahinbey	H.HÜSEYIN YANARD	233 25 14	910	2	3.516	18
Etiler	Þahinbey	HUSEYIN DOGAN	251 85 40	410	2	4.348	19
Süleymanþah	Þahinbey	MUSTAFA SERVET	251 89 89	780	2	4.246	20
Kolejtepe	Þahinbey	DOGAN KOCAK	233 11 51	580	2	8.308	21
Gültepe	Þahinbey	ALI COREKCI	230 78 41	440	2	1.564	22
Özdemirbey	Þahinbey	HAYDAR AYDIN	232 08 92	930	2	1.264	23
Ýnönü	Þahinbey	MEHMET ALKAN	252 41 60	970	2	5.800	24
Düztepe	Þahinbey	IZZET AKDOGAN	252 06 75	390	2	13.490	25
Seferpaþa	Þahinbey	METIN OZKALELI	234 34 37	740	2	1.517	26

Figure 4.3 District Data as Browsed

Hospital Data consist of HASTANE_ADI, MAHALLE_ADI, ILCE_ADI (Figure 4.4).



HASTANE_ADI	MAHALLE_ADI	ILCE_ADI
Devlet Hastanesi	Kozanlý	Þahinbey
Çocuk Hastanesi	Kozanlý	Þahinbey
Doðum Evi	Kozanlý	Þahinbey
SSK Hastanesi	Sarýgüllük	Þehitkamil
Amerikan Hastanesi	Tepebaþý	Þahinbey
Konukoglu Hastanesi	Ýncilipýnar	Þehitkamil
Kan Merkezi	Alleben	Þahinbey
Emek Saðlýk Ocaðý	Emek	Þehitkamil
Göllüce Saðlýk Ocaðý		Þehitkamil
Saðlýk Eðitim	Kozanlý	Þahinbey
Binevler Saðlýk Ocaðý	Binevler	Þahinbey
Saðlýk Ocaðý		
Saðlýk Ocaðý		
Saðlýk Ocaðý		
Saðlýk Ocaðý		
Saðlýk Tesisi		
Saðlýk Tesisi		
Konukoglu Saðlýk Kompleks	Ýncilipýnar	Þehitkamil
Týp Fakültesi	Kolejtepe	Þahinbey
Kafadar saðlýk Ocaðý	Ýstiklal	Þahinbey
Kurbanbaba Saðlýk Ocaðý	Kurbanbaba	Þahinbey
Atatürk Saðlýk Ocaðý	Bey	Þahinbey
M.Niziplioðlu Saðlýk ocaðý	Etiler	Þahinbey
Türktepe Saðlýk Ocaðý	Türktepe	Þahinbey
TAM MED	Kozanlý	Þahinbey
Halk Saðlýk Labaratuvarý	Kozanlý	Þahinbey

Figure 4.4 Hospital Data as Browsed

4.3. Development of the Model

4.3.1. Overview of the Model

Estimating, improving and solving of the model consist of two phases. Phase 1, finding candidate(s) hospital site location. This is achieved by the computer program written in MapBasic. Phase 2, enumerating candidate site location from new hospital locations found. This is also achieved by using the computer program developed in Visual Basic.

Phase 1: Finding the Candidate Hospital Site Location

Before AHP is used in multicriteria decision support system, for finding the candidate site locations a computer program is developed in MapBasic.

Two criteria are taken into consideration in writing program. These are:

1. All the districts' population which are intersected or included in buffer analysis must be greater than 10 % of the general population.

2. The program checks whether there is another hospital in the buffer area.

Assumption

1. Buffer size is taken as 500meters.

2. It is assumed that the program will scan from the first district to the last district respectively.

4.3.2. Progressing of the Model

There are 168 districts for scanning. As shown in Figure 4.5, districts layer and hospital are come into one layer. Called "new hospital" program written in MapBasic is run for finding new hospital facility location. After that "Selective Hospital" is shown in MapInfo menu. If selective hospital is clicked, user interface is seemed like in Figure 4.5. In this thesis, it is assumed that the dimensions of imaginary hospital site location (ISL) are 100X100 meters and from the first district to tenth district will be scanned.

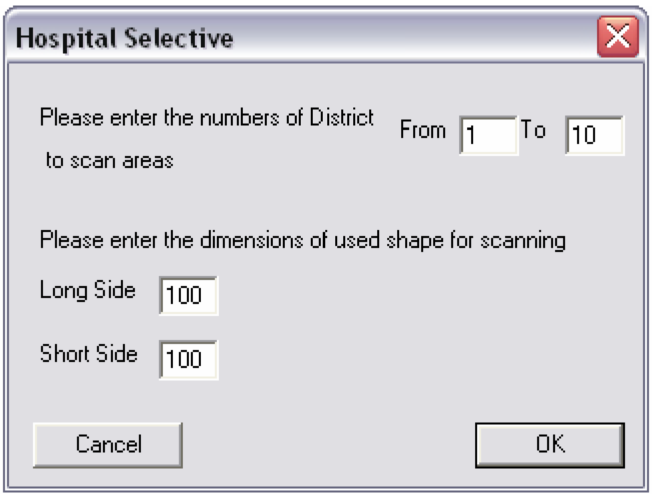


Figure 4.5 Imaginary Hospital Site Location User Interface

All districts can be scanned at once. If this way is selected, MapInfo program is locked. Because hospital facility location which don't have the criteria is erased and sent to temporary file directory of the computer. These files are reached up to 9999 file, and then the program restarts from the first file. In this thesis, all the districts file, and then the program restarts from the first file. In this thesis, all the districts must be scanned ten by ten for the solution of the problem. After each ten-district scan is completed, MapInfo program is closed. So temporary file directory is cleaned automatically. Then, MapInfo is restarted for other scans.

1. After user or decision maker enter the values required at user interface, if OK button is pressed, they are launched to grid function. Grid function is like in Table 4.1.

Table 4.1 The Code of Grid Function

```
Function GridMaker (byval tname as string, byval x1 as float, byval y1 as float, byval x2 as float, byval y2 as float, byval dx as float, byval dy as float) as integer
Dim i as integer
Dim x as float
Dim y as float
If dx=0 or dy=0 then
Exit Function
End if
nx=(x2-x1)/dx
ny=(y2-y1)/dy
x=x1
y=y1
 For i=1 to nx
For j=1 to ny
Create rect into variable o (x,y) (x+dx,y+dy)
Insert into tname (obj) values (converttoregion(o))
Call buffer_atama
x=x+dx
y=y+dy
Next
y=y1
Next
End Function
```

In this function, value of dx stands for short side and value of dy stands for long side. Scanning of the all districts is realized by this function. If grid function is run without taking into consideration "call buffer_atama" statement (in line 16), Figure 4.6 will be appeared.

Figure 4.6 means that after grid function selects the first district from the districts file, the first district is divided into squares which have the long side of 100 meters and the short side of 100 meters.

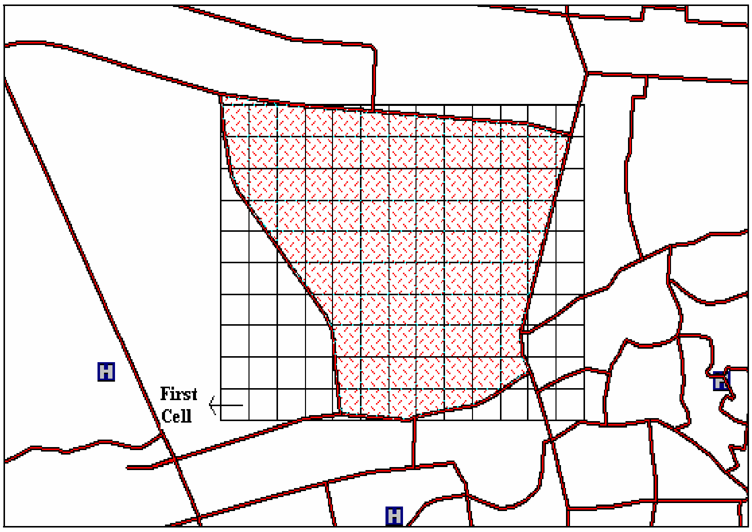


Figure 4.6 Grid Function

2. After the grid function selects the district, the first scan is started with the first grid from lower side to upper side. If grid function is run with "call buffer_atama" statement (in line 16), the first grid is constituted and at that time, this first grid will be imaginary hospital site location. Also the first grid will be initial point for buffer analysis. (Figure 4.7)

In this thesis, buffer analysis is applied by using the grid method.

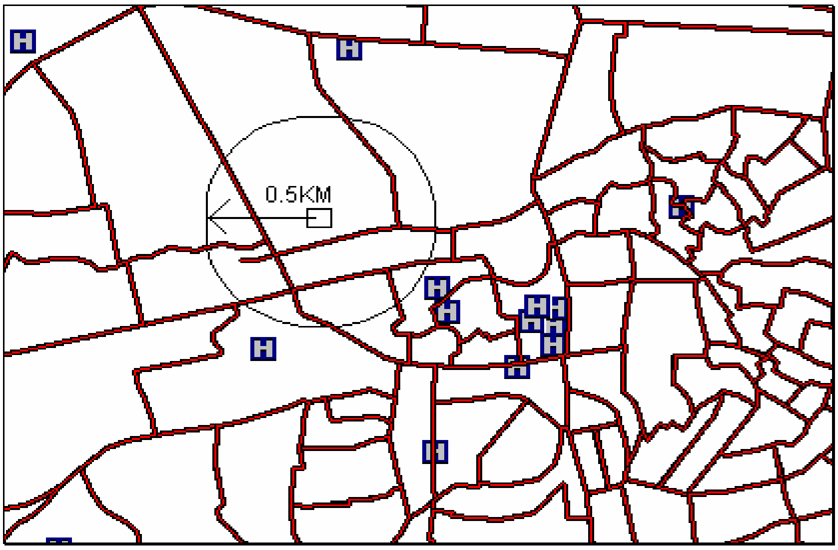


Figure 4.7 The First Grid and Buffer Analysis

Buffer analysis's code written in MapBasic appears in Table 4.2.

Table 4.2 The Code of Buffer Analysis

```
Sub buffer_atama
Dim sec_nufus,ox,oy as integer
Dim buf as object
i=i+1
Select * from hastane where rowid=i
Create object as buffer from selection
Into variable buf width 0.5 Units “km"
Select * from mahalle where mahalle.obj intersects buf
Select Nufus from selection
Fetch first from selection
sec_nufus=mahalle.nufus
Do While Not EOT (selection)
Fetch next from selection
sec_nufus=sec_nufus + mahalle.Nufus
Loop
Select * from hastane where hastane.obj intersects buf
sec_hastane=tableinfo (selection, TAB_INFO_NROWS)
Select * from hastane where rowid=i
```

Table 4.2 The Code of Buffer Analysis (Continue)

```
If (sec_nufus<tum*0.1) then
Delete from selection
Else
If (sec_hastane>1) then
Delete from selection
Else
z=z+1
sechas(z)=selection.obj
End if
```

3. Buffer analysis will buffer on the point of the last Imaginary hospital site location (ISL).

4. The position of the first grid is x=0 and y=0 as coordinate. This position is also position of imaginary site hospital. From this position, 500 meters radius will constitute buffer. The total population of all districts in buffer area, intersected or included by buffer area is calculated automatically. As viewed in Figure 4.8, districts intersected and included in buffer area are İncilipınar, Degirmiçem, Sarıgüllük, Kavaklık, Allaben, Akyol, Bahçelievler and Kolejtepe.

5. The population found by buffer analysis is 49841. The population of all districts is 963974. According to the first criterion, the relative population is less than 10 % of the total general population. If the first grid is not supplied, “buffer_atama” procedure will delete the imaginary site location. If the first grid had been applied, it would pass the second criterion.

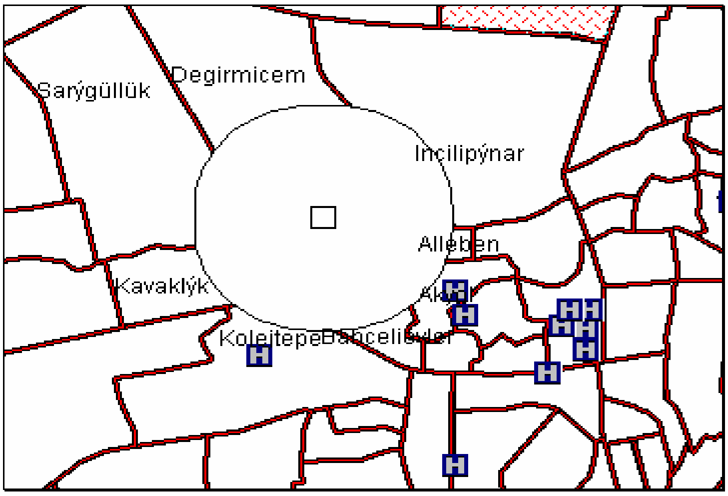


Figure 4.8 All Districts Intersected and Included in Buffer Area

6. Because the first criterion can not be applied, the first grid (imaginary hospital site location) is not a candidate. The first grid will be deleted, and then buffer analysis is going to constitute the second grid (Figure 4.9). The first grid is deleted, and then launched to temporary files. If the first and second criteria had been supplied by the first grid, it would be candidate hospital site location.

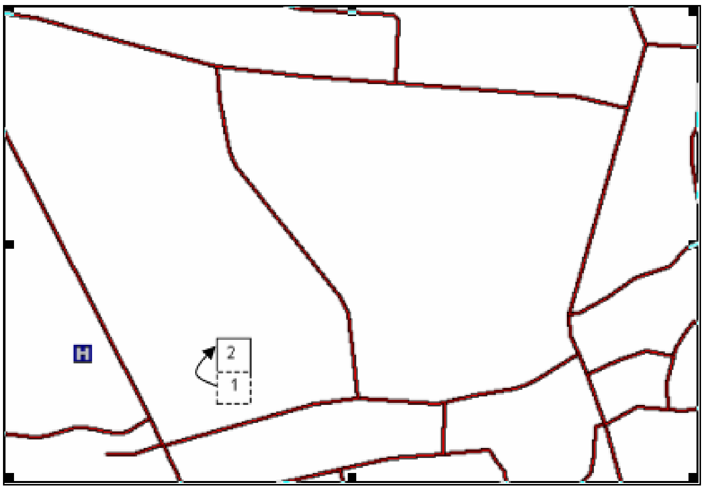


Figure 4.9 Constituting the Second Grid by Grid Function

7. Here grid function will approximately constitute between 150.000 and 200.000 imaginary site locations and this process will take 8 hours approximately. After all districts are scanned, in this application, 7 candidates are found (Figure 4.10). After this stage, the candidates found are enumerated by using Analytic Hierarchy Process (AHP) from the best choice to the worst choice.

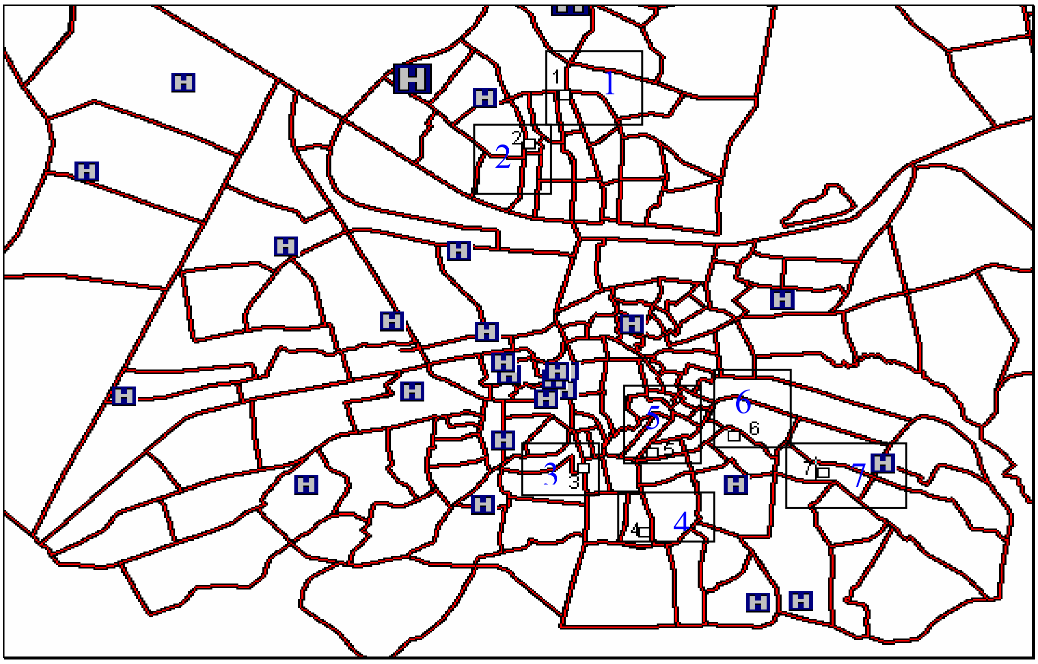


Figure 4.10 Displaying of Seven Candidates Found by Using Grid Method and Buffer Analysis

Phase 2: Enumerating the Choices according to weightiness respectively

As mentioned in section 4.1 the solution of AHP Model is supplied by a computer program written in Visual Basic as integrated MapInfo Professional (Figure 4.11).

At user interface (Figure 4.11), on the left side of the user interface, there are text cells to enter the values required. On the right side of the user interface, there are new hospitals, districts and old hospitals maps. The number of criteria is limited to 5 and the number of alternatives is limited to 7. Here there are seven candidates and three criteria. Criteria are population, environmental conditions and transportation.

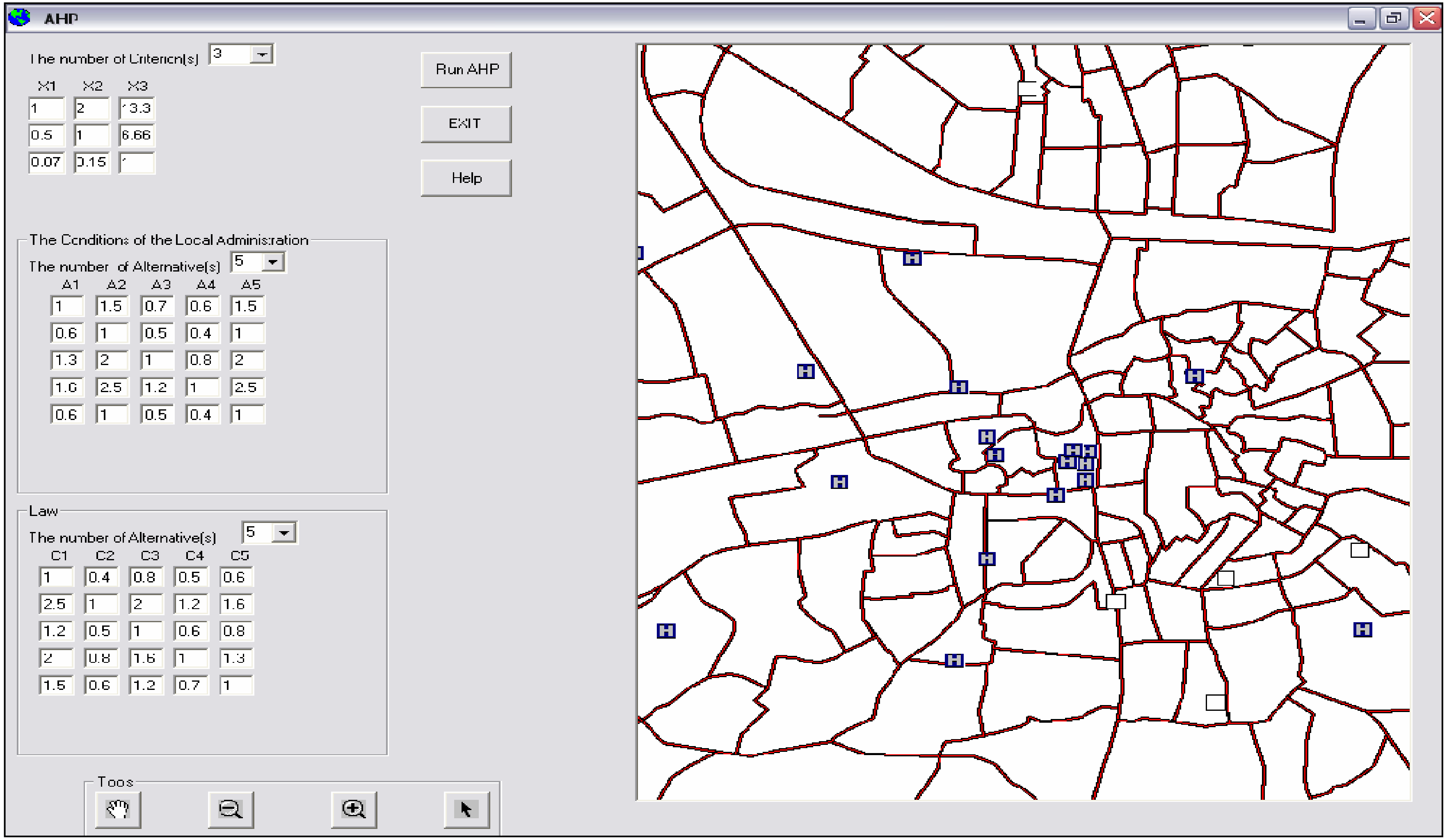


Figure 4.11 User Interface for AHP Model

4.3.2.1. The Aim of AHP Model:

According to the three criteria, the best candidate is selected among the alternatives. These criteria are:

1. Like in phase 1, relative population will be taken into consideration.

2. Environmental conditions consist of sewer system, water, nearness to the fire station, green area, etc…

3. Transportation

4.3.3. Execution of the AHP Model

1. The alternatives and criteria are displayed as hierarchical structure (Figure 4.12).

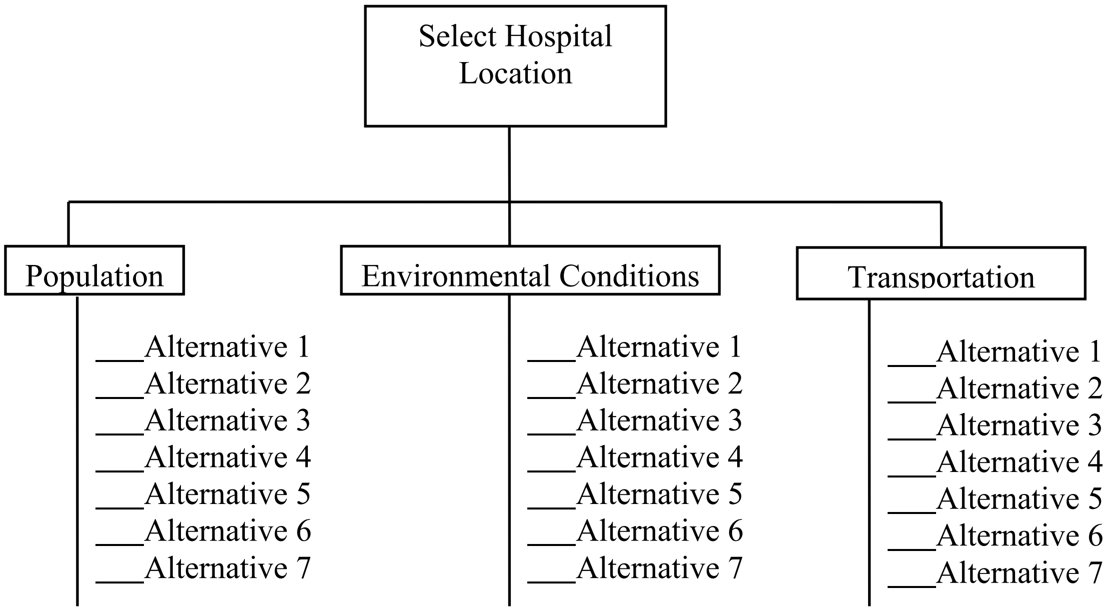


Figure 4.12 Hierarchical Structure of AHP Model

2. Pairwise Comparison Matrix of Criteria (Table 4.3).

Table 4.3 Pairwise Comparison Matrix for Criteria

	1	2	3
1	1	1/2	3/4
2	2	1	2/3
3	4/3	3/2	1

All values of Table 4.1 are described according to Table 3.2 (Page 29). After identifying the pairwise comparison matrix, eigenvector is found by squaring the matrix (Table 4.4).

Table 4.4 Taking the Square of Matrix

	1	2	3
1	1,00	0,50	0,75
2	2,00	1,00	0,67
3	1,33	1,50	1,00

X

	1	2	3
1	1,00	0,50	0,75
2	2,00	1,00	0,67
3	1,33	1,50	1,00

With these values, the consistency ratio (CR) is 0.2874. This ratio is greater than 0,1. Therefore, the values of criteria will be entered again (Table 4.5).

Table 4.5 New Values for Criteria

	1	2	3
1	1	2	40/3
2	1/2	1	20/3
3	3/40	3/20	1

3. After entering the values of the criteria again, the consistency ratio (CR) is 0.04. These values are appropriate. Eigenvectors are found by squaring the matrix (Table 4.6).

Table 4.6 The Pairwise Comparison Matrix and Eigenvectors Found

	1	2	3			1	2	3			
1	1,00	2,00	13,33		1	1,00	2,00	13,33	0,72		0,63
2	0,50	1,00	6,67	X	2	0,50	1,00	6,67	0,16	=	0,32
3	0,08	0,14	1,00		3	0,08	0,14	1,00	0,12		0,05

4. Each one of the 7 alternatives' population is calculated by buffer analysis and then the population data of Gaziantep are added to this model automatically via code written in AHP Program. All the eigenvectors are calculated in AHP Program automatically.

5. For the seven alternatives according to the environmental conditions are given the fitting values (Table 4.7). All values on Table 4.5 are described from Table 3.2(like Table 4.1)

Table 4.7 Pairwise Comparison Matrix According to Environmental Conditions

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	3/2	4/3	3/5	3/2	1/2	3/4
2	2/3	1	1/2	2/5	1	1/3	1/2
3	4/3	2	1	4/5	2	2/3	1
4	5/3	5/2	5/4	1	5/2	5/6	5/4
5	2/3	1	1/2	2/5	1	1/3	1/2
6	2	3	3/2	6/5	3	1	3/2
7	4/3	2	1	4/5	2	2/3	1

6. For the seven alternatives according to transportation are given the fitting values(Table 4.8). All the values of Table 4.6 are described from Table 3.2.

Table 4.8 Pairwise Comparison Matrix According to Transportation

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	1	2/5	4/5	1/2	2/3	1	4/7
2	5/2	1	2	5/4	5/3	5/2	10/7
3	5/4	1/2	1	5/8	5/6	5/4	5/7
4	2	4/5	8/5	1	4/3	2	8/7
5	3/2	3/5	6/5	3/4	1	3/2	6/7
6	1	2/5	4/5	1/2	2/3	1	4/7
7	7/4	7/10	7/5	7/8	7/6	7/4	1

7. According to these values, the results are calculated by using the AHP Program (Table 4.9).

Table 4.9 Eigenvectors of Population, Environmental Conditions, Transportation, Criteria and Results, respectively

	1	**2**	**3**			**1**			**1**
1	0,138	0,03	0,021		**1**	0,634		**1**	0,098
2	0,14	0,02	0,447	**X**	**2**	0,32	**=**	**2**	0,118
3	0,139	0,15	0,042		**3**	0,05		**3**	0,138
4	0,151	0,23	0,26					**4**	0,182
5	0,145	0,01	0,076					**5**	0,100
6	0,141	0,4	0,021					**6**	0,218
7	0,145	0,15	0,133					**7**	0,147

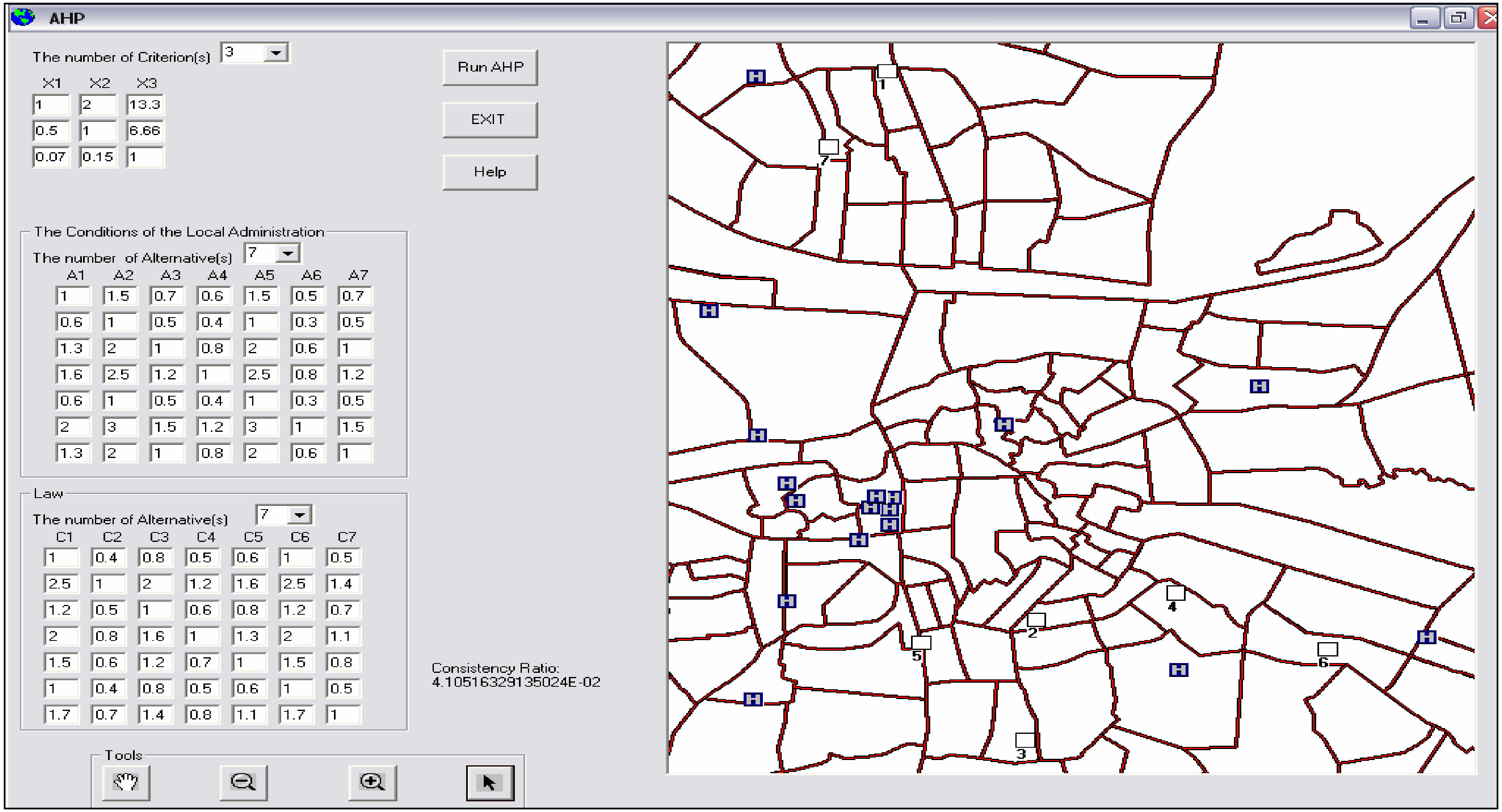


Figure 4.13 The Results of AHP Model for Selecting Hospital Facility Location

The results are depicted on the map (Figure 4.13). The first candidate is a grid among 8 Şubat, Karacaoğlan, Nurtepe, Yunus Emre and Kocatepe districts.

4.4. Conclusions

In this chapter, the solution of hospital location problem is presented. The proposed system integrated GIS with AHP technique in finding and evaluating the best possible hospital locations. The proposed system makes use of buffer analysis in searching for alternative hospital locations. The developed system is applied to Gaziantep for illustrative purposes.

CHAPTER V

GIS BASED DECISION SUPPORT SYSTEM FOR SUPERMARKET FACILITY LOCATION

5.1. Introduction

In this chapter, the multiple criteria supermarket location problem is studied. A computer program is developed in Visual Basic to enumerate from the best one to the worst one respectively by using the Simple Additive Weighting (SAW) method. Simple Additive Weighting Method is explained shortly in section 3.3.2. A two-step approach is used in this application.

Step-1: Select the three alternatives for facility location.

Step-2: Evaluate alternatives by using the Simple Additive Weighting Method and then show the alternatives on the map.

5.2. Supermarket Facility Location

The aim of the application is to display the applicability of GIS with multicriteria decision support systems to find supermarket facility locations. Simple Additive Weighting Method (SAW) is used to determine the best possible location for locating a new supermarket. Data used in this application are districts data only (Figure 5.1).

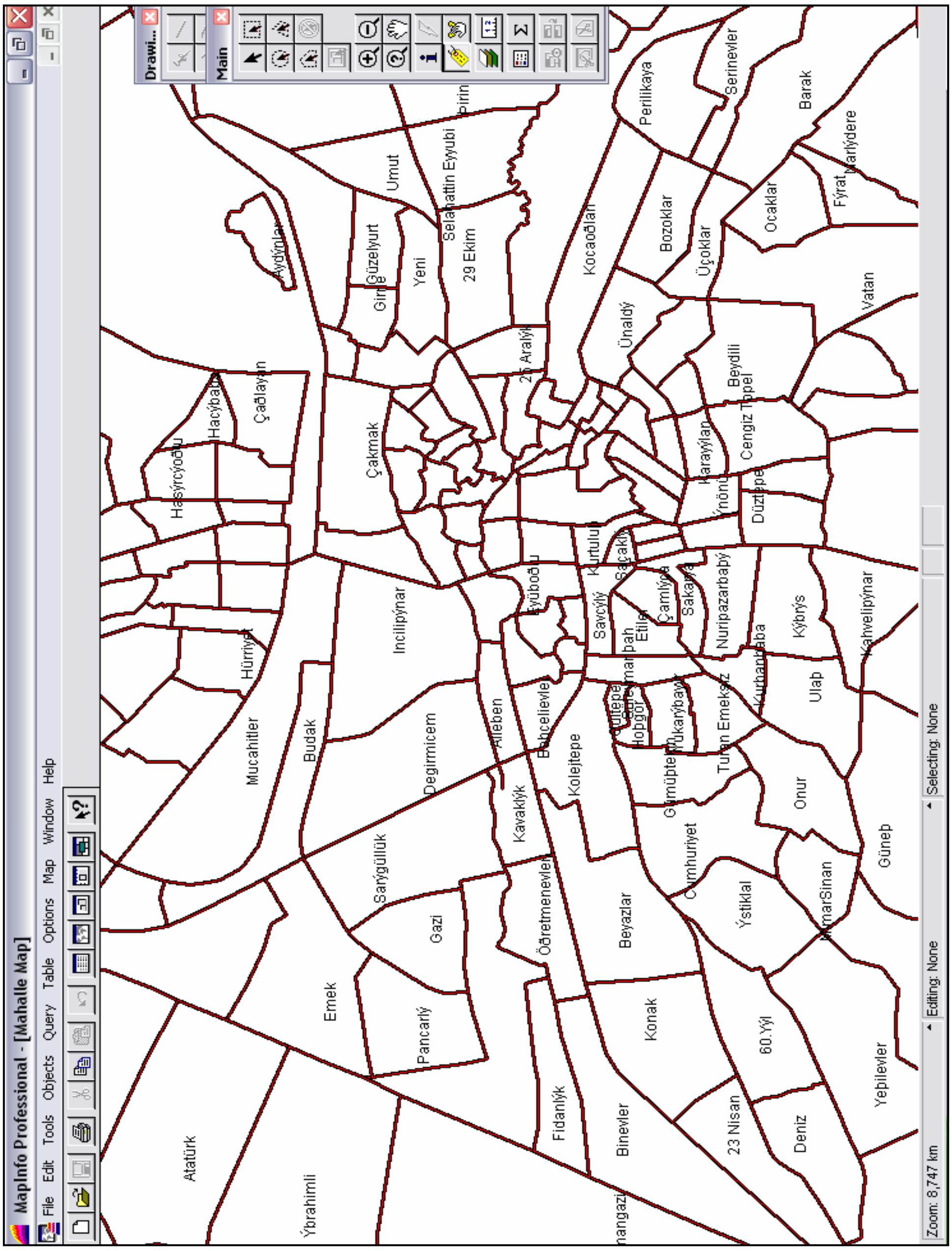


Figure 5.1 Districts Data

5.3. Development of the Model

5.3.1. Overview of the Program

The structure of the proposed new supermarket site location system is depicted in Figure 5.2. A computer program is developed and its interface is demonstrated in Figure 5.3 for finding new supermarket site locations. While the program is being written, simple additive weighting (SAW) method is used to enumerate the districts. As viewed in Figure 5.1, supermarket program is run in integration with the integrated MapInfo program.

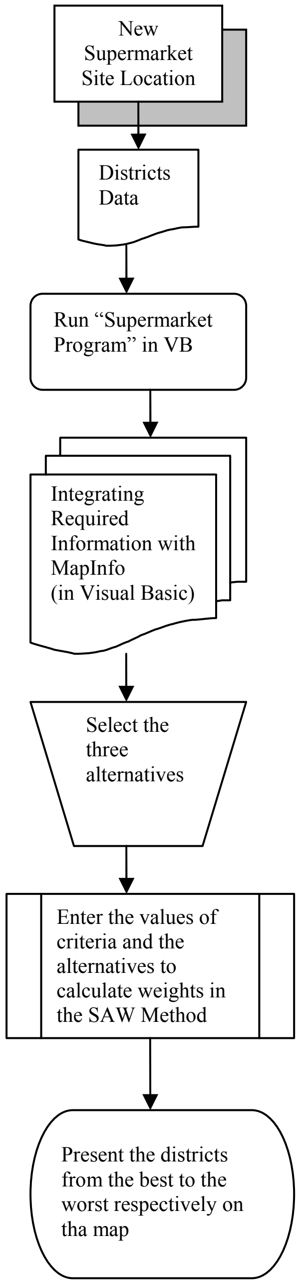


Figure 5.2 The Structure of the Supermarket Facility Location System

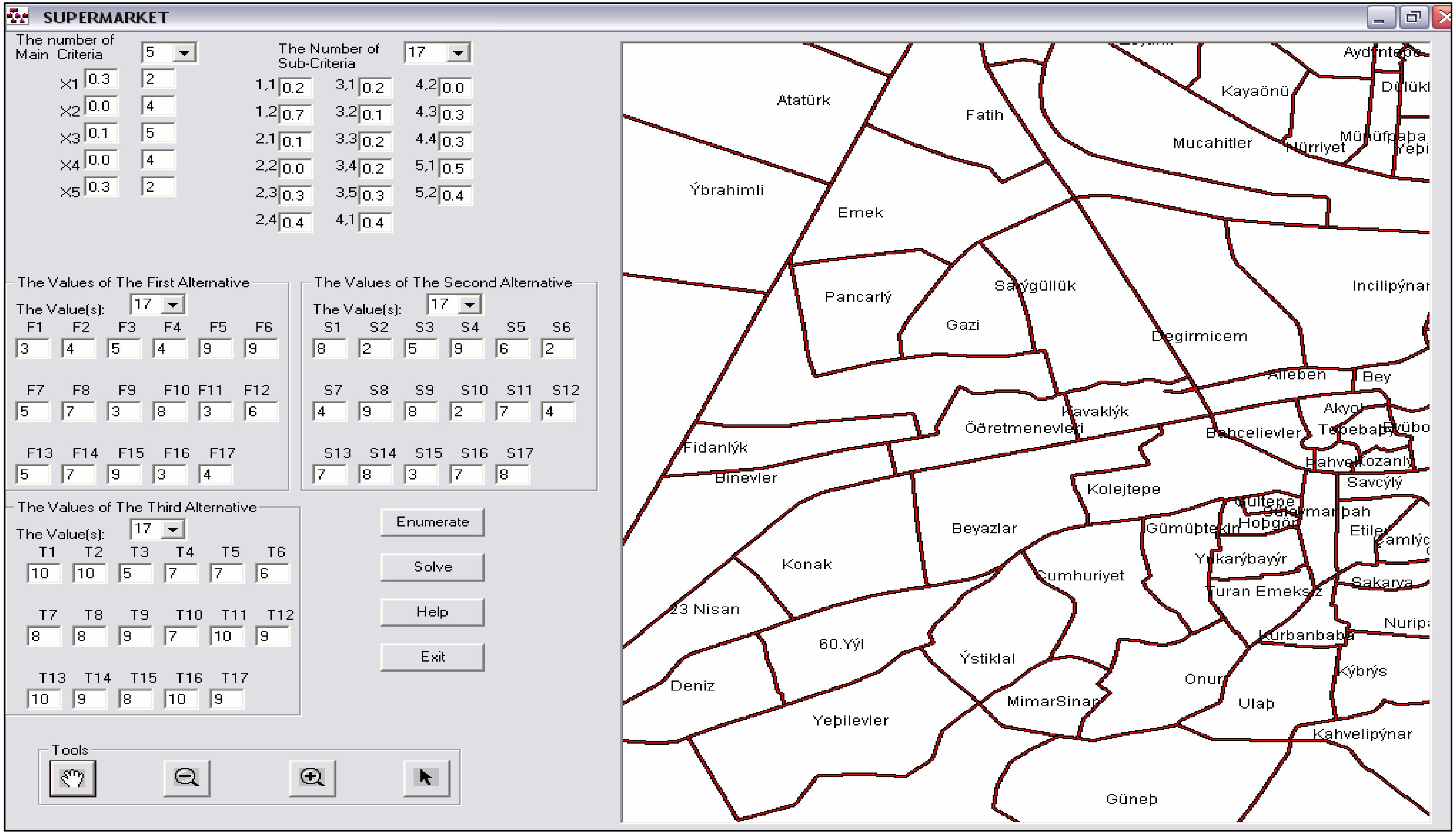


Figure 5.3 User Interface of the Supermarket Facility Location

On the right side of the user interface, district map is given. On the left side of the user interface, there are text cells related to the main criteria, sub-criteria and alternatives for entering values.

In this model there are five main criteria and eighteen sub-criteria related to main criteria. These main criteria are population and allocation of population, law conditions in that district, land circumstance, transportation, and park area. Concerning main criteria sub-main criteria are density of population, income level in that district, duty policy, the conditions for rent and possession, service of security, service of emergency, the largeness of land, distance between new location and the nearest existing supermarket, the state of sub-way, sufficiency of storage, frequency of public transportation, distance to main road, cost of transportation, distance to city center, whether park area is available or not, and the capacity of park area (Table 5.1). User or decision maker can manually select three districts on the map. Values of weightiness concerning main criteria, sub-criteria and alternatives are obtained from the study (Baykasoğlu et al. 2003). The weightinesses values of main criteria and sub-criteria are the same in that study. The values of alternatives are obtained from Table 3.2. For example, in that study, the values of density of population for Turan Emeksiz, Deniz, and İbrahimli districts are 0.087, 0.231 and 0.682 respectively. From these values are assigned new values for simple additive weighting method. These values are 3, 8, and 10 for alternative 1, alternative 2 and alternative 3 respectively. The other values are assigned in such way. (Table 5.1) This is made for comparing the results of two studies. Choosing the operation is flexible. Here İbrahimli, Deniz and Turan Emeksiz districts are selected. After the solving problem, user or decision maker can select the other districts to enumerate.

Table 5.1 The Values of The Main Criteria, Sub-Criteria and Alternatives

Main Criteria and Values	**Sub Criteria and Values Related to Main Criteria**	**Alternative 1**	**Alternative 2**	**Alternative 3**
Population and Allocation (0,347)	Density of Population (0,25)	3	8	10
	Income Level in That District(0,75)	4	2	10

Table 5.1 The Values of The Main Criteria, Sub-Criteria and Alternatives (Continue)

Land Circumstance(0,145)	The Largeness of Land(0,210)	5	4	8
	Distance Between New Location and the Nearest Existing Supermarket(0,15)	7	9	8
	The State for Expanding the Land(0,285)	3	8	9
	The State of Sub-Way(0,215)	8	2	7
	Sufficiency of Storage(0,35)	3	7	10
Transportation(0,091)	Frequency of Public Transportation(0,47)	6	4	9
	Distance to Autobahn(0,05)	5	7	10
	Cost of Transportation(0,35)	7	8	9
	Distance to City Center(0,35)	9	3	8
Park (0,326)	Whether Park Area is Available or not(0,55)	3	7	10
	The Capacity of Park Area(0,45)	4	8	9

5.4. Execution of the Model

1. After the program is run, user selects three districts on the map manually (Figure 5.4). This operation is performed, after first district is selected, press shift button on the keyboard and then select the other districts. Here selected districts are İbrahimli, Deniz and Turan Emeksiz.

2. Selected the first district's name is İbrahimli, the second district's name is Deniz and the third district's name is Turan Emeksiz (Figure 5.4).

3. After the districts are selected, press “Enumerate” button to determine the first district is which one (Figure 5.5). So alternative 1 will be Turan Emeksiz, alternative 2 will be Deniz and alternative 3 will be İbrahimli. This operation is necessary. Because at user interface, which alternatives are suitable which selected districts? That is, selected the first district’s name was İbrahimli. This sentence does not mean that İbrahimli is alternative 1 at user interface. Actually İbrahimli district is assigned to alternative 3 via “Enumerate” button. The other assignments are made in such a way. The program performs this by means of in ordering districts data.

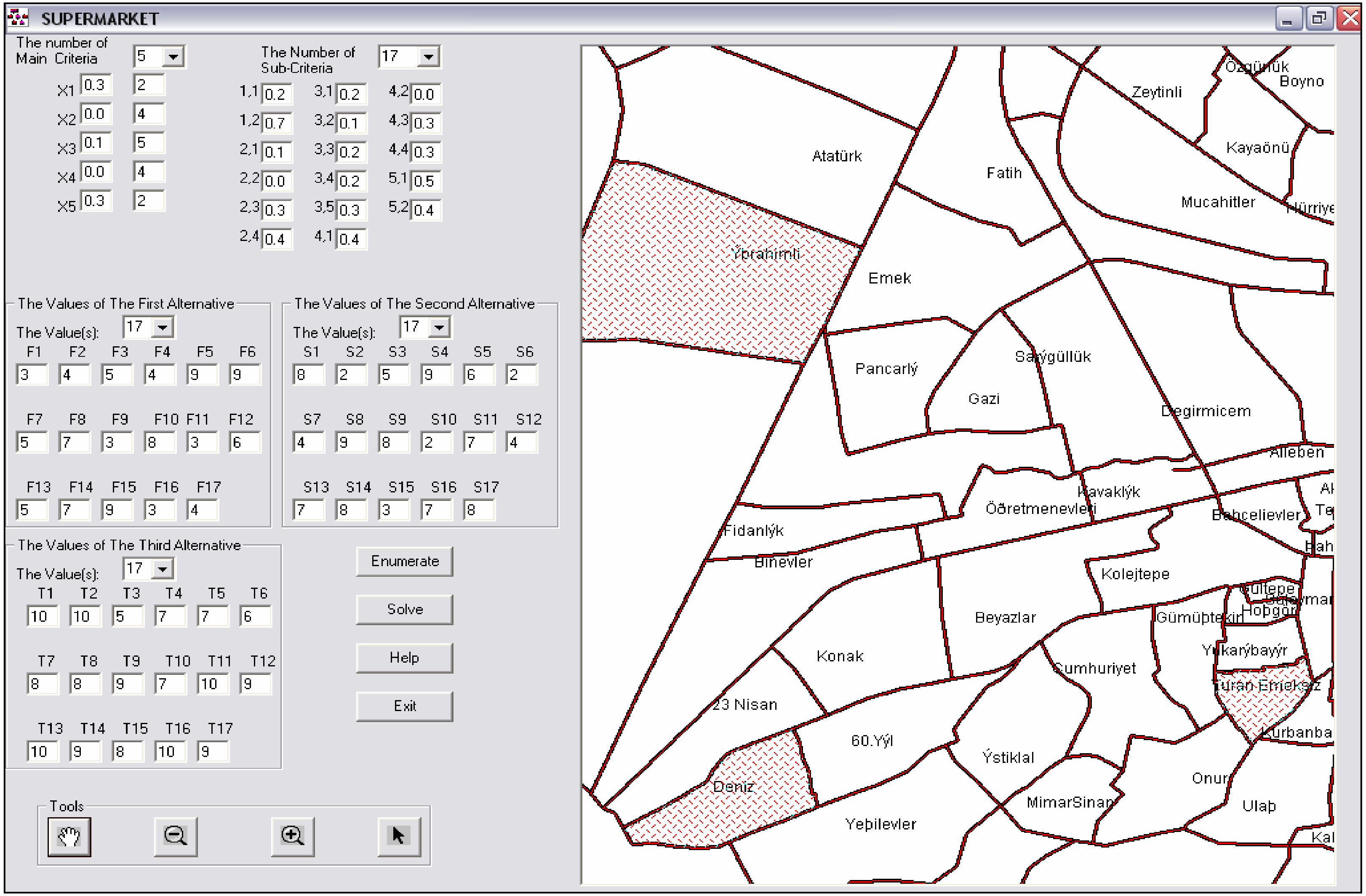


Figure 5.4 Choosing Three Districts

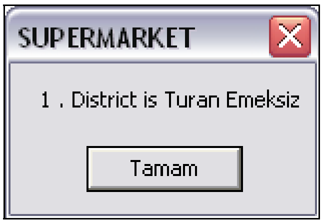


Figure 5.5 Enumerating the Selected District

4. As viewed in Figure 5.6, values of sub criteria are entered according to selected the first district. That is, in Table 5.1, the values of alternative 1 column from upper side to lower side are entered to the first alternative at user interface from left side to the right side. The values of the other alternatives are entered at user interface. Values of main criteria and sub-criteria are entered into suitable place at user interface (Figure 5.3).

5. According to equation 3.6 the program will calculate weights. With this equation, normalizing values are obtained.

6. After all the values are entered, press "Solve" button to calculate with respect to simple additive weighting (SAW) method (Figure 5.3).

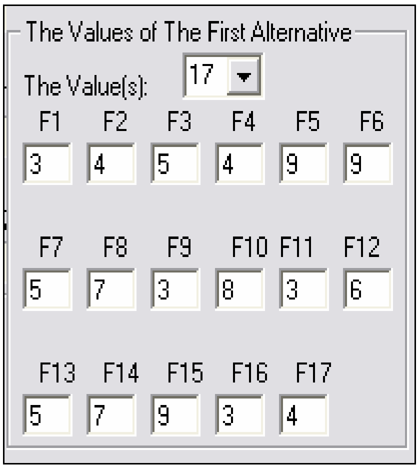


Figure 5.6 Entering the Values of the First Alternative

7. The results are demonstrated in Figure 5.7.

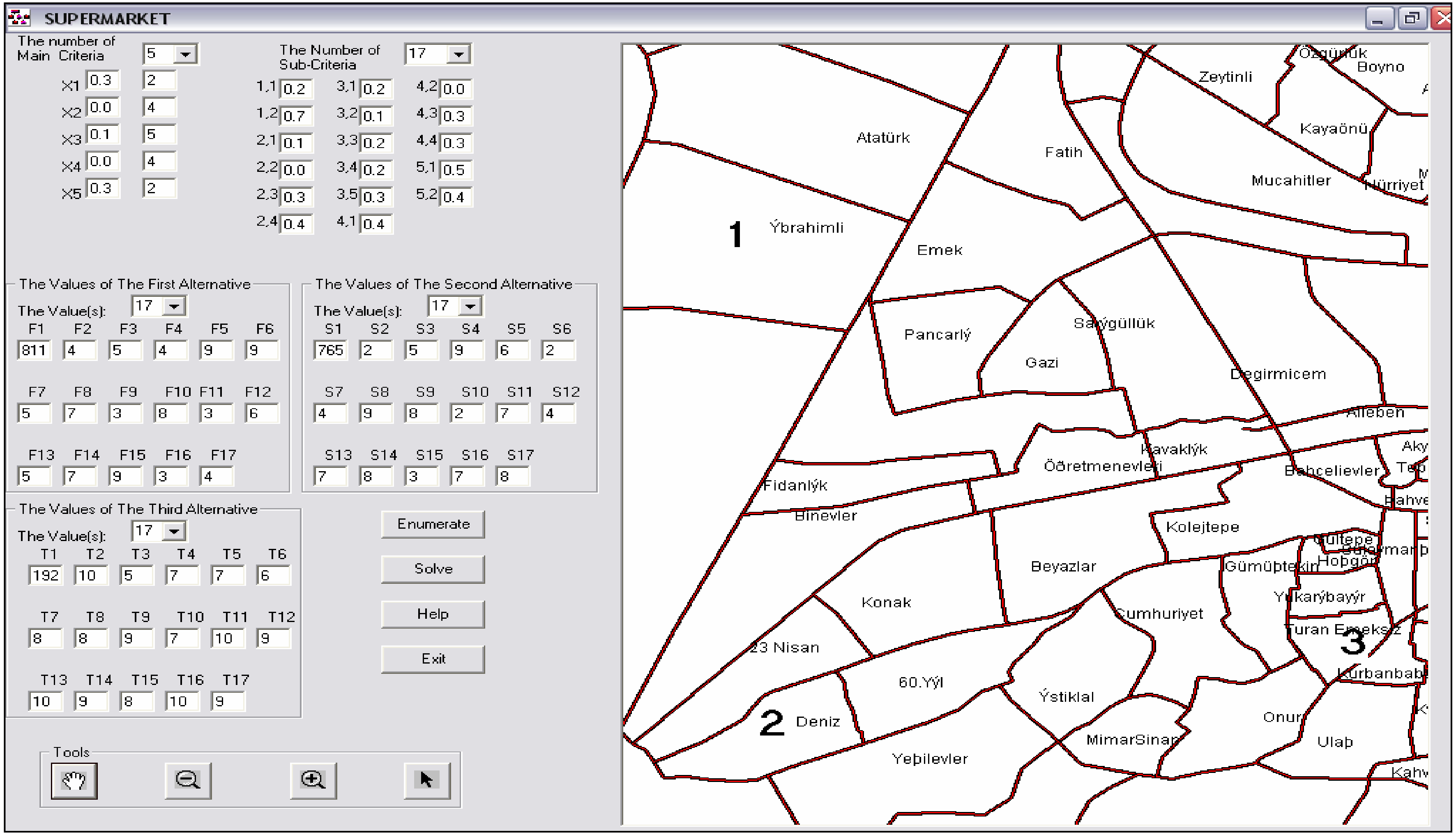


Figure 5.7 The Results of Supermarket Program Using SAW Method

5.5. Conclusions

In this chapter, the solution of supermarket location problem is presented. The proposed system integrated GIS with Simple Additive Weighting (SAW) method in finding and evaluating the best possible supermarket locations. If the results of SAW method are compared with the AHP approach for supermarket facility location study (Baykasoğlu et al. 2003), the results are the same approximately. For example, İbrahimli district is the first for locating in the both study. The developed system is applied to Gaziantep for illustrative purposes.

CHAPTER VI

GIS BASED DECISION SUPPORT SYSTEM FOR POLICE STATION LOCATION

6.1. Introduction

In this chapter, the allocation of police stations is found by means of Set Covering Algorithm (SCP) as district based in existing police stations and not considering existing police stations. The allocation is made in a district which has the most neighborhoods. After such districts are allocated, the districts which have a police station must cover all districts. Set Covering Algorithm is mentioned in section 3.4. A three-step approach is used in this application.

Step-1: Determine the relation among all districts.

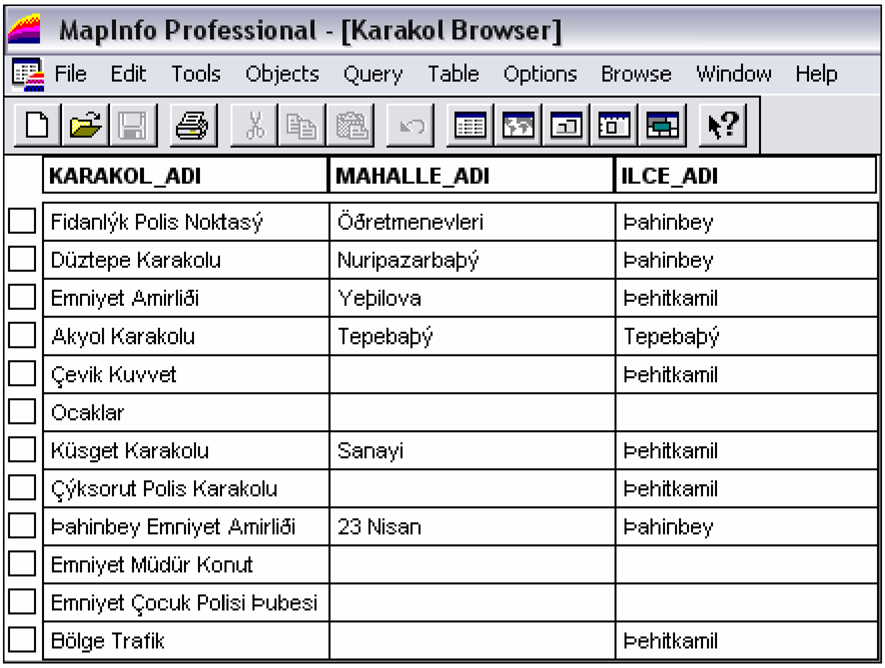
Step-2: Launch the relations from a computer program developed to Microsoft Excel Program.

Step-3: In Microsoft Excel, compute the relations among the districts by means of Set Covering Algorithm.

Step-4: Show the alternatives according to which district is possible.

6.2. Allocation of New Police Stations Using Set Covering Algorithm in Existing Conditions

The aim of this application is to allocate the new police stations using GIS and Set Covering Algorithm (SCA). Set Covering Algorithm is explained in section 3.4. For allocating the new police stations is developed a computer program in Visual Basic in considering the existing police stations and not considering the existing police stations. Data used in this application are districts and police station data (Figure 6.1).



KARAKOL_ADI	MAHALLE_ADI	ILCE_ADI
Fidanlýk Polis Noktasý	Öðretmenevleri	Þahinbey
Düztepe Karakolu	Nuripazarbaþý	Þahinbey
Emniyet Amirliði	Yeþilova	Þehitkamil
Akyol Karakolu	Tepebaþý	Tepebaþý
Çevik Kuvvet		Þehitkamil
Ocaklar		
Küsget Karakolu	Sanayi	Þehitkamil
Çýksorut Polis Karakolu		Þehitkamil
Þahinbey Emniyet Amirliði	23 Nisan	Þahinbey
Emniyet Müdür Konut		
Emniyet Çocuk Polisi Þubesi		
Bölge Trafik		Þehitkamil

Figure 6.1 Displaying the Police Stations Data as Browsed

As mapped the police stations data are depicted in Figure 6.2. Districts data have been depicted in Figure 4.2.

6.3. Development of the Model

6.3.1. Overview of the Program

The structure of the allocation of police stations is depicted in Figure 6.3. For both conditions a program was written in Visual Basic to find the allocation of police stations for existing and nonexistent police station as optimum (Figure 6.4). Police stations data and districts data are united in the program written as integrated MapInfo and Visual Basic. The program constitutes constraints according to set covering algorithm (SCP) and then the program sends the constraints to Microsoft Excel program to find the number of police stations. In Microsoft Excel Program is found a optimum value for number of police stations. And then the value is sent to the user interface to show the results. At user interface, police stations and districts data are displayed bottom of the user interface like a map. On the top of the user interface, according to existing conditions and new conditions (nonexistent) there are tools to run the program. While the program was written, Set Covering Algorithm (SCP) was used. This algorithm performs that every point gets covered by at least one set.

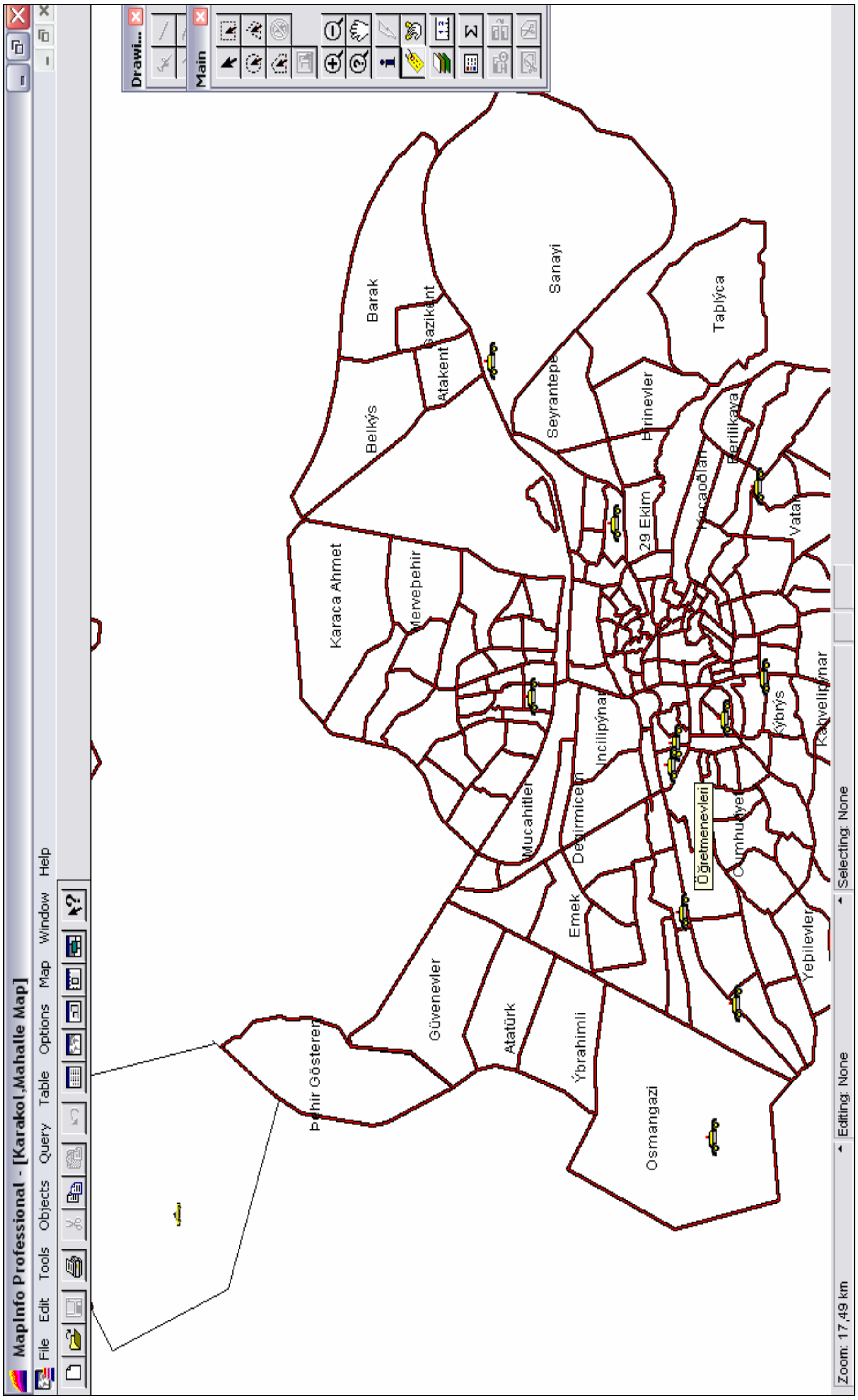


Figure 6.2 Displaying the Districts and Police Stations Data as Mapped

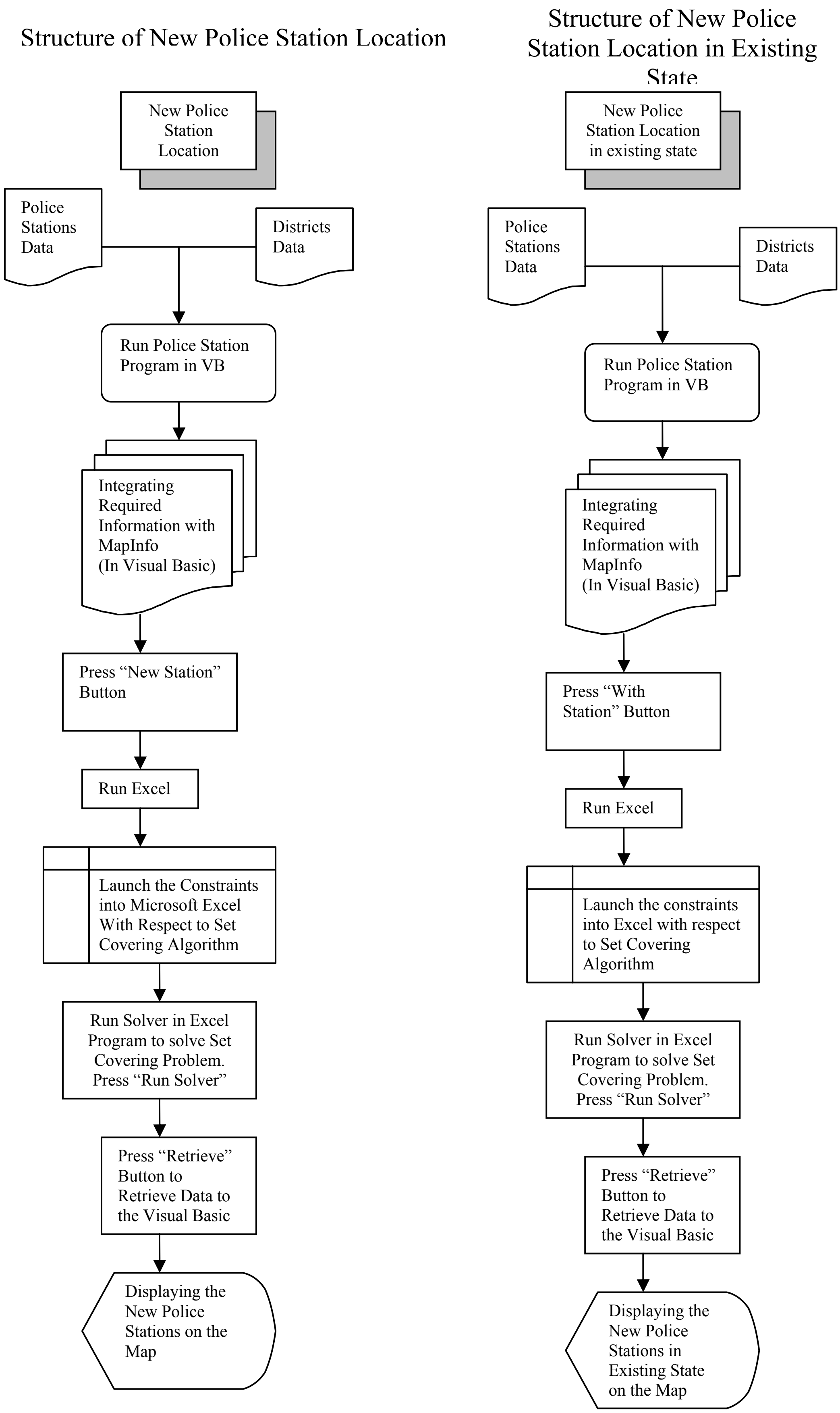
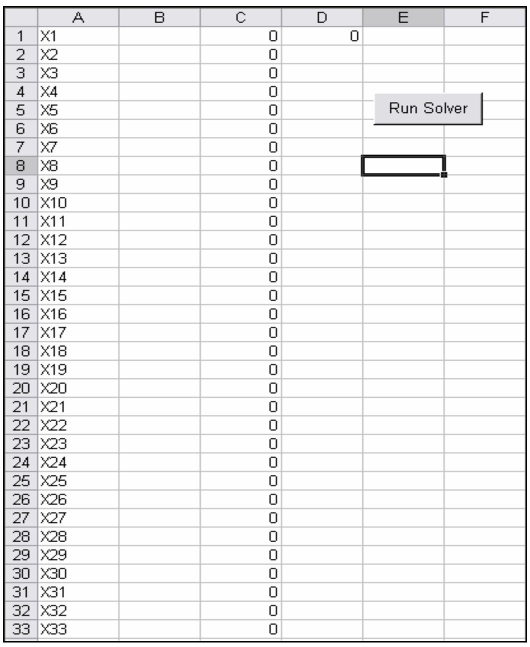


Figure 6.3 The Structure of Allocation Police Stations Facility Location System

6.3.2. Execution of the Model for Locating New Police Stations

1. There are 168 districts. As mentioned that “sira” data were added into the districts data. It is needed to constitute the constraints and the optimal objective function. “New Station(s)” button is pressed for the allocation of nonexistent police station (Figure 6.4).

After this button is pressed, the program constitutes constraints according to Set Covering Algorithm (SCP). For example, the first district is displayed as X1 (İncilipınar), the second district is displayed as X2 and the other district is displayed in such a way. So the last district will be displayed as X168. The first district (X1) is selected; other districts which are related to first district are selected. These districts are “Budak”, “Değirmicem”, “Mücahitler”, “Bey”, “Seferpaşa”, “Yaprak”, and “Allaben”. The symbols of these districts are X2, X3, X4, X13, X26, X27 and X104 respectively. The program sends the symbol of all districts into “A” column prepared in Microsoft Excel Program. It is sent into the first cell of “C” column to sum of all these districts. (like X1+X2+.....+X104) This is an equation. The equations of each district and related district are sent to Microsoft Excel Program according to Set Covering Algorithm (SCP). The optimum function must be minimized sum of the all districts. That is, X1 + X2 + X3 + X4 + ………. + X168. This equation is sent into “D1” cell. (Figure 6.5)



	A	B	C	D	E	F
1	X1		0	0		
2	X2		0			
3	X3		0			
4	X4		0			
5	X5		0			
6	X6		0			
7	X7		0			
8	X8		0			
9	X9		0			
10	X10		0			
11	X11		0			
12	X12		0			
13	X13		0			
14	X14		0			
15	X15		0			
16	X16		0			
17	X17		0			
18	X18		0			
19	X19		0			
20	X20		0			
21	X21		0			
22	X22		0			
23	X23		0			
24	X24		0			
25	X25		0			
26	X26		0			
27	X27		0			
28	X28		0			
29	X29		0			
30	X30		0			
31	X31		0			
32	X32		0			
33	X33		0			

Figure 6.5 The Data Embedded into Excel Program

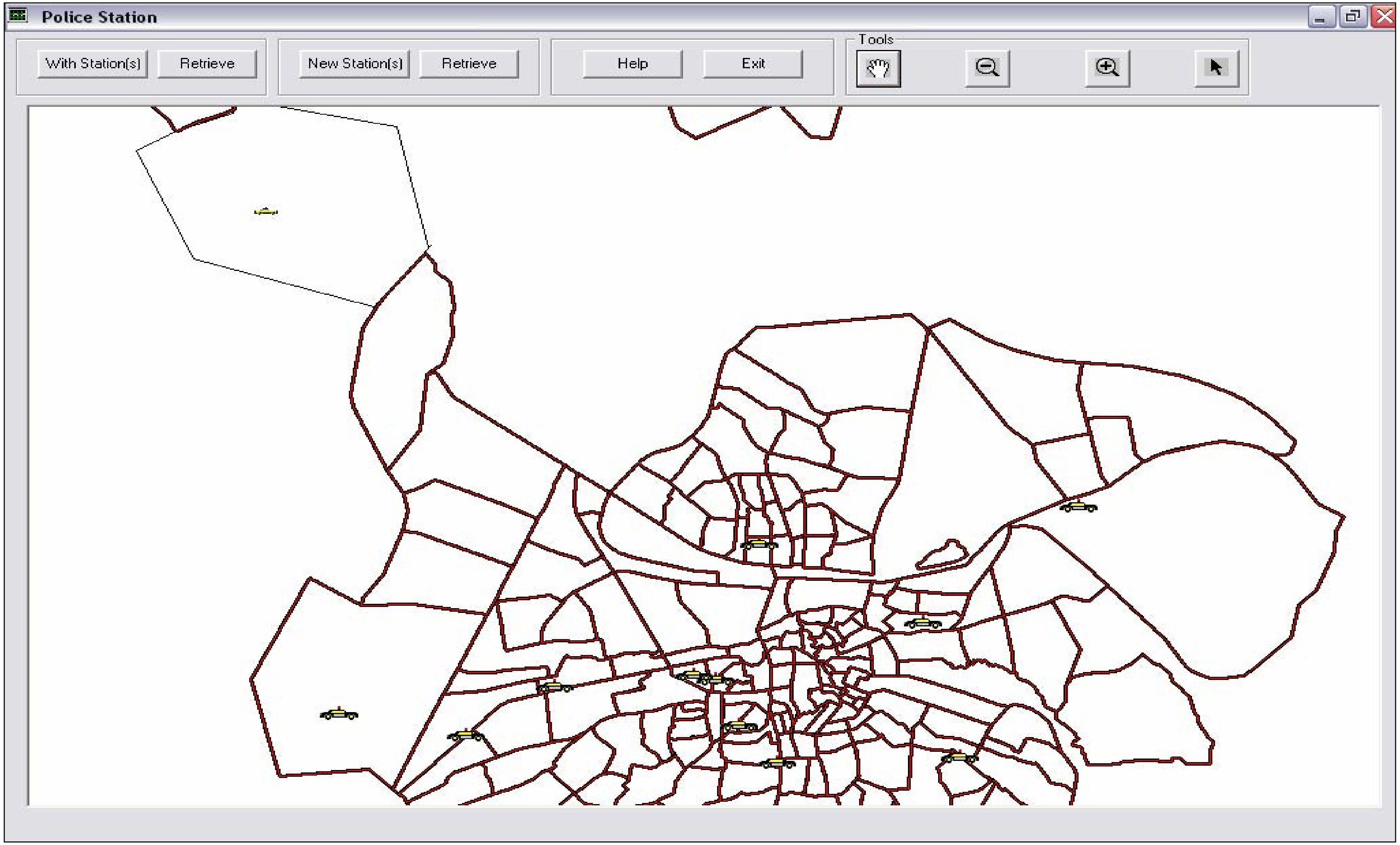


Figure 6.4 User Interface of the Program written for Allocation of Police Stations

2. Creating the equations using set covering algorithm are performed by the codes in Table 6.1.

Table 6.1 The Code of the Program written According to Set Covering Algorithm

```
m = 0
mi.do ("select * from mahalle")
j = mi.eval("tableinfo(selection,8)")
For a = 1 To j
l = l + 1
m = m + 1
mi.do ("select * from mahalle where rowid=(" & a & ")")
mi.do ("m=selection.obj")
mi.do ("select * from mahalle where obj intersects m")
c = mi.eval("Tableinfo(selection,8)")
mi.do ("fetch first from selection")
x1 = mi.eval("mahalle.sira")
x1 = "B" & x1
For b = 2 To c
mi.do ("fetch next from selection")
x1 = x1 & "+" & "B" & mi.eval("mahalle.sira")
Next
n = x1
Range("C" & m).Value = "=" & n
Next
mi.do ("select * from mahalle")
b = mi.eval("TableInfo(selection,8)")
mi.do ("fetch first from mahalle")
x1 = mi.eval("mahalle.sira")
x1 = "B" & x1
For a = 2 To b
mi.do ("fetch next from mahalle")
x1 = x1 & "+" & "B" & mi.eval("mahalle.sira")
Next
n = Val(x1)
x1 = x1 & "+" & "B" & mi.eval("mahalle.sira")
```

Table 6.1 The Code of the Program written According to Set Covering Algorithm

```
Next
n = x1
Range("D" & 1).Value = "=" & x1m = 0
mi.do ("select * from mahalle")
j = mi.eval("tableinfo(selection,8)")
For a = 1 To j
l = l + 1
m = m + 1
mi.do ("select * from mahalle where rowid= (" & a & ")")
mi.do ("m=selection.obj")
mi.do ("select * from mahalle where obj intersects m")
c = mi.eval("Tableinfo(selection,8)")
mi.do ("fetch first from selection")
x1 = mi.eval("mahalle.sira")
x1 = "B" & x1
For b = 2 To c
mi.do ("fetch next from selection")
Range ("C" & m).Value = "=" & n
Next
```

3. This problem will be linear programming problem. To solve this problem, a macro is described in the Solver Tool. The equations in “C” column are converted to constraints like X1+X2+X3……….X104 ≥ 1 (Figure 6.6). This macro is assigned to “Run Solver” button.

4. In Microsoft Excel, press “Run Solver” button to calculate optimum solution. In “B” column is stated the values of results as “0” or “1”. As depicted in Figure 6.7, the optimum solution is 31. This value means that police stations can be assigned to 31 districts which have values “1”.

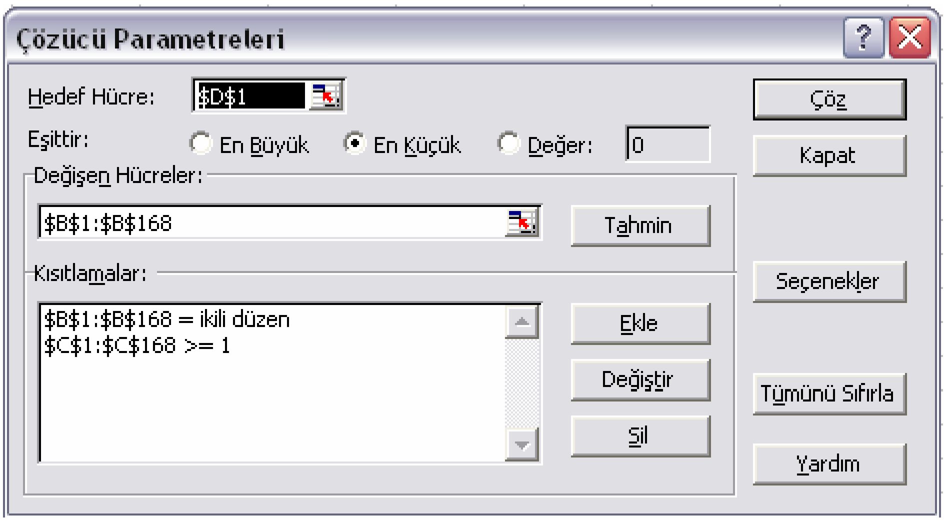
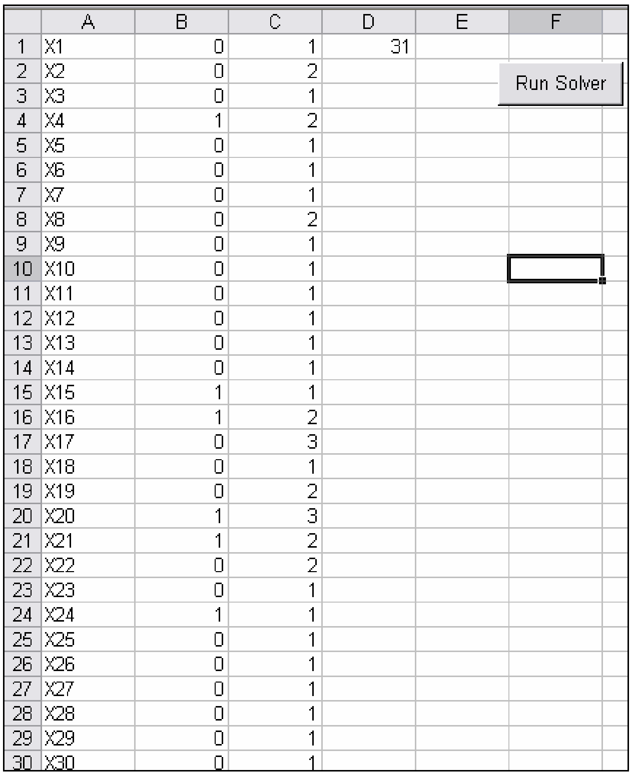


Figure 6.6 Solver Tool for Solving Linear Programming Problem



	A	B	C	D	E	F
1	X1	0	1	31		
2	X2	0	2			Run Solver
3	X3	0	1			
4	X4	1	2			
5	X5	0	1			
6	X6	0	1			
7	X7	0	1			
8	X8	0	2			
9	X9	0	1			
10	X10	0	1			
11	X11	0	1			
12	X12	0	1			
13	X13	0	1			
14	X14	0	1			
15	X15	1	1			
16	X16	1	2			
17	X17	0	3			
18	X18	0	1			
19	X19	0	2			
20	X20	1	3			
21	X21	1	2			
22	X22	0	2			
23	X23	0	1			
24	X24	1	1			
25	X25	0	1			
26	X26	0	1			
27	X27	0	1			
28	X28	0	1			
29	X29	0	1			
30	X30	0	1			

Figure 6.7 The Optimum Solution Found by Using “Run Solver” Macro

Optimal solution and optimal values are retrieved from Microsoft Excel to user interface. At user interface, again press “Retrieve” button to retrieve the values. After retrieving the values that equal to “1”, are depicted on the map as symbol (Figure 6.8).

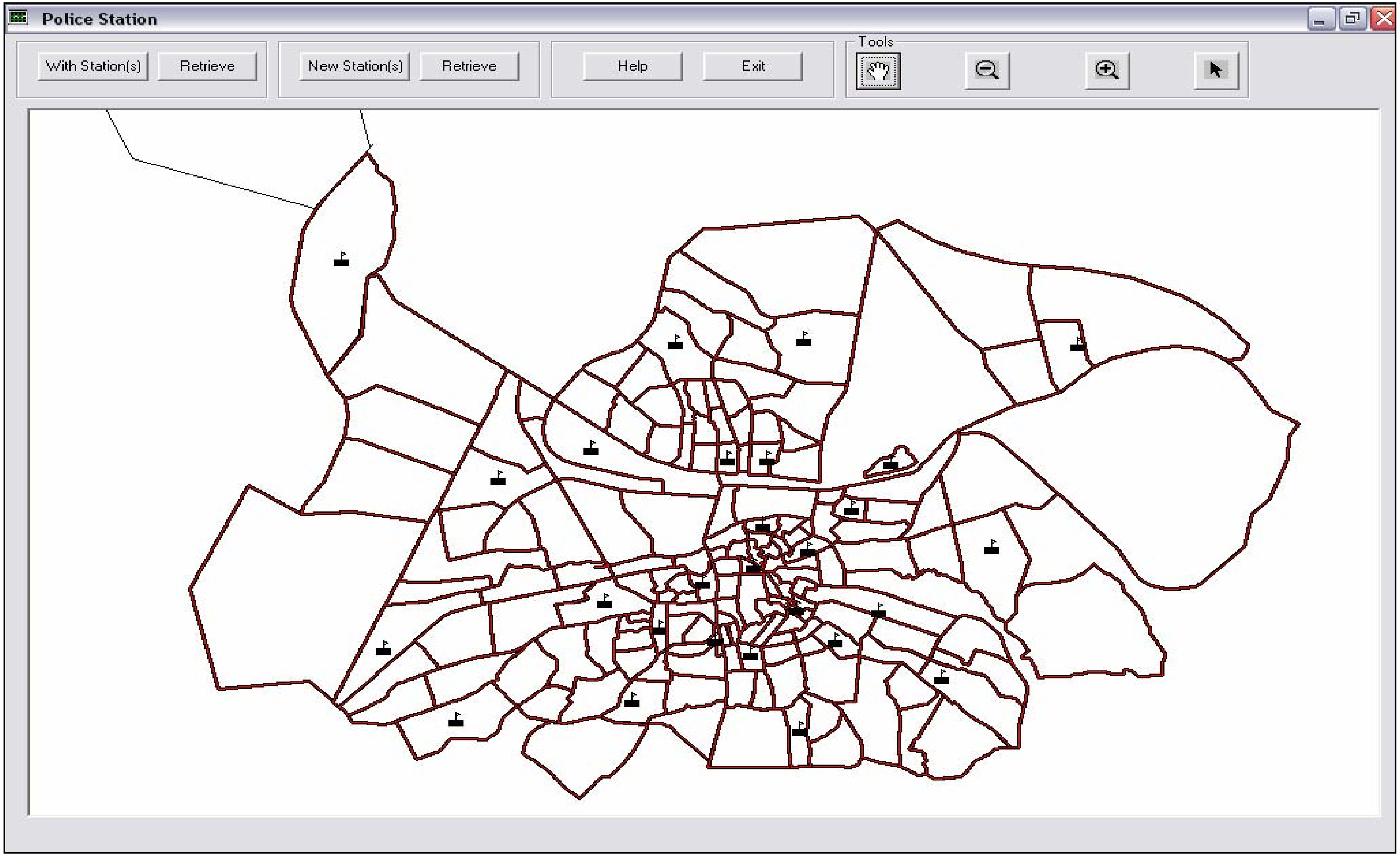
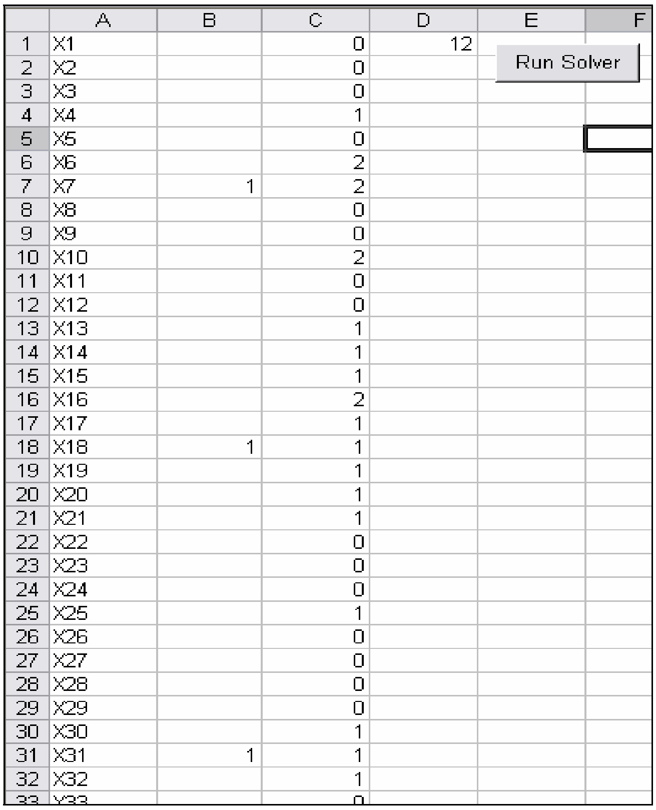


Figure 6.8 The Allocation of Police Station Facility Location by Using the Set Covering

6.3.3. Execution of the Model by Considering the Existing Police Stations

1. There are 168 districts. Also there are twelve police stations in existing conditions, too.

2. After the program is run, press "With station" button to send the equations to Microsoft Excel Program (Figure 6.4). The difference between these situations is that the existing police stations are added to this model. In previous section all the actions are the same to find optimal solution. But the equations of the existing twelve police stations are added to Microsoft Excel Program (Figure 6.9). In "B" column, "1" appeared values indicate to existing police stations.



	A	B	C	D	E	F
1	X1		0	12		
2	X2		0			
3	X3		0			
4	X4		1			
5	X5		0			
6	X6		2			
7	X7	1	2			
8	X8		0			
9	X9		0			
10	X10		2			
11	X11		0			
12	X12		0			
13	X13		1			
14	X14		1			
15	X15		1			
16	X16		2			
17	X17		1			
18	X18	1	1			
19	X19		1			
20	X20		1			
21	X21		1			
22	X22		0			
23	X23		0			
24	X24		0			
25	X25		1			
26	X26		0			
27	X27		0			
28	X28		0			
29	X29		0			
30	X30		1			
31	X31	1	1			
32	X32		1			
33	X33		0			

Figure 6.9 The Data Embedded into Excel Program in Existing Conditions

3. The conditions of the existing police stations are determined to "Run Solver" macro. For example, for B18 cell has existing police station. This is determined to the macro "B18=1". The other existing police stations are determined in such a way (Figure 6.10).

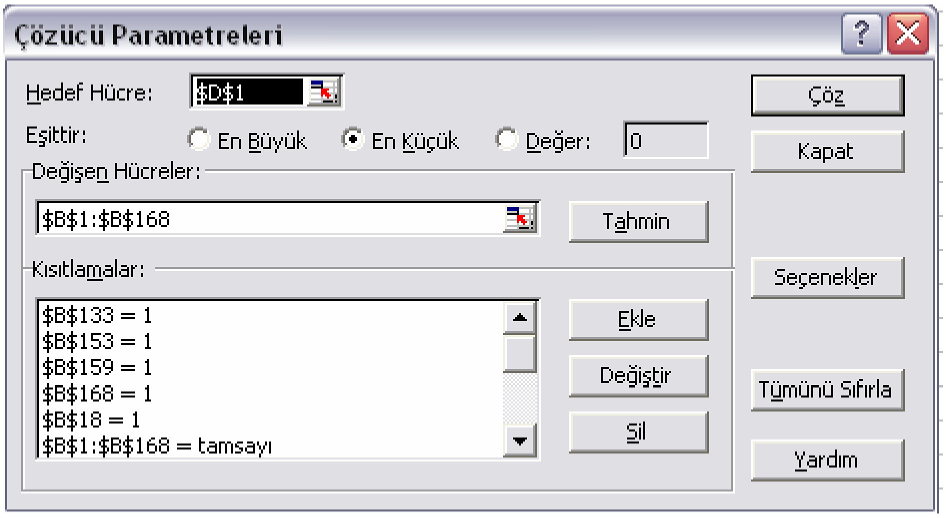


Figure 6.10 Solver Tool for Solving Linear Programming Problem in Existing Conditions

4. Creating the equations using set covering algorithm are performed by the codes in existing conditions in Table 6.2.

Table 6.2 The Code of the Program in Existing Conditions

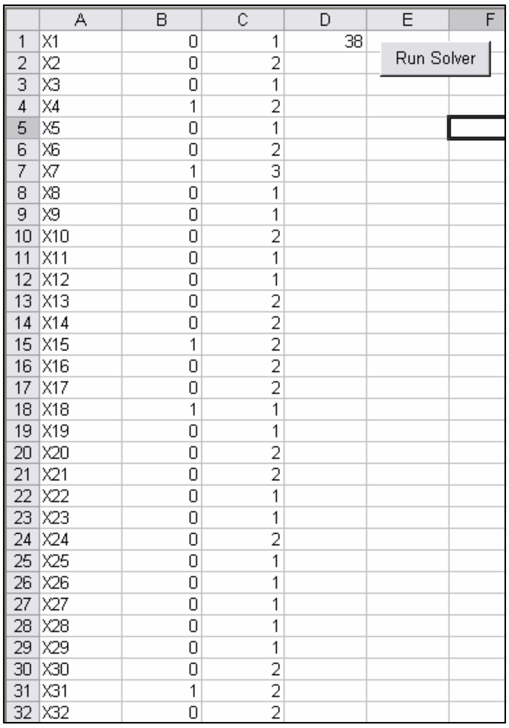
```
For i = 1 To 168
   Range("A" & i).Value = "X" & i
Next
m = 0
mi.do ("select * from mahalle")
j = mi.eval("tableinfo(selection,8)")
For a = 1 To j
l = l + 1
m = m + 1
mi.do ("select * from mahalle where rowid=(" & a & ")")
mi.do ("m=selection.obj")
mi.do ("select * from mahalle where obj intersects m")
c = mi.eval("Tableinfo(selection,8)")
mi.do ("fetch first from selection")
x2 = mi.eval("mahalle.sira")
```

Table 6.2 The Code of Program in Existing Conditions (Continue)

```
x1 = mi.eval("mahalle.sira")
x1 = "B" & x1
For b = 2 To c
mi.do ("fetch next from selection")
x1 = x1 & "+" & "B" & mi.eval("mahalle.sira")
Next
Range("C" & m).Value = "=" & n
Next
mi.do ("select * from mahalle where obj intersects Any(select obj from karakol)")
n = x1
p = mi.eval("Tableinfo(selection,8)")
mi.do ("fetch first from selection")
For e = 1 To p
n = x2
Range("B" & n).Value = 1
mi.do ("fetch next from selection")
Next
mi.do ("select * from mahalle")
mi.do ("m=selection.obj")
b = mi.eval("TableInfo(selection,8)")
mi.do ("fetch first from mahalle")
x1 = mi.eval("mahalle.sira")
b = mi.eval("TableInfo(selection,8)")
mi.do ("fetch first from mahalle")
x1 = mi.eval("mahalle.sira")
x1 = "B" & x1
For a = 2 To b
mi.do ("fetch next from mahalle")
x1 = x1 & "+" & "B" & mi.eval("mahalle.sira")
Next
n = Val(x1)
Range("D" & 1).Value = "=" & x1
```

5. Press “Run Solver” to calculate optimum values and objective function (Figure 6.9). In “B” column is stated the values of results as “0” or “1”. As depicted in Figure 6.11, the optimum solution is 38. This value means that police stations can be assigned to 38 districts which have values “1”.

6. In Figure 6.12, at user interface, press “Retrieve” button to retrieve back values which equal to “1”. Optimal solutions are depicted on the map (Figure 6.11.).



	A	B	C	D	E	F
1	X1	0	1	38	Run Solver	
2	X2	0	2			
3	X3	0	1			
4	X4	1	2			
5	X5	0	1			
6	X6	0	2			
7	X7	1	3			
8	X8	0	1			
9	X9	0	1			
10	X10	0	2			
11	X11	0	1			
12	X12	0	1			
13	X13	0	2			
14	X14	0	2			
15	X15	1	2			
16	X16	0	2			
17	X17	0	2			
18	X18	1	1			
19	X19	0	1			
20	X20	0	2			
21	X21	0	2			
22	X22	0	1			
23	X23	0	1			
24	X24	0	2			
25	X25	0	1			
26	X26	0	1			
27	X27	0	1			
28	X28	0	1			
29	X29	0	1			
30	X30	0	2			
31	X31	1	2			
32	X32	0	2			

Figure 6.11 The Optimum Solution Found by Using “Run Solver” Macro in Existing Conditions

6.4. Conclusions

In this chapter, the allocation of the police stations was presented. The proposed system integrated GIS with Set Covering Algorithm (SCP) in allocating and evaluating the best possible districts which have the most neighborhoods. This allocation was studied in both considering the existing police stations and not considering the existing police stations. in the allocation of the existing police stations is found 38 police stations. In the allocation of not considering the existing police stations is found 31 police stations. If the optimum value had been found 31 instead of 38 by considering in the existing police stations, the existing police stations had been allocated correctly. The proposed system is applied to Gaziantep for illustrative purposes.

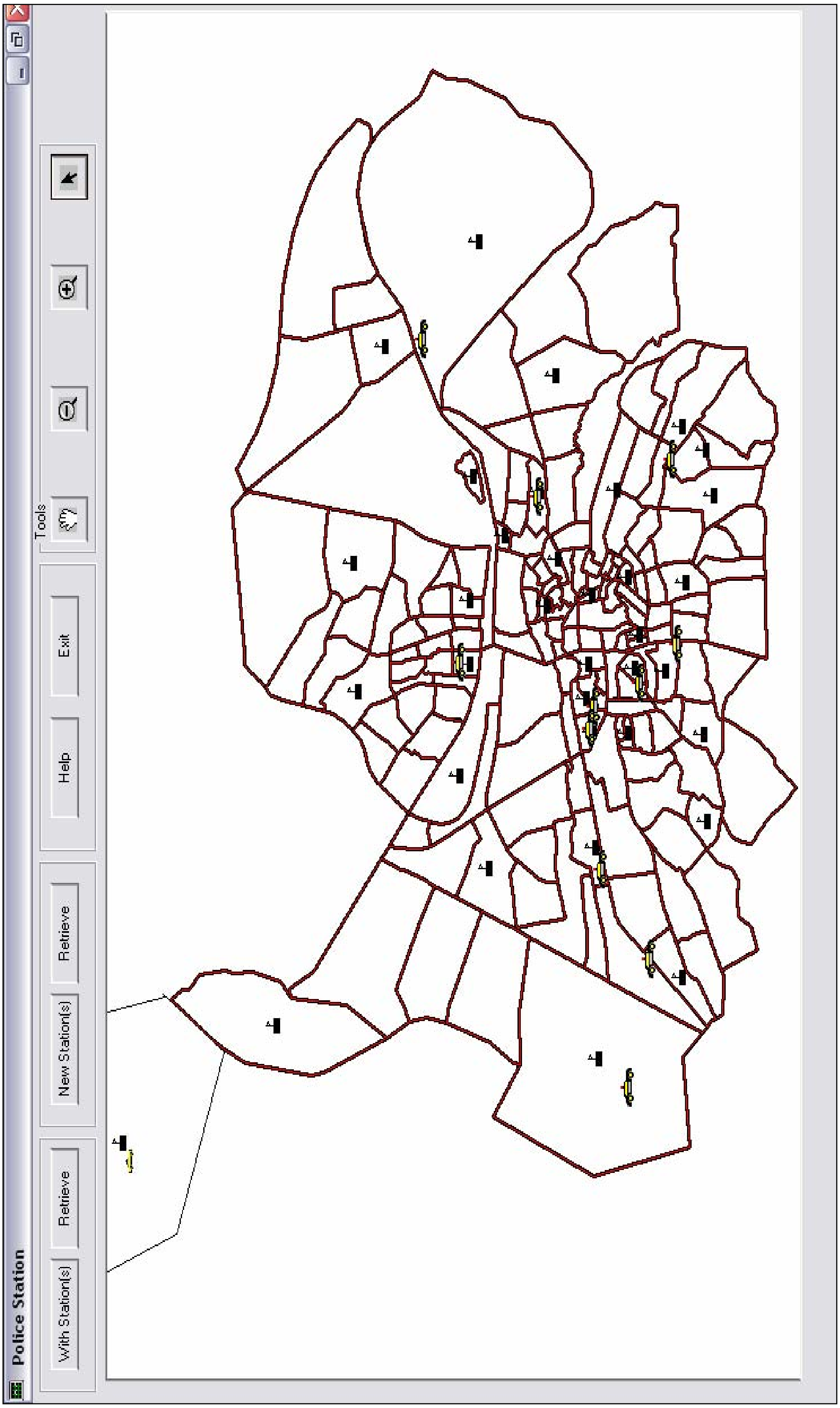


Figure 6.12 Finding New Police Stations in Case of Existing Police Stations

CHAPTER VII

CONCLUSION

7.1. Conclusion

In this thesis, GIS applications were investigated with multicriteria decision support systems. GIS and components were described in detail. Decision support systems, multicriteria decision support system and spatial multicriteria decision support system are explained. The case studies are presented. These are hospital facility locations, supermarket facility locations and allocation of police stations in Gaziantep. In hospital facility location problem, first alternative facility locations were found by developed the computer program in MapBasic. This program was written according to grid method and buffer analysis. Grid method means that dividing the selected district with respect to specified dimensions. Buffer analysis is to obtain data or information in specified distance from the determined object or point, too. The program found 7 candidates by using both methods. After that, from 7 candidates were found the best candidate by a computer program written in Visual Basic. The program was also written according to Analytic Hierarchy Process (AHP). GIS facilitates to finding facility location for specified purpose. In supermarket facility location problems are applied to compare with AHP approach for supermarket facility location study, Baykasoğlu et al. (2003). In that study, as a tool of multicriteria decision support system was used AHP. In this thesis as a tool of multicriteria decision support system was used Simple Additive Weighting (SAW) method. The results of both studies are the same. The allocation of police stations were applied by using Set Covering Algorithm (SCP). This algorithm is used in many areas such as crew scheduling in railway and airline and mass-transit transportation. Set Covering Algorithm was used in this thesis for finding the districts which have the most neighborhoods. Relations of districts are described and sent to Microsoft Excel Program as equations. The optimum solution was found by using Solver Tool. Finding optimal solution was retrieved to display on the map interactively. The allocation of police stations is important for emergency response.

In literature, there are many applications concerning facility location problem. Some of these applications have been interested in theoretical approach to the facility location problem. The other applications are interested in GIS. Selecting the location(s) is/are a complex process that involves physical, economical, social, environmental and political requirements that may have conflicting objectives. Such complexity necessitated the simultaneous use of several decision support tools such as SAW and AHP. Set Covering Algorithm is also useful tool for locating problem. These tools were used with Geographic Information System (GIS). GIS performed easiness and visualization in the hospital facility location. GIS facilitates also for calculating some values of criteria. For example, like calculating of the population in buffer area. In the supermarket location problem, GIS performed visualization again. In the allocation of police stations problem, GIS facilitates calculating of relations neighborhood very much. If they are made by manual, calculating of their relations neighborhood will be very hard. But GIS calculated easily. GIS facilitates also analysis and interpretation to answer questions related to geographic space.

The presented applications provided a comprehensive procedure in which two available commercial software packages were successfully integrated using OLE-Automation. GIS, SCP, SAW and AHP were successfully integrated using OLE-Automation tool. The integrated applications with a computer program could benefit developers, consultants, and planners. The programs used for GIS applications such as MapInfo and MapBasic was permitted by Başar Soft Co. which is distributor of MapInfo Co. in Turkey. For the academic users and industrial institutions, developed computer programs in this thesis would be provided for commercial and educational purposes.

Suggestions for improvement and issues for future research may include the following research topics:

1. Determined hospital facility locations can be investigated in depth on which have more criteria such as site's accessibility, economic factors, type of site, etc...

2. In the allocation of the police stations can be taken into consideration some criteria such as regions or districts which have the most crimes for covering of the police stations and distance for delivering the criminal place of police stations.

3. At present, as policy of government, police stations are abrogated. Instead of these, mobile police stations are being established. The scope of mobile police station can be explored according to suggestion 2.

4. Sensitivity analysis can be applied for three applications. Each application may be explored according to region, district and grid. After than they can be compared.

5. Supermarket facility location problem can be estimated and compared according to Central Business District and outside of City Center.

APPENDIX A: POPULATION OF GAZİANTEP ACCORDING TO DISTRICTS (2001)

ŞAHİNBEY	
District	Population
Akyol	3012
Alaybey	1888
Alibaba	2870
Allaben	4633
Altmışıncıyıl	11269
Aydınbaba	2124
Bahçelievler	3283
Barak	8963
Barış	9504
Bekirbey	4170
Bey	2111
Bayazlar	8873
Beydilli	15628
Binevler	8057
Bostancı	1780
Boyacı	2925
Bozoklar	4634
Cabı	1825
Cemal Gürsel	3473
Cengiz topel	12413
Cumhururiyet	10727
Çamlıca	3516
Çukur	242
Daracık	1363
Delbes	593
Deniz	7658
Dumlupınar	8355
Düğmeci	764
Düztepe	13490
Etiler	4348
Eyüpoğlu	1804
Fidnlık	2673
Gültepe	1564
Gümüştekin	5652
Gündoğdu	1052
Güneş	3510
Güneykent	5930
Güzelvadi	14022
Hoşgör	3039
İnönü	5800
İsmetpaşa	2058
İstikla	19234
Kahvelipınar	4574
Kanalıcı	1721
Karagöz	891
Karatarla	122
Karayılan	6890
Kavaklık	5027
Bilinmeyen	7157

ŞAHİNBEY	
District	Population
Kepenek	1800
Kıbrıs	12500
Kılınçoğlu	1789
Kocaoğlan	1202
Kolejtepe	8308
Konak	16131
Kozanlı	1406
Kozluca	4069
Kurbanbaba	5472
Kurtuluş	1638
Mimarsinan	7020
Nuripazarbaşı	7561
Ocaklar	14941
Oğuzlar	1477
Onur	12948
Öğretmenevleri	6246
Özdemirbey	1264
Perilikaya	8618
Saçaklı	1323
Sakarya	5130
Savcılı	2271
Serpaşa	1517
Serinevler	9477
Sultenselim	4363
Suyabatmaz	1055
Süleymenşah	4246
Şahinbey	789
Şahveli	1454
Şekeroğlu	959
Şenyurt	3701
Tepebaşı	1181
Tışlaki	2069
Turanemeksiz	8110
Türkmanler	7878
Türktepe	1522
Ulaş	7694
Ulucanlar	1263
Üçoklar	7858
Ünaldı	4691
Vatan	16013
Yavuzlar	3107
Yazıcık	3038
Yeşilevler	12447
Yetmişbeşinciyıl	3619
Yirmibeşaralık	4675
Yirmiüçnisan	4183
Yukarıbayır	7336
Bilinmeyen	716
Zeytinli	9807

ŞEHİTKAMİL	
District	Population
Aydınlar	3143
Aydıntepe	4448
Başpınar orb	1037
Boyno	13165
Baudak	3097
Çağlayan	4524
Çakmak	3803
Çıksorut	5550
Değirmiçem	13022
Dülükbaba	5985
Emek	5898
Eydibaba	3700
Eyüpsultan	8849
Fatih	6477
Fevzipaşa	2266
Gazi	5168
Gazikent	20065
Girne	6647
Göllüce	11303
Göztepe	5239
Güvncevlr	17858
Güzelyurt	8819
Hacıbaba	7530
Hasırcıoğlu	7407
Hürriyet	5871
İncilipınar	2638
Karacaoğlan	9197
Karaoğlan	3794
Karşıyaka	6178
Kayaönü	12241
Kocatepe	7296
Merve	4014
Mevlana	8992
Mithatpaşa	5545
Mücahitler	1942
Münüfpaşa	4173
Nurtepe	4878
Özgörlük	14399
Pancarlı	2371
Sanayi	1497
Sarıgüllük	9918
Sekizşubat	4588
Selimiye	7366
Serinevler	3629
Ulus	2007
Umut	5689
Yaprah	2152
Yenimahalle	10224
Yeşilova	4053

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