MEASUREMENT AND EVALUATION OF FIRE SERVICE ACCESSIBILITY BY USING GIS: A CASE STUDY ON ÇANKAYA DISTRICT, ANKARA

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

BY

KIVANÇ ERTUĞAY

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

APRIL 2003

Approval of the Graduate School of Natural and Applied Sciences

Prof. Dr. Tayfur Öztürk
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Oğuz Işık
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Prof. Dr. Ali Türel
Co-supervisor

Assoc. Prof. Dr. Oğuz Işık
Supervisor

Examining Committee Members

Assoc. Prof. Dr. Nurünnisa USUL

Prof. Dr. Ali TÜREL

Assoc. Prof. Dr. Oğuz IŞIK

Assist. Prof. Dr. Şebnem DÜZGÜN

Assist. Prof. Dr. Erkan MUMCUOĞLU

ABSTRACT

MEASUREMENT AND EVALUATION OF FIRE SERVICE ACCESSIBILITY BY USING GIS: A CASE STUDY ON ÇANKAYA DISTRICT, ANKARA

Ertuğay, Kıvanç

M.S. Department of Geodetic and Geographic Information Technologies

Supervisor: Assoc. Prof. Dr. Oğuz Işık

Co-supervisor: Prof. Dr. Ali Türel

May 2003, 134 pages

Human being has always been in a continual struggle with fire, which is an undeniable reality of life. It is a sudden and unexpected event and can occur anywhere, any time and at any scale causing irreversible damages to human life and property. Fire is a fact of life, but it is always possible to decrease the effects of fires by fire preparedness. Preparedness can be defined as a preparatory phase, including activities and precautions in order to be ready for emergency response and recovery and it is absolute that time is one of the most vital and important component of fire preparedness. In fire case, time can mean the difference between loosing a life or saving a life or loosing a room or loosing the whole houses of a street. When time is considered, accessibility concept takes its place in fire preparedness realm. Measuring fire service accessibility and understanding the ability of response units for a quick response gives a way for taking precautions in fire preparedness. By such an approach this

thesis aims to measure and evaluate the accessibility of the fire units in Çankaya district and to find out the critical areas that have low accessibility by using GIS.

KEYWORDS: Accessibility, Fire Service Accessibility, Fire Preparedness, Geographical Information Systems (GIS).

ÖZ

İTFAİYE ERİŞEBİLİRLİĞİNİN CBS KULLANARAK ÖLÇME ve DEĞERLENDİRİLMESİ : ANKARA, ÇANKAYA İLÇESİ ALAN ÇALIŞMASI

Ertuğay, Kıvanç
Yüksek Lisans, Jeodezi ve Coğrafi Bilgi Teknolojileri Bölümü
Tez Yöneticisi: Doç. Dr. Oğuz Işık
Tez Danışmanı: Prof. Dr. Ali Türel

Mayıs 2003, 134 Sayfa

İnsanoğlu, hayatın kaçınılmaz bir gerçeği olan yangın olgusuyla her zaman süregelen bir mücadele içinde olmuştur. Yangın ani ve beklenmedik bir afettir ve önlem alınmadığı taktirde her an ve her ölçekte yaşanabilir ve büyük zararlar verir. Yangın yaşamın bir gerçeğidir fakat şu unutulmamalıdır ki; yangına hazırlıklı olarak bu zararları asgaride tutmak mümkündür. Yangına hazırlıklılık, yangın çıktığı zaman en kısa sürede ve en az zararla söndürülmesini amaçlayan faaliyet ve önlemler bütününü içerir ve zaman, yangına hazırlıklı olmanın en hayati bileşenlerinden biridir. Zaman, yangın sürecinde, bir hayatı kurtarmayı yada onlarcasını kaybetmeyi, bir evi kurtarmayı yada tüm sokağı kaybetmeyi belirler. Zaman boyutu düşünüldüğünde erişebilirlik olgusunun yangın hazırlıklılığı içindeki rolü ve önemi yadsınamaz bir gerçek olarak ortaya çıkmaktadır. İtfaiye erişebilirliğinin ölçülmesi ve itfaiye birimlerinin kritik süreler içinde nerelere müdahale edebileceklerinin saptanması, bu bölgeler için öncesinden önlemler alınabilmesini sağlar. Bu anlamda, yapılan çalışmada Çankaya ilçesi itfaiye erişebilirliğinin coğrafi bilgi teknolojileri yardımıyla ölçülmesi ve sonuçlarının değerlendirilerek yangına müdahale süresi açısından sorunlu alanların tespit edilmesi ve tedbirler önerilmesi amaçlanmıştır.

Anahtar Kelimeler: Erişebilirlik, İtfaiye Erişebilirliği, Yangına Hazırlıklılık, Coğrafi Bilgi Sistemleri (CBS).

To My Family…

ACKNOWLEDGMENTS

I would like to gratefully thank to my supervisor Assoc. Prof. Dr. Oğuz Işık for his great guidance, encouragement and support throughout the bringing out of this thesis. This research would not have been possible without his assistance. I would also like to thank to my co-supervisor Prof. Dr. Ali Türel for his great guidance and orientation during my research of accessibility.

I would like to thank all my lecturers from Geodesy and Geographical Information Technologies Department, Assoc. Prof. Dr. Nurünnisa Usul, Assoc. Prof. Dr. Vedat Toprak, Assist. Prof. Dr. Zuhal Akyürek, Assist. Prof. Dr. Şebnem Düzgün, Assist. Prof. Dr. Mustafa Türker for their endless support and patience. It was an excellent learning period and academic experience for me to be with them.

Special thanks to Ankara Metropolitan Municipality Office of Water and Infrastructure and Ankara Metropolitan Municipality Office of Information Systems for their data provision.

Special thanks to Chiefs of the İskitler, Head office of Ankara Fire Department. Fire-fighters Mustafa Irmak and Nevzat Kaleli for sharing me their fire response experiences which was very necessary for study about fire service accessibility. They were interesting and exciting interviews for me with several fire alarms.

Special thanks to my dear friends Adem Tunca, Ceren Ercoşkun, Özge Yalçıner And Taner San for their endless motivation and moral support during this study. It is luck for me to be with them.

Final thanks go to my family members, my mother Nihal Ertuğay, my father Hüseyin Ertuğay, my sister Kıvılcım Ertuğay and my sweet grandmother Samiye Yıldızatay for their endless encouragement and support from the beginning.

TABLE OF CONTENTS

ABSTRACT iii
ÖZ v
ACKNOWLEDGMENTS viii
TABLE OF CONTENTS x
LIST OF FIGURES xiii
LIST OF TABLES xvii
LIST OF ABBREVIATIONS xix
CHAPTER
1. INTRODUCTION 1
2. DESCRIPTION OF THE ACCESSIBILITY CONCEPT 6
2.1. Definitions of accessibility 6
2.2. The Need for Accessibility Analyses 8
2.3. Components of Accessibility 10
2.3.1. Activity Element 11
2.3.2. Transportation element 12
2.3.3. Zones 13
2.4. Accessibility Measures 13
2.4.1. Simple measures 14
2.4.2. Cumulative Opportunity measures 15
2.4.3. Gravity based measures 16
2.5. Measuring Techniques of Accessibility using GIS 17
2.5.1. Zone based technique 17
2.5.2. Isochronal technique 24
2.5.3. The raster based technique 28
2.6. The importance of GIS in accessibility studies 35
2.7. Evaluation of the Chapter 39

3. FIRE PREPAREDNESS 42
3.1.Fire Management 43
3.1.1.Definition of Fire Management 43
3.1.2.Phases in fire management 44
3.1.2.1.Prevention 45
3.1.2.2.Preparedness 47
3.1.2.3.Response 50
3.1.2.4.Recovery 51
3.2.Interrelation Between Fire Service Accessibility and Fire Preparedness 52
3.2.1 The Importance of Measuring Fire Service Accessibility in Fire Preparedness 52
3.2.2.Critical fire response time thresholds for evaluation of fire service accessibility 53
3.2.3.The standards in fire response time 55
3.2.4.Precautions that can be taken according to the results of fire service accessibility in fire preparedness 56
4. CASE STUDY: MEASURING FIRE SERVICE ACCESSIBILITY IN ÇANKAYA DISTRICT OF ANKARA 58
4.1.Description of the study area 58
4.1.1. Why Çankaya District as case study area? 62
4.2. Ankara Metropolitan Municipality of Fire Department 63
4.3.Case Study Flowchart 67
4.4. Data Collection and the Basic Steps in the Study 68
4.4.1. Data Collection: The General Spatial and Non-Spatial Raw Data Contents in the Study 69
4.4.2. Data Conversion 70
4.4.3.Registration and Digitizing 71
4.4.4. Editing and Building the Database 76
4.4.4.1.Reclassification of Roads According to Their Types 77
4.4.4.2.Adapting Main Restrictions to Transportation Database 79
4.4.4.2.1.Adapting one-way restrictions to the database 80
4.4.4.2.2.Adapting turn restrictions to the database 82

4.4.4.3. Establishing Average Speeds According To Road Classifications........ 86
4.4.4.4.Calculation of cost values as transportation network impedance values........ 90
5. THE RESULTS: MAPPING ACCESSIBILITY........ 93
5.1. Accessibility Analyses with No Consideration of Fire Responsibility Zones........ 94
5.2. Accessibility Analyses with Consideration of Fire Responsibility Zones........ 107
6. CONCLUSIONS........ 122
REFERENCES........ 130

LIST OF FIGURES

FIGURE

2.1: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a simple measure 18

2.2: Traveling time less than 30 minutes selection among the retail employments as activity element in Dallas/Fort Worth area 19

2.3: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a cumulative opportunity measure 20

2.4: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a gravity measure.................................. 22

2.5: The isochronal representation of accessibility.................................. 25

2.6: The isochronal representation of 10 minutes accessibility of hospitals as a simple measure.. 26

2.7: The isochronal representation of cumulative number of education services within 10 minutes accessibility to hospitals by pedestrian as a cumulative opportunity measure 26

2.8: The isochronal representation of 5 kilometers accessibility from asthma clinics as a simple measure 27

2.9: IP, IC, national and regional road network of Portugal in raster environment 30

2.10: The raster based representation of accessibility to the municipality town starting from the city centroids as a simple measure................ 33

2.11: The raster based representation of accessibility to Lisbon as a simple measure 34

2.12: Representation of accessibility without GIS from public transport stations to urban facilities of hotels, banks, and cinemas in Trabzon 37

2.13: Representation of fire service accessibility without GIS in Ankara in 1998.. 38

2.14: Representation of bird-flight fire response time and distances without considering the transportation network and without geographical interaction 38
3.1:Time-temperature curve of fire in confined spaces 54
4.1: Study area, Çankaya district of Ankara 59
4.2: Quarters of Çankaya district 60
4.3: Landuse in Çankaya District 61
4.4: Fire Brigades of Ankara 64
4.5: Fire Responsibility Zones in Ankara 65
4.6: Fire Responsibility Zones in Çankaya District 66
4.7: Case study flowchart 67
4.8: Transportation Network data_1 after mif to shape conversion (all roads) 71
4.9: Two Ankara transportation maps in paper format 72
4.10: Imagewarp 2.0 extension of Arcview 3.1 software in registration process 73
4.11: The distribution of reference points on raster maps for registration process 74
4.12: Raster Ankara transportation maps after registration process 75
4.13: Digitization process by Arcmap 8.1 and the use of Arc Toolbox software for rebuilding polyline topology 76
4.14: The newly added "type" field and its records in transportation network_1 database 78
4.15: The Query of Road Types after Final Classification 79
4.16: The newly added "oneway" field and its records in Transportation network_1 database 82
4.17: Newly created turntable database file to set turn restrictions on separated state roads 84
4.18: The built-in script, used to produce "record_id" "from_node" "to_node" information for the turntable 85
4.19: The built-in script used to declare the turntable to network database 86

4.20: Transportation network data_2 of Ankara Metropolitan Municipality Office of Information Systems 87
4.21: The new database file, created to supply the connection between the transportation data_1 and the average speeds on main roads......... 88
4.22: The database of the main transportation network after the creation of speed fields "speed_ht", "speed_nt" and "speed_lt"......................... 90
4.23: Calculation of the cost values in seconds in Arcview field calculator 91
4.24: The final cost values of "seconds_ht", "seconds_nt" and "seconds_lt" in the main transportation network database 92
5.1: Fire service accessibility in heavy traffic conditions 95
5.2: Fire service accessibility in normal traffic conditions......................... 96
5.3: Fire service accessibility in light traffic conditions 97
5.4: Fire service accessibility for normal traffic conditions in polygon format 98
5.5: Critical quarters in respect of fire response in Çankaya district....... 100
5.6: Critical landuse types in respect of fire response in Çankaya district 102
5.7: Buildings in critical areas.. 103
5.8: Security, health and educational services in critical areas 105
5.9: Educational services in critical areas 106
5.10: Health centers in critical areas.. 106
5.11: Security services in critical areas 107
5.12: Fire service accessibility of Head office fire brigade 108
5.13: Fire service accessibility of Kurtuluş fire brigade 109
5.14: Fire service accessibility of Esat fire brigade 110
5.15: Fire service accessibility of Gölbaşı fire brigade 111
5.16: Fire service accessibility of Head office, Esat and Gölbaşı fire brigades within 10 minutes 114
5.17: Fire service accessibility of Kurtuluş, Esat and Gölbaşı fire brigade within 10 minutes 115
5.18: Inaccessible areas because of current fire responsibility zones.... 116
5.19: Inaccessible districts because of current fire responsibility zones 117

5.20: Inaccessible buildings 118
5.21: Inaccessible landuse types because of current fire responsibility zones 119
5.22: Inaccessible health, education and security services because of current fire responsibility zones 121

LIST OF TABLES

TABLE

2.1: Classification of roads according to their types 30
2.2: Impedance results according to cell crossing time 31
3.1: Phases of fire management according to the time of performed actions 44
4.1: Total area of landuse types in Çankaya district 62
4.2: Raw Data About The Study 69
4.3: Records of the "type" field in the transportation network database ... 77
4.4: Oneway restrictions on main streets based on "Ankara Governership Traffic Commision of Administrative Province" on 31.01.2003 80
4.5: Records of the "oneway" field in the transportation network database 81
4.6: Turn restrictions on separated state roads 83
4.7: Average speeds on normal traffic conditions based on the study of Ankara Metropolitan Municipality Office of Information Systems 88
4.8: Average speeds based on an interview with İskitler fire brigade drivers 89
4.9: Final accepted average speeds based on fire driver experiences and the study of Ankara Metropolitan Municipality Office of Information Systems 89
5.1: Total accessed area by fire brigades in Çankaya district under different traffic conditions 99
5.2: Total area of critical landuse types in Çankaya district 101
5.3: Number of buildings in critical areas 104
5.4: Total accessed area by fire brigades in normal traffic conditions by considering fire responsibility zones in Çankaya district 113

5.5: Total area of inaccessible landuse types because of current fire responsibility zones 120

LIST OF ABBREVIATIONS

ESRI: Environmental Sciences Research Institute

JPG: Joint Photographics Experts Group

GIS: Geographical Information Systems

DBF: Database File Format

HTTP: Hypertext Transfer Protocol

NFPA: National Fire Protection Association

NFRTS: National Fire Response Time Standard

WWW: World Wide Web

XLS: Excel File Format

UWDMC: University of Wisconsin Disaster Management Center

UTM: The Universal Transverse Mercator

CHAPTER I

INTRODUCTION

Human being has always been in a continual struggle with fire, which is an undeniable reality of life. As it is a sudden and unexpected event, it can occur anywhere, any time and at any scale causing irreversible damages to human life and property. Each year, hundreds of fires involve multiple civilian deaths around the world. On an annual base, these fires account for an estimated thousands of civilian deaths, thousands of civilian injuries, and millions of dollars in fire loss (U.S. Fire Administration Topical Fire Research Series, 2001). Fire, which is the most frequent one among all disasters, is a fact of life, but it is always possible to decrease the effects of fires by fire preparedness (Yalazı, 1998).

Fire preparedness, which basically reflects an organization's readiness to respond to an emergency in a coordinated, timely and effective manner, is a must for cities to reduce fire casualties of human life, environment and property loss and it is absolute that time is one of the most vital component of fire preparedness (Heritage Collections Council, 2000). A few seconds of delay by fire response units may mean a lot of loss of lives, health and money in fire fact.

When time is considered, accessibility concept takes its paramount place in fire preparedness reality. Accessibility refers to how easy it is to get to a site and can be measured in terms of travel time and distance. As a fire service provider, you can find out if fire services can reach most of the community within a few minutes and identify critical areas that are out of service range. For example, a fire brigade may not be able to access 5000 people or 5 districts or 4 hospitals or school within 15 minutes or so drive (ESRI, 1997). Examining accessibility can help us to identify critical areas in the city based on fire response time and to determine the extent to which a city is ready for a fire incident.

Measuring and evaluating fire service accessibility can help decision makers, who are local authorities including civil defence, fire service providers, department of planning, to test the current fire service response performance, to identify critical areas that have low or no accessibility, and to find out solutions in order to improve the response to these critical areas (Badri et al., 1996). That is why fire service accessibility is a vital concept in fire preparedness and has a leading role in reducing casualties.

With the development of science and technology, many new concepts and ideas have came out and are supported by new scientific and technological successes (Xin et al, 2000). The use of GIS as a decision support system in fire environment has grown rapidly in recent years as an outcome of this development. Many fire departments throughout the world have investigated and applied geographical information system technology to improve their operations at the strategic, tactical, and landscape levels (Englefield et al., 2000; Howard, 1997). Using GIS in fire preparedness can considerably contribute to decision makers, responsible for planning, with the ability to visualize, organize and manipulate large volumes of spatially referenced data, and understand geographical patterns and trends that would otherwise be difficult to comprehend (Peters and Hall, 1999).

In the light of the above-mentioned facts; the aim of this thesis is to measure and evaluate the fire service accessibility in Çankaya district of Ankara in order to determine the accessibility of places, based on fire response time, and to find out the efficiency and the effectiveness of the fire services in the present condition by using GIS. The study tries to find out the answer to the following questions to be able to take necessary precautions for fire preparedness;

- Which part of the district could not be accessed by fire units within critical time thresholds?

- Which critical urban services (education, health etc.) are found in these critical areas?

The results provide good support for decision makers to answer the question "To what extent the accessibility results could be used as a baseline in fire preparedness to take precautions and reduce the probable losses?". The results can also work as a part of a decision support system, and help local authorities to make pre-queries for nearby places of the incident area, and can provide a basis for an interactive route finding system that will allow fire services to assess, compare and select routes through urban areas by small database improvements. For example the questions of "How many km's or minutes do fire service units have to travel to reach fire incident area?" and "From which route in the city do fire service units have to travel to reach fire incident area?" can be answered easily.

This study includes a review of the literature about accessibility and fire preparedness. The review of the literature about accessibility is used to understand and define the accessibility measures, measurement techniques and database components of accessibility concept in GIS environment with respect to fire service accessibility. The review of the literature about fire preparedness is used to define the role of fire preparedness in fire management, to define the critical fire response time thresholds for evaluation of fire service accessibility, to learn the standards in fire response time and to understand; to what extent the accessibility results could be used as a baseline to take precautions and to reduce the probable losses in fire preparedness. Despite many studies about fire concept and accessibility concept separately in the literature, the main body of this research on measurement and evaluation of fire service accessibility is limited in terms of the number of applications reported in the literature. Therefore, the literature survey part of this study was very important and the findings of this literature survey formed a basis for the case study regarding the measurement and evaluation of fire service accessibility by using GIS in Çankaya district of Ankara.

The thesis starts with the literature survey about accessibility concept with respect to fire service accessibility which is a vital concept in fire preparedness. In this chapter, comparative definitions, components, measures, measuring techniques and practicing examples of the accessibility concept both in Turkey and in other countries are described. Then, GIS aspects of the concept are focused on, in order to understand the measuring techniques and database aspects of the concept and the relations between accessibility and GIS.

After covering the concept of accessibility, the concept of fire preparedness is explained briefly in the third chapter. First the terms like, fire prevention (mitigation), fire preparedness, fire response and fire recovery, related with fire management are described, then the place of preparedness in fire management, interrelation between fire service accessibility and fire preparedness, critical fire response time thresholds, the standards in fire response time and importance of GIS in fire preparedness are discussed in order to define what extent accessibility results could be used as a baseline to take precautions and reduce the probable losses in fire preparedness.

In chapter four, the case study is described based on the findings in the previous literature survey chapters. The aim of the study, the location of the study, including the reason of why this area is selected for the case study, the data of the study and the basic steps, including data collection, digitizing, editing, database building, are described.

Chapter five presents the final fire service accessibility maps, the evaluation of the results concerning critical urban areas and facilities in Çankaya district of Ankara. "Arcview 3.1 software and Arcview Network Analyst module of Arcview 3.1 software, by ESRI" is used to perform accessibility analyses in the study.

Finally, last chapter concludes the study by a general summary, critiques and suggestions according to the results extracted from the thesis.

CHAPTER 2

DESCRIPTION OF THE ACCESSIBILITY CONCEPT

In this chapter, comparative definitions of accessibility, the need for accessibility analyses, the components of accessibility, accessibility measures and measuring techniques of accessibility in GIS are described by different examples both from Turkey and from other countries.

The purpose of this chapter is to extract information about the accessibility measures and measuring techniques of accessibility in order to understand the steps and database aspects of measuring accessibility regarding fire service accessibility by using GIS.

2.1. Definitions of accessibility

"Accessibility… is a slippery notion… one of those common terms that everyone uses until faced with the problem of defining and measuring it" (Gould, 1969, page 64)

There have been different aspects of accessibility and many different definitions of accessibility can be found in the literature. The reality about accessibility is that; the term accessibility is used by various disciplines in different meanings and it is really difficult to define and measure it as Gould said in his study in 1969.

Makrí (2001) states some of the different aspects of accessibility in the literature;

"Physical accessibility" is being able to reach a point in spite of any physical hindrances.

"Mental accessibility" is understanding and being able to use a given area and its facilities.

"Social accessibility" is having friends and a job and being able to get to and from work, meet friends and participate in social activities.

"Organizational accessibility" is having access to travel opportunities, information and service regarding a journey.

"Financial accessibility" is being able to afford available public or private means of transport.

And "Virtual accessibility", which is a very popular term of our new century, is being able to access information and people without moving from a certain place, by using electronic facilities.

The mentioned accessibility concept in this study is directly related with physical accessibility which means being able to reach a point in spite of any physical hindrances.

One of the definitions of physical accessibility is the ease and convenience of access to spatially distributed opportunities with a choice of travel (Dong et al., 1998). Kuntay (1976b) defines physical accessibility as the ability to reach from one place to another securely and comfortably by shortest way, simple route and appropriate speed, and ability to reach the intended location. Joly (1999) defines the physical accessibility as a geographical concept in transport planning and in evaluation of projects and as a capacity to reach customers, a service or a message. And Chen (2000) defines physical accessibility as a significant index that reflects the ease for travellers to achieve desired movements in urban areas. All the definitions about physical accessibility in the literature points out the same common direction; physical accessibility is being able to reach an intended point or location in spite of the hindrances like transportation and reflects the ease for travellers.

Kwan (1998) emphasizes in his study that physical accessibility can be handled either for people (individual accessibility) or for places (place accessibility) according to the aim of the study in such a way that; physical accessibility can be handled either as a property of people defining how easily an individual can reach activity locations, or as an attribute of locations indicating how easily certain places can be reached.

In this study, as mentioned before, the focus is on the physical (place) accessibility, which answers the question of how easily fire services are able to reach the locations within a threshold time, from an emergency point of view. Thus, from now on, the mentioned accessibility is the physical accessibility in the following parts of this chapter.

2.2. The Need for Accessibility Analyses

Accessibility has long been used by planners and politicians, and directly or indirectly always been an important part of urban fact (Makrí, 2001; Makrí and Folkesson, 1999)

Juliao (1999) states accessibility as a key variable for planning policies and territorial development. Planning policies and territorial development are concerned with equity and a better distribution of people and activities in the territory. That is why accessibility, regardless if it is measured in time, cost, distance, or population, is the most important variable that one must consider in the early stages of planning.

Accessibility analyses have a wide usage to check the benefits of plans as a planning control tool, and help decision makers to investigate the new locations of urban services, to test the benefits of the current locations of urban services, to identify thresholds about urban services, to find out the capacity and service area of urban services such as education, emergency, leisure, industry and shopping etc. (Kuntay, 1990; Kemeç, 2001). Halden et al (2000) also emphasize accessibility analyses as practical tools in evaluating the performance of transportation systems. Accessibility results can be used to check if urban services are highly accessible by walking, cycling or public transport etc., to identify critical regions that are out of current service range or to select appropriate sites for new services.

Accessibility analyses can answer the questions of;

- If districts or services are accessible from certain locations, by different vehicles (walking, cycling, public transport etc.) within *accepted time and distance thresholds?*

For example if education services are within 500 meters, 5 minutes from bus stops or if housing are within 5 - 10 minutes to recreational services (People have always been in an effort to live in locations that optimize access to various utilities such as production, food, sales, purchases, leisure activities etc.) (Makrí, 2001).

- If services are equally distributed within the city?

- Where is the service area for a facility? (e.g. shopping centre, fire station, hospital)

- What is the level of access for particular facilities?

- How many people, jobs, employees, floors, areas, etc. are within 15-20 minutes from defined locations?

Accessibility analyses evaluate the interrelationships between patterns of land use and the nature of transportation systems and enable us to understand the various issues such as level of access, service area, capacity, threshold and distribution etc. Therefore, accessibility measures are useful indices in decision making and help decision makers to define optimum strategies for action.

2.3. Components of Accessibility

There are three generally mentioned components of accessibility in the literature which are;

- activity element

- transportation element

- zones[1]

All accessibility measures include representation of the activity element, transportation element and the zones which need to be expressed at a

---

1 The usage of zones as a component in accessibility studies is sometimes not necessary depending upon the measuring techniques. In isochronal based technique and raster based technique using zones, is not necessary as a component of accessibility (Explained in Section 2.5.Measuring techniques of accessibility).

level of detail, appropriate for the needs of the particular situation about accessibility (Halden et al., 2000; Makrí, 2001).

2.3.1. Activity[2] Element

The activity element of accessibility is usually based upon the land use of interest and type of person or traveller at alternative origins or destinations. Depending on the issue at hand, it can be handled as type of landuse or type of people or traveller, etc. (Makrí and Folkesson, 1999; Halden et al., 2000).

Land use of interest in accessibility studies can consider several facilities such as education and training facilities (like schools, colleges, universities, training centres), emergency facilities (like health centres, hospitals, police offices, fire services), or shopping and leisure facilities (like shops/shopping centres, cinemas, theatres, sports centres, outdoor activity opportunities, pubs, clubs) etc.

Type of person or traveller in accessibility studies can consider employment status of the traveller (unemployed, retired, economically active etc.) or age of the traveller (adult, children etc.) the mobility[3] of the traveller according to the needs of the particular situation.

---

2 The activity element can also be seen as "attractiveness", "opportunity", "attraction", "utility" or "motivation" in the literature.

3 Mobility is a critical component of accessibility. The term mobility refers to the potential for movement. A number of factors affect mobility including the availability and cost of transportation infrastructure. For example, if two people have the same residential location, but one person has a car and the other does not, each person's access to employment and shopping activities may be very different (Transportation Statistics Annual Report, 1997).

For example; the number of economically active people which have access to a new trade center by public transport in 15 minutes as shopping accessibility or total size of recreational areas accessed by the residentials by foot in 5 minutes as recreational accessibility etc. can be investigated as type of activity elements regarding the aim of the study. In this study; activity element is handled as the number of critical facilities and people that can be accessed within critical time thresholds by fire trucks.

2.3.2. Transportation[4] element

The transportation element of accessibility aims to represent the real behaviour of travel and based on the resistance effect of different types of travel modes (pedestrian, bicycle, car, bus, rail, etc. or combination of several travel modes) and transport element is generally represented by travel time, travel cost, travel distance, or generalized cost/time etc.

The time of the travel (rush hour, normal hour, etc.), the day of the travel (Sunday, Monday, etc.), or season of the travel (winter, summer, etc.), the quality and capacity of the roads, the economy, comfort, cost and safety considerations about the travel, are important factors and must be considered in representation of transportation element in accessibility studies according to the aim of the study (Kuntay, 1976b; Halden et al., 2000).

---

4 The transportation element can also be seen as "deterrence" or "impedance" or "resistance" in the literature.

2.3.3. Zones

The zone element of accessibility represents the level of detail in accessibility studies. Geographical regions, districts or quarters are mostly used as zone elements of accessibility in the literature (Halden et al., 2000).

The detail of the study depends upon how much effort can be afforded on the analysis and depends upon the aim of the study. For example if the aim is about a national or regional issue, which requires a wide geographical coverage, a fairly coarse zoning system which means low detail may be adequate. However a local issue such as the accessibility of a school may require very detailed local representation. Reliable data are usually easier to obtain for coarser zones.

2.4. Accessibility Measures

At its simplest level, qualitative descriptions can be used to define the accessibility of a location. Terms such as "good accessibility", "average accessibility" or "poor accessibility" can be used as simple qualitative accessibility measures for describing the accessibility level of a location in meaning of the accessed population, accessed facilities, or sometimes the level of transport supply (Halden et al., 2000).

However, accessibility measures will usually need a more comparative approach than qualitative accessibility measures in order to support practical decision making. In the literature there are three generic but overlapping types of widely used quantitative indicators. The most basic and most widely used measures about physical accessibility can be described as below;

- simple measures

- cumulative opportunity measures

- gravity measures (Makrí, 2001; Chen, 2000).

In spite of the existence of various accessibility measures, Makrí and Folkesson (1999) claim that a best approach for accessibility measures does not exist. Different situations and purposes demand different approaches.

2.4.1. Simple measures[5]

The use of time and distance is the basic representation of this type of accessibility measures and it has been used for much of the case study work (Chen, 2000).

A 10 minute drive zone to city centre or 800 meters walk zone to education services or total length of motorways, etc., are usually good indicators to define the accessibility in terms of time and distance (Halden et al., 2000).

Although time and distance is the main and most common measures of simple accessibility, various indices like amount, frequency or cost etc. can also be handled among this type of accessibility measures.

The number of stations, bus lines, the variety of vehicles (i.e. rail/bus/light rail etc.), the frequency of public transportation, (i.e. 1 bus for every 15 minutes etc.) or cost of transportation between certain locations are also

---

5 This type of measures can also be seen as "spatial separation measures" or "distance measures" in the literature.

simple but useful indicators of simple accessibility measures and has been used for much of the studies by providing a comparative approach (Halden et al., 2000).

In spite of the limited scope, simple type of measures (or indices) have wide applications within research and are used in many studies because of their simplicity.

2.4.2.Cumulative Opportunity measures

Cumulative opportunity measures are based on the concept of geographical proximity to a single reference location and they represent *accessibility in terms of the cumulative number or proportion of* opportunities that can be reached within specified travel distances or times from a reference location (Kwan, 1998).

The cumulative opportunity type accessibility measures are used for a wide variety of planning purposes and are usually calculated from major centres of population such as towns, cities or public services such as hospitals, schools, fire brigades. The numbers of students within 10 minutes travel time from schools or the number of shops / floor spaces within 5 km distance from districts are good examples of this kind of accessibility indices. Cumulative opportunity measures provide an idea of the range of various choices available within an area (Makrí and Folkesson, 1999). A higher value of the cumulative opportunity for a location means more accessible location (Halden et al., 2000).

The basic formulation for cumulative opportunity measure is that;

$$A_t = \sum_t O_t$$

in which t is the threshold, and O_t is the cumulative opportunity that can be reached within that threshold. The cumulative opportunities can be the number of jobs, number of people, number of employees, total retail floor spaces, area of the facilities, etc., within a threshold travel cost (distance, time etc.) from a defined location (Chen, 2000).

Because of the fact that all the destination opportunities beyond critical threshold are cut off, the threshold travel distance or time is a key factor in the cumulative opportunity measures and very sensitive for the final accessibility results (Makrí, 2001).

2.4.3. Gravity based measures

Gravity based indices measure accessibility by weighting the opportunities in an area by a measure of their attraction and discounting each opportunity by a measure of the travel impedance (Kwan, 1998; Makrí, 2001). Gravity based indices examine both destination characteristics and transportation characteristics jointly and depending on the problem at hand, various measures of attraction such as total retail floor space or the number of households have been used (Chen, 2000).

Basic formulation for gravity model is that;

$$A_i = \sum_j \frac{O_j}{f_{ij}}$$

in which O_j represents the attraction factor, f_{ij} represents the impedance factor (Chen, 2000).

The gravity-based measures are identical to the cumulative opportunity measures. However, the gravity based measures represent the joint effect of transportation systems and land use patterns in accessibility studies without time or distance thresholds (Dong et al., 1998).

2.5. Measuring Techniques of Accessibility using GIS

The literature on measuring techniques of physical accessibility using GIS can broadly be divided into three which are;

- Zone based technique
- Isochronal technique
- Raster based technique

Although there are various accessibility measuring techniques, the best approach for measuring techniques of accessibility does not exist. Different situations and purposes demand different approaches as previously mentioned (Makrí and Folkesson, 1999).

2.5.1. Zone based technique

The reason of the name "zone based technique" is that; the accessibility evaluations are calculated and presented in a zone logic like districts, quarters etc. (also discussed in Section 2.3).

A zone based technique for measuring accessibility by GIS is argued by (Chen, 2000) as a case study specific to shopping purpose. The study evaluates accessibility by using simple, cumulative opportunity and gravity accessibility measures specific to shopping purpose by auto and by transit during off peak hours for Dallas/Fort Worth area. The retail employment in destination zone is taken as an activity element which is also described in Section 2.3.

The formula of $A_3 = 1 / \sum_j t_{ij}$ is used in representation of shopping accessibility as simple measure in which,

t_{ij} is the minimum total travel time between the centroids of zones i and j by auto and by transit in off peak hours. Two impedance values by travel time is calculated in the formula to produce accessibility results as a simple measure (Figure 2.1 as example).

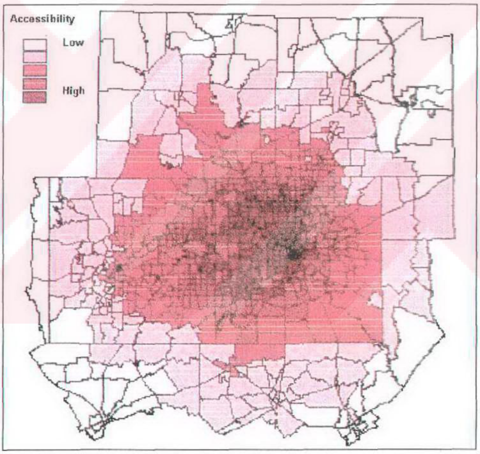


Figure 2.1: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a simple measure

Source: (Chen and Qinglin, 2000)

It can be seen that simple measure presents higher accessibility in central area and lower in peripheral areas, which means accessibility to other areas in downtown area is easier for the residents than in suburb according to the simple accessibility distribution in Figure 2.1. The accessibility results can be explained by the formulation in which only travel time is considered and no destination attraction is taken in account as previously described in Section 2.4.1 (Chen, 2000).

The formula of $A_i = \sum_{t_{ij} < T} R_j$ is used in representation of shopping accessibility as cumulative opportunity measures, in which,

i is the origin zone ID; j is the destination zone ID; R_j is the number of retail employments in destination zone j; t_{ij} is the travel time from zone i to destination j; T is the time threshold which is set as 30 minutes for auto and 45 minutes for transit in the Chen's project.

From the related databases attached, the cases with travelling time less than 30 minutes and 45 minutes (Figure 2.2 as example) are selected among the retail employments as activity element for each origin zone. The cumulative number of retail employments, with travelling time less than the transportation threshold, shows the representation of shopping accessibility for each zone as cumulative opportunity measure (Figure 2.3 as example).

zonedata.dbf

Orig_zon	Dest_zon	traveltime	Dist_op	Imp_op	Cost_op	Time_op	Dist_pk
1	4	28.08	18.15	418	0	25.08	18.15
1	5	16.48	9.82	225	0	13.48	9.82
1	6	19.08	13.07	269	0	16.08	13.07
1	7	24.33	16.33	355	0	21.33	16.33
1	8	23.61	15.34	343	0	20.61	15.34
1	9	18.57	11.25	258	0	15.57	11.06
1	10	16.83	9.97	230	0	13.83	9.97
1	11	11.94	6.87	149	0	8.94	6.87
1	12	37.93	28.10	582	0	34.93	28.10
1	13	34.25	25.35	520	0	31.25	25.35
1	14	34.75	25.07	529	0	31.75	25.07
1	15	38.86	27.19	597	0	35.86	27.19

Figure 2.2: Traveling time less than 30 minutes selection among the retail employments as activity element in Dallas/Fort Worth area

Source: (Chen and Qinglin, 2000)

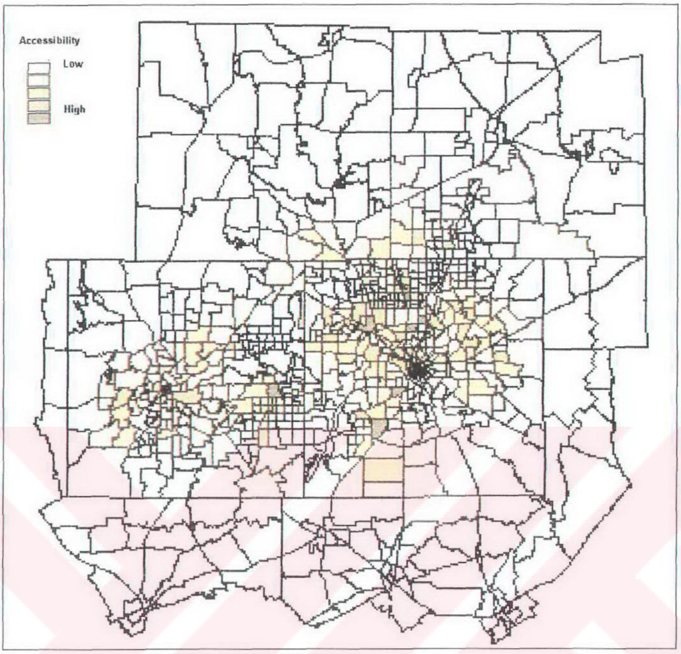


Figure 2.3: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a cumulative opportunity measure

Source: (Chen and Qinglin, 2000)

The accessibility representation of each zone as cumulative opportunity measure is the count of cumulative retail employment opportunities for the origin zone and surrounding zones within the time threshold. More retail employments exist in downtown areas and surrounding areas, so these areas present higher accessibilities. In outer areas, although some zones also have large retail employments themselves, they still present low accessibility because of they are usually large and they don't have enough shopping opportunities surrounding them within time threshold.

The formula of $A_i = \left[\frac{1}{J} \sum_{j=1}^{J} \left(\frac{\log R_j}{\log H_{ij}} \right) \right]$ is used in representation of shopping accessibility as gravity based measure, in which,

R_j is the retail employment in zone j (proxy for shopping opportunities); J is the total number of zones in the area; H_{ij} is the transportation impedance element. The cumulative retail employments, divided by the transportation impedance without a threshold, shows the representation of shopping accessibility for each zone as gravity based measure (Figure 2.4 as example).

The formulation includes both destination attractions of retail employment and transportation impedances. The zones which are surrounded with large shopping opportunities and have low transportation impedances present higher accessibilities when compared with other zones.

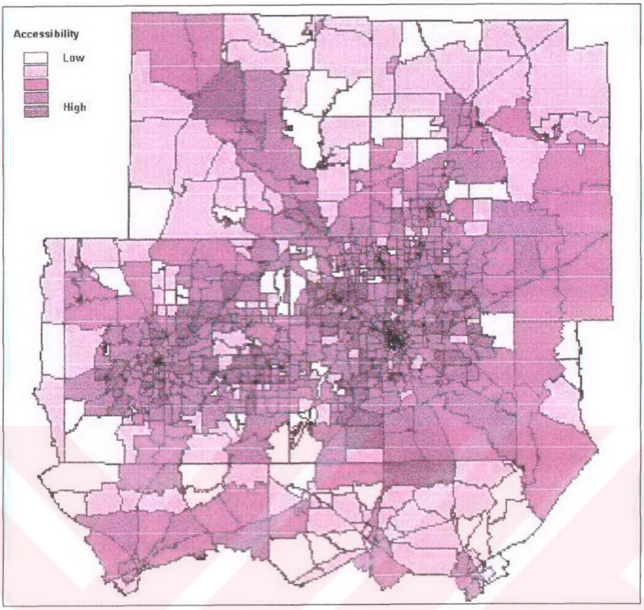


Figure 2.4: The zone based representation of shopping accessibility by auto in Dallas/Fort Worth area as a gravity measure

Source: (Chen and Qinglin, 2000)

Another example to zone based technique for measuring accessibility by GIS is the Kwan's study, in Franklin county, Ohio in 1998. It is also about shopping accessibility and gravity and cumulative opportunity measures are used to represent shopping accessibility. Kwan's study is a good example in order to understand the steps and database aspects of measuring accessibility.

The data used in the study are a detailed digital street network of Franklin county and a digital geographical information about land parcels which includes various kinds of shopping and retail facilities such as restaurants, personal business establishments, banks, entertainment, outdoor activities, educational institutions and office buildings.

Land parcels are used as a zone element which is necessary to represent accessibility in a zone based technique. A point coverage of the centre point of the parcels is generated in order to calculate the travel times and distances between land parcels. A weighted area, that equals the parcel area multiplied by a building height factor, is computed for each land parcel as activity element for the calculation of gravity and cumulative opportunity measures of shopping accessibility.

All point to point distances between land parcels are measured in terms of travel time in minutes on the Franklin county transportation network. Travel time between land parcels are taken as the shortest time between them. Seven road classes in the digital street network are reclassified into three categories in order to simplify the computation in the study. Travel impedance is assigned as the average travel speed[6] on the transport network as follows;

- 55 miles per hour for controlled access freeways,

- 25 miles per hour for state highways and municipal arterials without access control and

- 15 miles per hour for other city streets.

The travel time obtained is further adjusted upward 25 percent to take into account delays at traffic lights and turns.

---

6 Travel time estimates are usually based on average speeds assigned to different classes of road. However it is preferable to use comprehensive data on congestion by time of day allowing more accurate estimates of travel time and to check travel times between particular locations on the basis of travel records if possible (Halden, Mcguigan, Nisbet, Mckinnon, 2000).

In Kwan's study the visualization of the shopping accessibility results confirmed that the used techniques generates a realistic travel environment for the study without introducing additional data structure such as turn impedance, which may substantially increase the computational charge of the GIS procedures. Lastly weighted sum of urban opportunities within reach in 20, 30, and 40 minutes of travel time are measured and visualized in the study.

2.5.2.Isochronal technique

The other and simpler kind of accessibility measurement technique is the isochronal technique. The reason of the name "isochronal" is that the accessibility evaluations are calculated and presented in a isochronal logic.

An isochrone is a line on a map that connects points of equal travel time away from a single reference point. If an origin is defined as the reference point, isochrones can be drawn connecting points in all directions that can be reached in a threshold time or distance (Figure 2.5 as example). The isochrone is irregularly shaped because of the structure of transportation network. Routes make it possible to travel faster in some directions than in others (Transportation Statistics Annual Report, 1997).

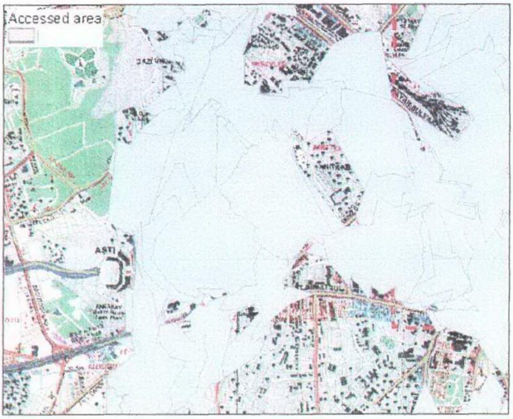


Figure 2.5: The isochronal representation of accessibility

If an accessibility indicator of the time or distance is needed, the indices like 10 minutes or 500 meters relative to a location can give useful results as simple measures of accessibility. If hospitals are used as the reference point, isochrones can be drawn connecting points in all directions that can be reached in exactly 10 minutes as simple measures (Figure 2.6 as example).

If an indicator of the total number of education opportunities within 10 minutes to hospitals is needed, the cumulative number of facilities located within the 10-minute isochrones can be counted. If 20 minutes is considered a reasonable threshold of the time, then a 20-minute isochrones can be drawn and cumulative number of the facilities can be counted as cumulative opportunity measures. The indices of cumulative number of people or facilities etc. can give useful results in accessibility studies (Figure 2.7 as example).

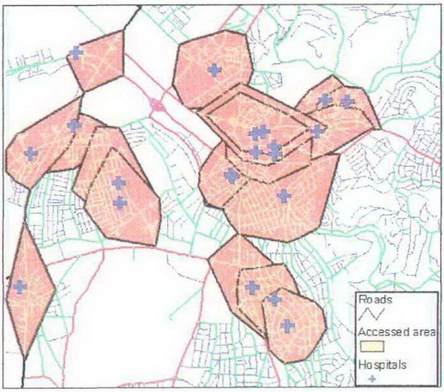


Figure 2.6: The isochronal representation of 10 minutes accessibility of hospitals as a simple measure

Figure 2.7: The isochronal representation of cumulative number of education services within 10 minutes accessibility to hospitals by pedestrian as a cumulative opportunity measure

Dodge and White's study in 1995 is a good and simple example of isochrone based representation of accessibility for public services. The study identifies how far people had to travel to reach a healthcare service in Wales. Around each clinic 5 km buffer is created and several gaps were found which shows the areas where accessibility to the clinics could be problematic (Figure: 2.8).

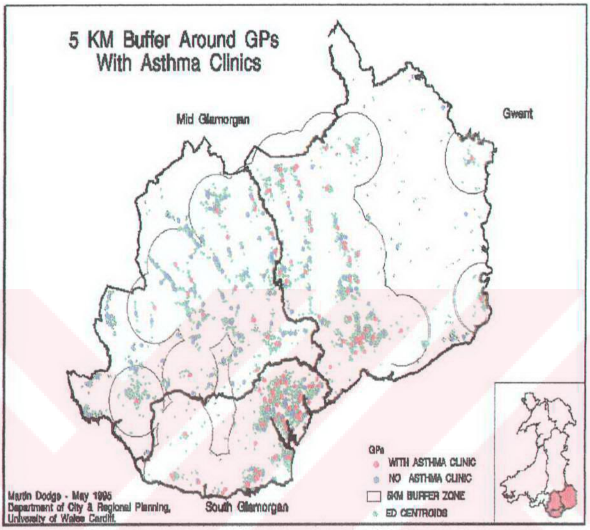


Figure 2.8: The isochronal representation of 5 kilometers accessibility from asthma clinics as a simple measure

Source: (Dodge and White, 1995)

As in all techniques, isochronal representation of accessibility measures are most useful when they are evaluated at more than one threshold and at more than one point, and compared. For example doubling the travel time can triple the number of shopping opportunities or 7 shopping facilities can be within 10 minutes and 13 can be within 20 minutes. Comparing the accessibility results in more than one district or in different locations can help us to draw a more clear conclusion about the related subject.

As mentioned before one main weakness of cumulative opportunity measures in isochronal type of representation is that these measures are highly sensitive to the analyst's judgment about what constitutes reasonable threshold travel time. Thus, despite the shortcomings, isochronal technique has an important place in accessibility studies and very useful in evaluating accessibility from the stand point of various fields regarding job accessibility for people of different income groups or several facility accessibility within critical thresholds by different transportation types.

2.5.3. The raster based technique

The raster based technique is the other and simple kind of accessibility measurement which is very similar to isochronal technique. The differences from isochronal technique is that, the equal travel time or distance from a reference point is represented by the value of pixels in raster environment instead of isochrones which are lines in vector environment. Raster based technique is mostly used in regional studies which doesn't necessitate spatial accuracy.

Juliao (1999) describes a raster based technique in Portugal for measuring accessibility to the nearest municipality town, measuring accessibility to the nearest highway node and measuring accessibility to city centre, considering the travel time. The study is also one of a good example in order to understand database aspects and the steps of measuring accessibility.

Juliao (1999) argued in the study that the traditional methods of accessibility evaluation do not consider the whole territory; and mainly based on node/arc logic, so accessibility evaluation must be done in raster environment in order to create a continuous model. Working in raster environment reduces the geometrical accuracy of the information, but opens a wide range of new analysis capabilities. This is why although the original information was in vector format, the analysis is made mainly using raster data by Juliao.

In the study the general structure of the accessibility evaluation is summarized in 3 phases which are mainly;

- Data acquisition and integration (preparation of the geographical information)

- Cost surface and modeling (calculating the impedance/resistance across each individual cell by cost surface) and

- Accessibility analysis (measuring and visualizing the accessibility)

Data acquisition and integration phase of the study contains preparation of the geographical information which are the data with every highway node, the data with the central point of every municipality town and data of the urban road network system.

The first step in the data acquisition and integration phase of the study is the classification of roads according to their types which is presented in Table 2.1.

Another step is converting vector data to raster format as a continuous surface, which is a necessary step to work in raster environment (Figure 2.9 as example). Because of the study is at a regional level, a pixel dimension of 100 m is used in data conversion process, which seems enough for the accuracy purpose of the study. Matrix of 1,580 rows by 1,519 columns are used to cover the whole region, which means a total of 2.400.020 cells.

Table 2.1: Classification of roads according to their types

Road Category[7]
IP highway
IP 2 lane
IC highway
IC 2 lane
National Road
Regional Road
Municipal Road (former national)
Municipal Road

Source: (Juliao, 1999)

Figure 2.9: IP, IC, national and regional road network of Portugal in raster environment

Source: (Juliao, 1999)

---

7 IP and IC are the two main route categories in Portugal: IP (Main route) is the first level and IC (Complementary route) is the second level route.

Cost surface and modelling phase of the study contains the calculation of cell crossing time for each pixel. This surface can be created in many different cost units (distance, time, currency, or any other unit). In the Juliao's study, travel time is used as travel impedance unit. Calculation of cell crossing time in the study is found by establishing the average speed according to the road category and then calculating the cell crossing time by using the following equation:

$$CCT = \frac{P \times 60}{TS \times 1000}$$

where;

"CCT" is the Cell Crossing Time (minutes)
"P" is the Pixel Size
"TS" is the Traveling Speed (Km/h)

For example if one is travelling in an IP 2 lane, the result is the following:

$$CCT = \frac{P \times 60}{TS \times 1000} = \frac{100 \times 60}{80 \times 1000} = \frac{6}{80} = 0.0750$$

After this calculation Juliao achieves an impedance result for traveling in IP highway or national road like the following (Table:2.2).

Table 2.2: Impedance results according to cell crossing time

Road Category	Average Speed	Cell Crossing Time (minutes)
IP highway	110	0.0545
IP 2 lane	80	0.0750
IC highway	110	0.0545
IC 2 lane	70	0.0857
National Road	60	0.1000
Regional Road	55	0.1091
Municipal Road (former national)	50	0.1200
Municipal Road	50	0.1200

Source: (Juliao, 1999)

To fill the gaps between road infrastructures and to consider the whole territory, the average walking speed for every cell outside the network is established as 6 Km/h (1 minute of cell crossing time) by Juliao.

In the last phase of the study which is the measuring and visualising phase of accessibility, the only necessary step is to define an origin and than apply a cost distance function using the cost surface. The cost distance function calculates the less cumulative cost starting from one or several origins and travels through a cost surface and achieve a final simple accessibility measure as presented in accessibility to the nearest municipality town (Figure 2.10), accessibility to the nearest highway node and accessibility to city centre (Figure 2.11).

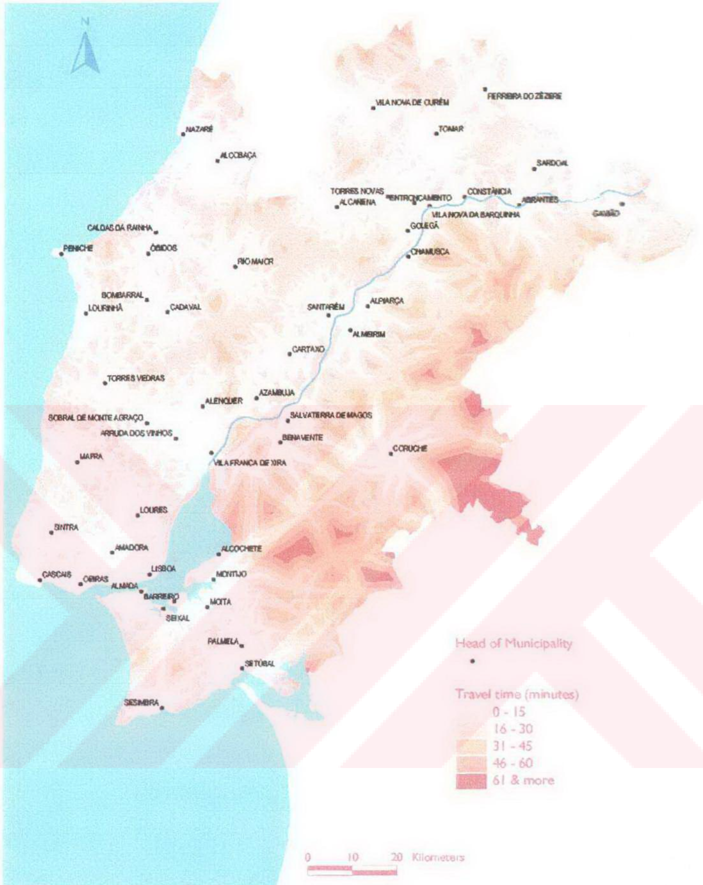


Figure 2.10: The raster based representation of accessibility to the municipality town starting from the city centroids as a simple measure

Source: (Juliao, 1999)

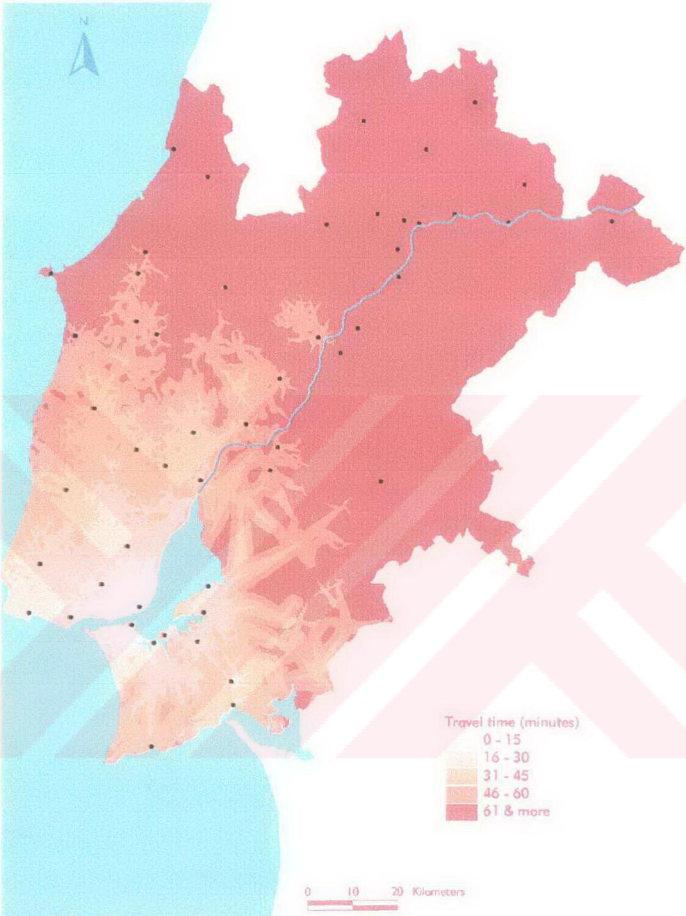


Figure 2.11: The raster based representation of accessibility to Lisbon as a simple measure

Source: (Juliao, 1999)

2.6. The importance of GIS in accessibility studies

GIS is a computer system capable to store, manipulate and display data related to geographical location through a convenient and visual interface.

Using GIS in accessibility studies can contribute to decision makers with the ability to visualize, organize and manipulate large volumes of spatially referenced data, and understand geographical patterns and trends that would otherwise be difficult to comprehend (Chen, 2000; Peters and Hall, 1999)

Halden et al (2000) emphasize in their study that accessibility analysis often lends itself to GIS for analysis and presentation. Since accessibility measures describe the characteristics of a location, origin or destination, GIS has powerful tools to present such spatially referenced information in a way which aids decision making.

In a more detailed way, Makrí and Folkesson, (1999) mention the advantages of GIS in measuring accessibility. According to their study GIS has a lot of strong capabilities in;

- calculating the distances or costs in the spatially referenced transportation data, (all distances between origins and destinations can be computed in single steps)

- building regulations of streets such as one-way streets, closed streets, overpasses and underpasses,

- estimating driving times based on actual speeds of vehicles on the road and the delays in intersections in the transportation data in measuring accessibility.

- extracting spatially referenced accessibility information from the basic data

- presenting accessibility results with opportunity of different scales and resourceful colour and figure choices.

Although measuring accessibility without GIS is possible, it has disabilities to visualize, organize and manipulate large volumes of spatially referenced data, and insufficiencies to comprehend spatial patterns and trends.

In the literature, Kuntay's study about measuring physical accessibility in 1976b is one of the good examples of measuring accessibility without using GIS. The study evaluates physical accessibility from public transport stations to urban facilities of hotels, banks, and cinemas (Figure 2.12 as an example) and from residential areas to "Tekel Tobacco Checking and Processing Workshop" (in Turkish "Tekel Tütün Bakım ve İşleme Atölyesi") by public transport in Trabzon.

Difficulties and insufficiencies in the measuring and evaluating process of accessibility without GIS can clearly be extracted from the Kuntay's study and can be summarized as;

- Only the main roads of the city get into consideration assuming that the speed is the same inside the whole network,

- The distances and times between locations are manually calculated in matrix format without spatially referenced,

- Regulations of streets and the delays in intersections are not considered,

- There is lack of spatial interaction with the data and geography, so it is difficult to extract accessibility information from the data,

- There is poor accessibility presentation without resourceful colour and figure choices and different scales.

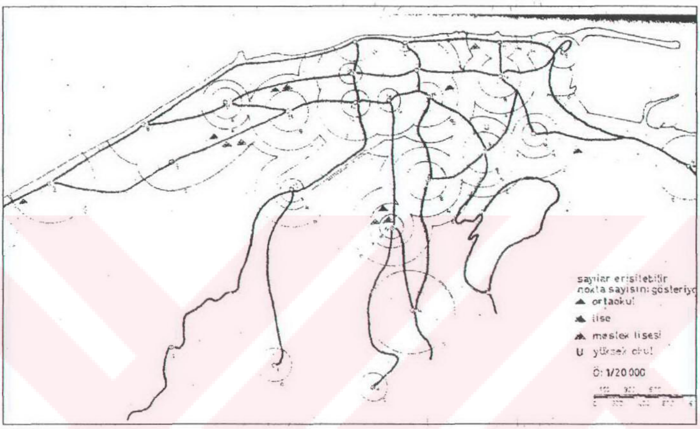


Figure 2.12: Representation of accessibility without GIS from public transport stations to urban facilities of hotels, banks, and cinemas in Trabzon

Source: (Kuntay, 1976b)

In the literature, Yalazı's study is also another example of measuring accessibility without using GIS. Yalazi analyses physical accessibility of fire services within their responsibility area in Ankara in 1998 and defines the approximate response times for fire stations (Figure 2.13; Figure 2.14). The average response time from fire stations to incident areas are generalized for all fire stations by bird-flight distances without considering the transportation network by using fire response statistical data of 1998, obtained from İskitler, Kurtuluş and Esat fire stations.

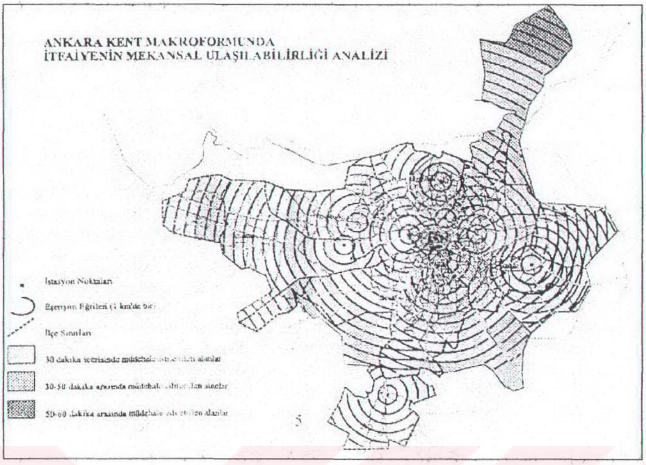


Figure 2.13: Representation of fire service accessibility without GIS in Ankara in 1998

Source: (Yalazı, 1998)

İstasyon	Kuş Uçuşu Sorumluluk	Kuş Uçuşu Eş Ulaşım Mesafesi	Kuş Uçuşu Eş Ulaşım Süresi
Keçiören	6 Km	0-1 Km	2-6 dak
		1-2 Km	3-8 dak
		2-3 Km	4-10 dak
		3-4 Km	5-12 dak
		4-5 Km	6-14 dak
		5-6 Km	7-16 dak
Gölbaşı	7 Km	6-7 Km	8-18 dak
Esat	8 Km	7-8 Km	9-20 dak
Batı Kent	9 Km	8-9 Km	10-22 dak
Kayaş	9 Km		
		9-10 Km	11-24 dak
		10-11 Km	12-26 dak
		11-12 Km	13-28 dak
Siteler	13 Km	12-13 Km	14-30 dak
Kurtuluş	13 Km		
		13-14 Km	15-32 dak.
		14-15 Km	16-34 dak.
		15-16 Km	17-36 dak.
		16-17 Km	18-38 dak.
İskitler	18 Km	17-18 Km	19-40 dak.
Sincan	18 Km		
		18-19 Km	20-42 dak
		19-20 Km	21-44 dak
		20-21 Km	22-46 dak
		21-22 Km	23-48 dak
		22-23 Km	24-50 dak
Altın Park	24 Km	23-24 Km	25-52 dak

Figure 2.14: Representation of bird-flight fire response time and distances without considering the transportation network and without geographical interaction

Source: (Yalazı, 1998)

2.7.Evaluation of the Chapter

The literature survey about accessibility is needed to understand the issues of "what type of measures and which measuring techniques can be used", "what kind of data is needed" and "what are the steps" for analysing fire service accessibility by using GIS.

It is clearly understood from the literature survey that using isochronal technique to measure fire service accessibility is the most suitable one among other techniques and using simple and cumulative opportunity type of measures is the most suitable measures to evaluate the fire service accessibility according to critical response time thresholds as described below.

The reason of "why isochronal technique to measure fire service accessibility is the most suitable one among other techniques?" is that; it is the only technique, which can represent accessibility in detail of street scale (in detail of roads, parcels etc.) (see Section 2.5). In zonal technique, representation of accessibility depends on a zone logic, and the whole of a district or a quarter is assumed to have the same accessibility. Because zones are the smallest unit to represent accessibility in zonal technique. Raster based technique is also not suitable for local issues such as accessibility of a fire brigade and mostly used in national or regional studies which doesn't necessitate a detailed local representation and high spatial accuracy.

The reason of "why simple measures best represent fire service accessibility?" is that; the use of time and distance is the basic representation of simple type of measures which directly answer the questions of "where are 5, 10, 15 minutes or 1, 5 , 10 kilometres access zones for fire services". Simple measures are good indicators to define the accessibility in terms of time and distance as mentioned in the accessibility measures part of the chapter (Section 2.4).

The reason of "why cumulative opportunity measures can also be used to represent fire service accessibility?" is that; cumulative opportunity measures provide an idea of the range of various choices available within defined thresholds in an area and they directly answers the questions of "how much people or how amount of facilities etc. are within 5, 10, 15 minutes or 1, 5, 10 kilometres access zones from fire services" as mentioned in the accessibility measures part of the chapter (Section 2.4).

Using gravity type measures to represent fire brigade accessibility is not appropriate for the aim of the study. Because gravity type indices can only be measured by zone based technique, which represents accessibility in a zone based logic such as districts, quarters etc., and is not suitable for measuring fire service accessibility which needs a more sensitive approach.

Most of the effort required for accessibility analysis is associated with data collection and processing rather than analysis. The general steps and database components of measuring accessibility in GIS regarding fire service accessibility is clearly extracted from the literature survey and can be summarized as;

- Collection of the digital street data as transportation element and the digital land use data as activity element (such as fire services, health services, education services etc.) which are the two main database components of measuring accessibility.
- Classification of roads according to the type, quality and capacity,
- Establishing average speeds according to the road classifications, time of the day (rush hour, normal hour etc.) weather conditions (sunny, foggy, rainy etc.), season (winter, summer etc) and mobility of fire service (fire plane, fire truck, fireman etc.) as transportation resistance element,

- Defining critical time thresholds regarding fire service accessibility (5 minutes,15 minutes, 30 minutes etc.).

Measuring and evaluating fire service accessibility can help decision makers, who are local authorities including civil defence, fire service providers, department of planning, to test the current fire service response performance, to identify critical areas that have low or no accessibility, and to find out solutions in order to improve response to these critical areas (Badri et al., 1996). That is why fire service accessibility is a vital concept in fire preparedness and has a leading role in reducing casualties.

In the next chapter, the concept of fire preparedness, interrelation between fire service accessibility and fire preparedness, critical fire response time thresholds and standards and possible precautions that can be taken according to the results of fire service accessibility are discussed in order to understand what extent time thresholds and standards in fire preparedness could be used as a baseline to measure and evaluate fire service accessibility.

CHAPTER 3

FIRE PREPAREDNESS

In this chapter, the concept of fire preparedness, a vital phase in fire management, is explained briefly. Firstly, the general definitions and phases related with preparedness and the place of preparedness in fire management are covered in order to understand the preparedness concept generally, then, interrelation between fire service accessibility and fire preparedness, critical fire response time thresholds and standards, and possible precautions that can be taken are discussed in order to understand what extent time thresholds and standards in fire preparedness could be used as a baseline to measure and evaluate accessibility.

The aim in this chapter is not to understand the whole processes in fire preparedness. The focus is limited in terms of the role and importance of time and accessibility in fire preparedness. The aim of this chapter is to define critical fire response time thresholds, to define the standards in fire response time and to define the possible precautions, which are all necessary to measure and evaluate fire service accessibility and to understand what extent accessibility results could be used as a baseline to take precautions and reduce the probable losses in fire preparedness.

3.1. Fire Management

3.1.1. Definition of Fire Management

In the literature, one of the definitions of fire management from Fire and Emergency Services Authority of W.A. is a range of measures to manage the fire related risks to communities and the environment. It involves the development and maintenance of arrangements to prevent, prepare for, respond to, and recover from fire emergencies and disasters (Heritage Collections Council, 2000). United Nations Department of Humanitarian Affairs defines fire management as the organized analysis, planning, decision making, assignment, and coordination of available resources to the mitigation of, preparedness for, and response to or recover from fire emergencies of any kind, whether from attack, man-made, or natural sources. University of Wisconsin Disaster Management Centre defines fire management as the range of activities designed to maintain control over fire disasters and emergency situations and to provide a framework for helping at-risk persons to avoid or recover from the impact of the fire disaster. Heritage Collections Council (2000) also explains fire management in the study as; identifying the risks, taking action to prevent or reduce those risks, preparing the for effective response to the emergency, an ability to plan a recovery for a fire disaster.

All the definitions about fire management in the literature points out the same common direction; fire management is a total of activities to manage the fire related risks to communities and the environment and deals with situations that occur prior to, during, and after the fire disaster.

3.1.2.Phases in fire management

In the literature there are mainly four basic phases of fire management which are;

- Prevention,
- Preparedness,
- Response and
- Recovery

(Heritage Collections Council (2000); UWDMC, http://dmc.engr.wisc.edu/courses/aimscope/AA02-intro.html visited on 7.11.02; Radke et al., (2000). These four main phases can also be handled according to time of performed actions as below;

Table 3.1: Phases of fire management according to the time of performed actions

FIRE MANAGEMENT PHASE	TIME
Prevention (mitigation)	Before-fire
Preparedness	
Response	During fire
Recovery	After-fire

Source: UWDMC, http://dmc.engr.wisc.edu/courses/aimscope/AA02-intro.html visited on 7.11.02

Before-fire phase consists of two main phases and can be handled as fire prevention, and fire preparedness. In general, fire prevention is event-focused. The objective of prevention is to prevent the disaster from occurring at all, however fire preparedness assumes that the disaster will occur and focuses on structuring response and laying a framework for recovery in order to meet a future disaster and aims to lessen the impact of fire in terms of loss of lives, health and money

During fire phase contains activities performed during the actual fire emergency and can be handled as "fire response" in fire management. it starts with the occurrence of fire emergency and continues until the emergency is over.

Post-fire phase starts when the initial response has been totally completed and emergency is over. Post-fire phase contains the recovery activities in fire management (UWDMC, http://dmc.engr.wisc.edu/courses/aimscope/ AA02-intro.html visited on 7.11.02).

3.1.2.1.Prevention

Basically, prevention can be explained as the activities taken to minimize the probability of a disaster. "Erection of dams or levees to prevent flooding" or "determination and removal of potential fire sources to prevent fire" etc. can be given as some examples of disaster prevention.

Prevention provides permanent protection from disaster, and can be handled either as;

- structural activities like using engineering technology (building disaster-resistant buildings or protective structures such as flood-walls, dikes, dams etc.) or as;
- non-structural activities like regulations, legislations and education (controlling land use and urban planning, building regulations, disaster legislation, public education and information) (Lake County Indiana Local Emergency Planning Commission "Emergency

Management Glossary And Acronyms" http://www.lepc.co .lake.in.us/empglos.pdf_visited on 1.12.02; Radke et al., 2000).

Heritage Collections Council, 2000 states that prevention can also be referred as a part of hazard risk management which aims preventing or lessening the effects of the natural hazard or taking actions that will reduce the risks to an acceptable level[1]. Hazard risk management consists of;

- hazard mapping; identifying threats, determining their probability of occurrence, estimating what the impact of the threat might be to the communities at risk,

- vulnerability mapping such as analysing the vulnerability level of places exposed to hazards, or expected loss from hazards

- estimation of potential losses, such as losses of housing and physical structures, agricultural losses, economic losses, losses to physical infrastructure (such as roads, bridges, electric lines, etc.)

- development of appropriate disaster prevention strategies and taking precautions to prevent or reduce the threat.

In the light of the above-mentioned facts; fire prevention can be explained as an event-focused phase and basically answers the questions of; what

---

1 For example, if flooding is determined to be a major risk, the risk can be reduced by physical measures such as dams, flood control embankments, or channelling of the streams. Risk can also be reduced by moving threatened communities from flood plains and/or restricting economic activities in the flood zone to those that could absorb flood losses (such as forestry or agriculture) (UWDMC, http://dmc.engr.wisc.edu/courses/ aimscope/AA02-intro.html visited on 7.11.02).

has the potential to cause fire emergencies? and what can be done to prevent fire disaster? The main objective of fire prevention is to prevent the fire disaster at all without occurring.

3.1.2.2.Preparedness

Preparedness, which is a pre-disaster phase of fire management, assumes that the disaster will occur and focuses on structuring response and laying a framework for recovery in order to meet a future disaster.

In the literature there are several definitions about preparedness. Radke et al., (2000) defines preparedness as activities taken before a disaster occurs, when mitigation cannot prevent disasters. California Emergency Management Department defines preparedness as a discipline that ensures an organization's readiness to respond to an emergency in a coordinated, timely, and effective manner. United Nations Department of Humanitarian Affairs defines preparedness as activities, programs, and systems designed to support and enhance response to an emergency and to facilitate timely and effective rescue, relief and rehabilitation in order to minimize loss of life and damage. University of Wisconsin Disaster Management Center describes fire preparedness as a vital phase in fire management, and basically defines as understanding the risks, alleviating those risks and preparing for the impact of a fire.

All the definitions about fire preparedness point out the same common direction; preparedness is a preparatory phase in fire management and can be defined as a total of activities and precautions taken to get ready for an emergency response and recovery in order to lessen the impact of fire disaster on society and environment in terms of loss of lives, health and money.

Disaster preparedness focuses on reducing the society's vulnerability to the disaster and refers to a broader range of activities which can be handled as a combination of legislative, operational and educational activities.

Legislative activities includes;

- making legislations for establishing emergency policies,
- specification of actions what to be taken and by whom for coordination of emergency organizations and
- urban planning

operational activities include;

- preparation of emergency plans (response and evacuation plans),
- Identification of the degree of fire risks[2] that the population is subjected to and evaluation of vulnerability level of places (for example; identification of the ability of response units to provide timely response and taking precautions for such places that have high response risk.

---

2 There are mainly four risk element elements when we consider the built environment and fire science:
First is the fire ignition risk, related with the factors affecting the start of a fire;
Second is the fire detection risk related with the determination of the fire and reporting to the fire department by occupants;
Third is the fire spread risk related with the factors affecting fire growth and;
Fourth is the fire response risk related with intervention and fire fighting operations (Sarıkaya, 2001).

- identification of the availability of fire personnel and equipment and the needs of specific population

- identification of the possible losses in terms of specific populations, critical land use and facilities and infrastructure (damage assessment)

Educational precautions include:

- Education and training of the population, emergency personnel, special teams

- training operations, seminars, courses and broad campaigns of public awareness aimed at preparing communities for the fire disaster

- preparation of emergency manuals and procedures to take the various steps needed to safeguard lives and property during emergency phase (Heritage Collections Council, (2000); UWDMC, http://dmc.engr.wisc.edu/courses/preparedness/BB04-intro.htm visited on 7.11.02; Lake County Indiana Local Emergency Planning Commission, http://www.lepc.co.lake.in.us/empglos.pdf visited on 1.12.02.

In the light of the above mentioned facts it can easily be said that the preparedness is the most vital phase in fire management and the success in fire response and recovery directly depends on the success in fire preparedness. That's why preparedness save lives and limit the amount of damage that might otherwise be caused by the event.

3.1.2.3.Response

Basically, fire response can be explained as activities performed to lessen the immediate effects of an emergency in order to return the scene to normal pre-emergency conditions.

In threat of fire disasters, response starts with the occurrence of fire and involves the following actions;

- Report of fire to the fire department and fire alarm,
- Departure from the emergency service and arrival to fire area,
- Intervention to fire and extinguishment (Meşhur, 1997).

Response phase also covers search-and-rescue, evacuation of threatened communities, emergency assistance, first aid and the other actions taken to lessen the immediate aftermath during the time when the community is rather disorganized during the disaster (Heritage Collections Council, 2000).

Fire response can be summarized as a synthesis of operational co-ordination of fire reporting, arrival to fire area, fire extinguishment, and search-and-rescue. All phases in fire response has vital importance for minimization of the losses of lives, environment and property during a fire emergency.

3.1.2.4.Recovery

Recovery covers the activity of returning the systems into normal functionality both in the short term and in the long term (Radke et al., 2000; Heritage Collections Council, 2000).

Recovery period can be subdivided into two phases of rehabilitation (or transition) and reconstruction. The rehabilitation period begins at the end of the emergency phase and is a transitional phase that people try to re put their lives back in order. It contains a time period of weeks to months which people begin to return to work, and to repair infrastructure (damaged buildings and critical facilities). During this phase appropriate forms of assistance (provision of temporary shelter, food, and water etc. or resumption of basic infrastructure such as water, sanitation, communication and transportation) must be continued so that people can begin to regain their self-reliance.

The reconstruction phase of a disaster is a time period of months to years which contains large-scale efforts in order to replace damaged buildings, revitalize economies or restore agricultural systems to their full pre-disaster production capacity The reconstruction phase involves the physical reordering of the community and of the physical environment and may last for many years (Lake County Indiana Local Emergency Planning Commission, http://www.lepc.co.lake.in.us/empglos.pdf visited on 1.12.02; UWDMC, http://dmc.engr.wisc.edu/courses/aimscope/AA02-intro.html visited on 7.11.02; UWDMC, http://dmc.engr.wisc.edu/courses/preparedness/BB04-intro.htm visited on 7.11.02).

3.2.Interrelation Between Fire Service Accessibility and Fire Preparedness

3.2.1 The Importance of Measuring Fire Service Accessibility in Fire Preparedness

As described before, fire, which is the most frequent one among all disasters is a sudden and unexpected event and an undeniable reality of life. It can occur anywhere, any time and at any scale causing irreversible damages to human life, environment and property. It is not possible to prevent fires totally, but it is always possible to respond quickly to fires and minimize the effects by fire preparedness (Yalazı, 1998).

Fire preparedness of a city or locality can be measured severally in terms of "education and training level of the population and emergency personnel", "preparation of emergency plans", "identification of the degree of fire risks that the population is subjected to", "the ability of response units to provide timely response", "availability of equipment" etc. (Emelinda and Shashi, 1995). However, evaluation of the ability of response units to provide timely response is a primary consideration and has a basic role in fire preparedness. Because time has a vital role in fire and directly affects the growth of fire, the opportunity for a successful rescue and the level of losses. In the case of a fire, the temperature in a closed space can go from two or 300 degrees to 1200 degrees quicker than a snap with fingers. That's why, the ability of response units for a quick response can mean the difference between losing a life or saving a life or loosing a room or losing the whole houses of a street (ESRI public safety literature, http://www.esri.com/ industries/public_safety/fire.html visited on 11.10.01).

This study aims to measure and evaluate fire service accessibility within critical response time thresholds and to determine the zones based on critical fire response time in Çankaya district of Ankara. Analysing fire service accessibility would enable us to understand the ability of response units to provide timely response, would open a road for the estimation of critical zones, determination of critical places in critical zones such as governmental buildings, big commercial and market places, hotels, hospitals, student dormitories etc. and would enable responders to take effective precautions in order to minimise the possible losses (Los Osos South Bay Fire Department, http://www.losososcsd.org/firedept.html# Response visited on 11.9.02)

3.2.2.Critical fire response time thresholds for evaluation of fire service accessibility

After fire ignition, there is three important phase in the fire process.

The first phase includes the first 20 or 30 minutes time in which fire response units can intervene a fire from the interior of the building and the most important period for the fire extinguishment. If emergency units respond to fire in this phase, the losses of people and property can be minimized.

Fire accelerate exponentially until reaching a critical point called flashover which occurs when a fire generates enough heat and combustible gases to cause almost explosive fire conditions (Figure 3.1). At the end of this phase there is no oxygen inside and the interior degree is nearly 200 degrees. When victims are considered, a quick response in this period significantly improves chances of a successful rescue and it must also be considered that if a person has stopped breathing, brain damage from oxygen deprivation begins within 4 minutes (Yalazı, 1998; Los Osos South Bay Fire Department, "http://www.losososcsd.org/firedept.html#Response" visited on 11.9.02).

The second phase in fire process starts at the end of the first 20 or 30 minutes. When the first phase is exceeded, it is rather difficult to control the fire. The fire completely covers the space and spread out of the other parts of the building. The temperature increases to 400 degrees in earlier than 20 minutes and some explosions can occur. It is rather dangerous for fire response units to intervene a fire from the interior in this period. The fire come into contact with open air and within a 10 minutes time it reaches a temperature of 500 and upper degrees.

After 40 or 50 minutes in second phase, the third step starts in which fire response units can not intervene a fire from the interior of the building and the fire starts to threaten the other buildings with a 600 and upper degrees. The dominant aim of response units in this phase is to control the spreading out of the fire and to prevent a possible collapse (Yalazı, 1998).

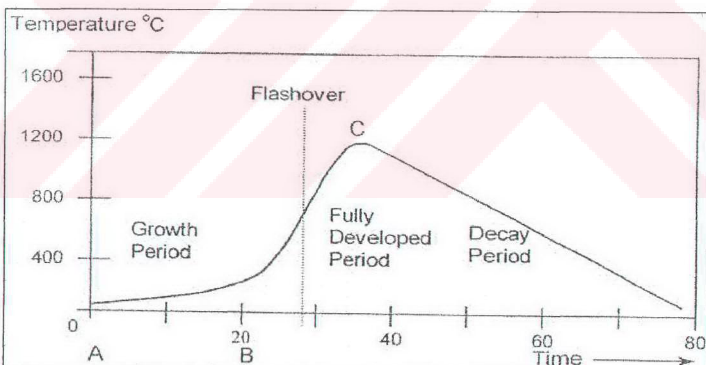


Figure 3.1: Time-temperature curve of fire in confined spaces

Source: (Shields and Silcock, 1987)

When fire process is investigated, approximately the first 20 or 30 minutes can be accepted as the most effective threshold time to respond to a fire and initiate an interior attack. That's why, the fire response activities of;

"reporting of fire to the fire department and fire alarm", "departure from the emergency service and arrival to fire area" and "intervention to fire and extinguishment activities" must be achieved during this 20 or 30 minutes in order to minimise the losses. However there is an important point that must be taken into consideration. One third of this 20 or 30 minutes (5 – 10 minutes) is the time that generally passes for the report of fire to the fire department and fire alarm. In this case there is only maximum 20 minutes time left to intervene a fire. Furthermore the used materials in many buildings necessitate to be responded less than 20 minutes (Yalazı, 1998).

3.2.3. The standards in fire response time

In the light of the above mentioned facts about fire, National Fire Protection Association (NFPA)[3], including more than 75,000 individuals from around the world and more than 80 national trade and professional organizations, suggested a maximum national fire response time standard that fire departments can take into consideration which are;

- to respond to a fire and initiate an interior attack within maximum 10 minutes of the call for service,
- to answer all emergency calls within maximum 60 seconds, and
- to dispatch other appropriate resources to those calls within maximum 60 seconds if necessary (NFPA Codes and Standards

---

3 NFPA is an independent, voluntary, nonprofit organization that periodically revises and develops national standards on virtually every aspect of fire and rescue services. A worldwide leader in providing fire, electrical, and life safety to the public since 1896. The mission of the international nonprofit NFPA is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically-based consensus codes and standards, research, training and education (National Fire Protection Association, "About NFPA" http://www.nfpa.org/Home/AboutNFPA/index.asp visited on 12.08.02)

http://www.nfpa.org /Codes/index.asp visited on 12.08.02; National Public Employer Labor Relations Association, http://www. npelra.org/articles/nfpa.asp visited on 15.10.02).

These maximum standards which are suggested in meeting of NFPA are vital standards to minimize the losses of fires. However a reality must be pointed out that it is impossible for all fire services to accept and put these uniform fire response standards into practice because of critical differences in local geography, huge variations in settlements of rural and urban, and differences in staffing (paid and volunteer), and in equipment. Deciding a unique fire response time standard for every fire service is like deciding how many police officers a city should have, based on the number of residents and the number of crimes.

Targeting a response time standard for a settlement's fire service depends not only on the technical matters but also the policy decisions appropriately made by decision makers who reflect the unique needs characteristics and budget of each community. The decision of setting a response time standard affects the number of station, equipment and staffing. If having a faster response time is aimed, more stations closer to fires must be located, better transportation network must be organized and more budget is needed to build, staff and to equip the stations (National Public Employer Labor Relations Association, http://www. npelra.org/articles/nfpa.asp visited on 15.10.02).

3.2.4. Precautions that can be taken according to the results of fire service accessibility in fire preparedness

Evaluation of the results of fire service accessibility would open a road for the estimation of critical zones, determination of the critical places in critical zones such as governmental buildings, big commercial and market places, hotels, hospitals, student dormitories etc. and would enable responders to take effective precautions for these areas and places in order to minimise the possible losses. These precautions can be summarized as:

- Strengthening or building new fire stations closer to inaccessible areas,
- Deployment of fire stations in order to minimize inaccessible areas (Distribution of current fire staff and equipment into smaller and widespread stations considering critical areas),
- Replacement or deployment of critical facilities if necessary,
- Improving transportation network from fire stations to inaccessible areas (new traffic arrangements for example organizing emergency bands on roads to speed up response),
- Improving the fire resistance of buildings and physical structures,
- Improving fire communication opportunities,
- Legislative obligations for improving fire resistance of buildings by using fire resistant materials in constructions,
- Legislative obligations for building fire warning systems (alarm) and fire sprinkler systems (automatic fire extinguishment systems) in constructions (especially for inaccessible areas),
- Legislative obligations for fire insurance in critical areas (Yalazı, 1998; UWDMC, http://dmc.engr.wisc.edu/ courses/aimscope /AA02-intro.html visited on 7.11.02).

CHAPTER 4

CASE STUDY: MEASURING FIRE SERVICE ACCESSIBILITY IN ÇANKAYA DISTRICT OF ANKARA

The chapter starts with a general description of the study area, including "why Çankaya district is selected as a case study area?" and continues with the general description of Ankara Metropolitan Municipality of Fire Department. Then the general spatial and non-spatial data contents about the study area and the basic steps of the exercise are described, including digitizing, registering, updating, editing and building of the database for measuring accessibility (reclassification of roads, adapting restrictions, establishing average speeds etc.).

4.1.Description of the study area

The city of Ankara is the second biggest city of Turkey with a population of more than 4 million people. Ankara is governed by the Ankara greater metropolitan municipality, including 8 main metropolitan districts, which are Çankaya, Yenimahalle, Keçiören, Altındağ, Mamak, Sincan, Etimesgut and Gölbaşı (see Figure 4.1).

Çankaya district is one of the oldest districts of Ankara with a plane area of 12.699 hectars, with 102 quarters and 3 villages (Figure 4.2) and with a population of 769.331 people according to the results of 2000 census. It is differentiated from the other districts by its historical development and its urban services such as public buildings, big commercial and market places, residences etc. There are nearly 350.000 dwelling units and 70.000 commercial offices and 11 hospitals, 166 primary education schools, 35 high school, 8 universities and 2 academies within the borders of Çankaya district (Çankaya municipality web page, http://www.cankaya-bld.gov.tr/cankaya_rakamlar.asp visited on 31.03.2003).

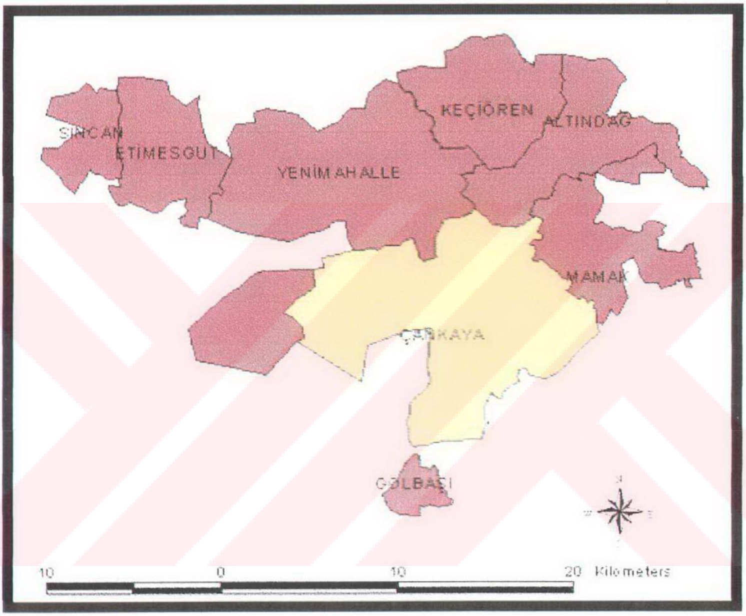
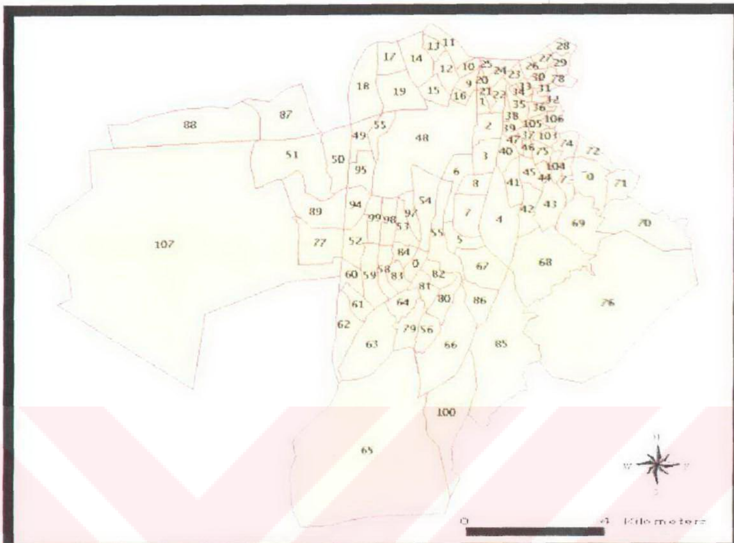


Figure 4.1: Study area, Çankaya district of Ankara

Çankaya district has nation-wide importance including the main central business district, Kızılay, main administrative center of Turkey with the national assembly, presidencial palace, prime ministry, ministry buildings and embassies of 107 countries. It is also an educational center with its nation-wide university campuses (Sarıkaya, 2001).



Bademlidere Mah	-0	Incesu Mah	34	Kırkkonaklar Mah	69
S. Mevlüt Meriç Mah	0	Seyran Mah	35	Orta imrahor	70
Meşrutiyet Mah	1	Zafertepe Mah	36	Aşağı imrahor	71
Kavaklıdere Mah	2	Doğuş Mah	37	Boztepe Mah	72
Remzi Oğuz Arık Mah	3	Tınaztepe Mah	38	Bağcılar Mah	73
Çankaya Mah	4	Esatoğlu Mah	39	Aşıkpaşa Mah	74
Güzeltepe Mah	5	Barbaros Mah	40	Umut Mah	75
Ayrancı Mah	6	Gaziosmanpaşa Mah	41	Yeşilkent (muh.ye) Mah	76
Aziziye Mah	7	Kazım Özalp Mah	42	Karakusunlar Mah	77
Güven Mah	8	B.esat Mah	43	Ellinci Yıl Mah	78
Kızılay Mah	9	Murat Mah	44	Mürsel Uluç Mah	79
Korkut Reis Mah	10	Yüzüncüyıl Mah	45	Metin Akkuş Mah	80
Eti Mah	11	Muhsinertuğrul Mah	46	Osman Temiz Mah	81
Maltepe Mah	12	Küçükesat Mah	47	Naci Çakır Mah	82
Anıttepe Mah	13	Devlet Mah	48	S.cengiz Karaca Mah	83
Mebusevleri- Anıtkabir	14	Balgat Mah	49	S.cevdet Özdemir Mah	84
Yücetepe Mah	15	Kızılırmak Mah	50	Sancak Mah	85
Namık Kemal Mah	16	Çukurambar Mah	51	Hilal Mah	86
Bahçelievler Mah	17	Cevizlidere Mah	52	Söğütözü Mah	87
Emek Mah	18	Öveçler Mah	53	Mustafa Kemal Mah	88
Y.bahçelievler Mah	19	Harbiye Mah	54	100.yıl işçi Blokları	89
Cumhuriyet Mah	20	Nasuh Akar Mah	55	Ehlibeyt Mah	94
Kocatepe Mah	21	ilkadım Mah	55	Oğuzlar Mah	95
Kültür Mah	22	İlker Mah	56	Sokullu Mehmet Paşa M.	97
Öncebeci Mah	23	Ata Mah	58	Aşağı Öveçler Mah	98
Fidanlık Mah	24	Huzur Mah	59	Yukarı Öveçler Mah	99
Sağlık Mah	25	Gökkuşağı Mah	60	Aşağı Dikmen Mah	100
Cemiltepe Mah	26	Karapınar Mah	61	Özgürlük - Metin Oktay M	103
Fakülteler Mah	27	Akpınar Mah	62	Bayraktar Mah	104
Cebeci Mah	28	Keklikpınarı Mah	63	Göktürk Mah	105
Ertuğrulgazi Mah	29	Malazgirt Mah	64	Mimarsinan Mah	106
Topraklık Mah	30	Oran Mah	65	Ortadoğu Mah	107
Dikmen Mah	31	Yukarı Dikmen Mah	66		
Arketopraklık Mah	32	Yıldızevler Mah	67		
İleri Mah	33	Birlik Mah	68		

Figure 4.2: Quarters of Çankaya district

Source: Ankara Metropolitan Municipality Office of Information Systems, 2002

The district is mainly composed of residential areas with 30% and forest areas with 27%. The other usages in the district are administrative usages with 8,5%, military usages with 6,5%, commercial usages with 3,16%, parks and green areas with 2,6, dam with 1,24 and etc. (Figure 4.3).

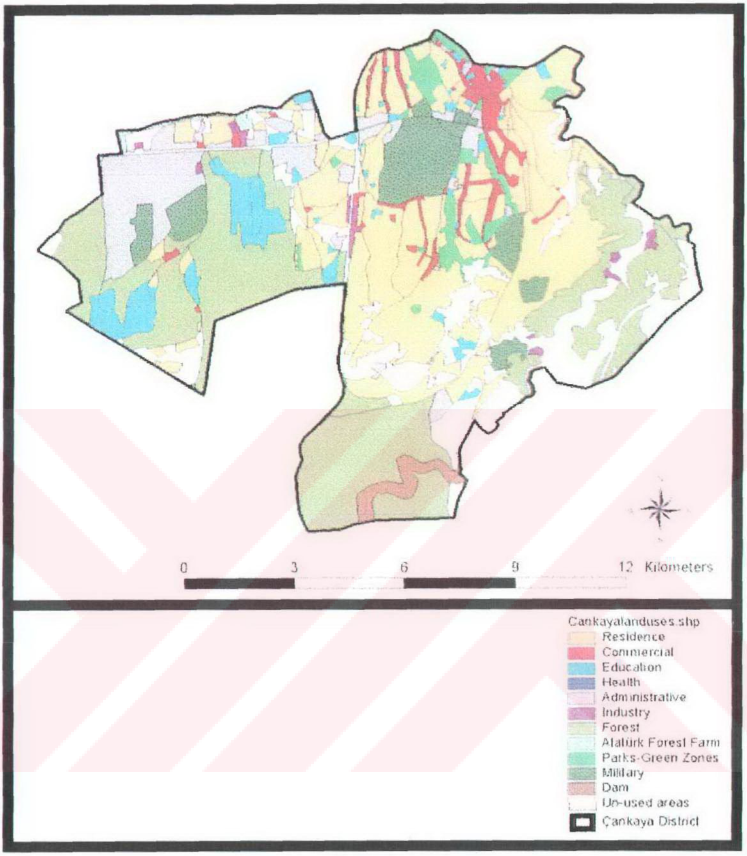


Figure 4.3: Landuse in Çankaya District

Source: Ankara Metropolitan Municipality Office of Information Systems, 2002

Table 4.1: Total area of landuse types in Çankaya district

LANDUSE	SUM_HECTAR(hectar)	Percentage(%)
Residence	3899,94	30,43
Forest	3582,89	27,96
Vacant area	1770,74	13,82
Administrative	1070,77	8,36
Military	842,29	6,57
Education	618,21	4,82
Commerce	405,59	3,16
Parks-green zones	333,40	2,60
Dam	158,37	1,24
Industry	89,11	0,70
Atatürk Forest Farm	44,51	0,35
Health	0,11	0,00
TOTAL	**12815,93**	**100,00**

4.1.1. Why Çankaya District as case study area?

Çankaya district is very convenient for "measuring fire service accessibility and defining critical areas that cannot be accessed within critical time thresholds" because of the following reasons;

- Çankaya district contains mostly critical usages of Ankara in fire point of view such as big residential areas and forest areas, administrative areas, educational areas, military areas, big commercial areas and market placeș etc.

- Çankaya district has nation-wide importance including the main central business district, Kızılay, main administrative center of Turkey with the national assembly, presidential palace, prime ministry, ministry buildings and embassies of 107 countries. It is also an educational center with its nation-wide university campuses.

- Çankaya district is an intersection point of 4 different fire responsibility zones which are Head office (İskitler), Kurtuluş, Esat and Gölbaşı responsibility zones and in responsibility of 6 different fire brigade services which are Head office, Kurtuluş, Esat, Gölbaşı, Aşti, and Köşk fire brigades (Explained in detail in Section 4.2).

4.2. Ankara Metropolitan Municipality of Fire Department

The responsibility of fire protection and rescuing, taking necessary measures against fires, rescuing the citizens in accidents and other emergency situations and organizing training programs against fire threat is assigned to municipalities by Law of Municipalities no 1580 in Turkey and in metropolitan cities this responsibility is executed by Metropolitan Municipalities pursuant to Law of Metropolitan Municipalities no 3030.

When the structure of Ankara Metropolitan Municipality of Fire Department is analysed, Head office of Ankara Fire Department in İskitler (Ankara Büyükşehir Belediyesi İtfaiye Daire Başkanlığı) is the head and the most authorized unit of Ankara fire department and reports to the Mayor of Metropolitan Municipality of Ankara. There are 13 fire brigades reporting to Ankara Metropolitan Municipality Head office of Ankara Fire Department: Sincan, Batıkent, Keçiören, Altınpark, Siteler, Kurtuluş, Kale, Kayaş, Esat, Köşk, Gölbaşı, Aşti, and Esenboğa (Figure 4.4).

4 of the 14 fire brigade units, namely Aşti, Köşk, Esenboğa and Kale fire departments, are special departments and only responsible from their specific areas which are historical Kale region, Presidential Palace, Ankara Intercity Bus Terminal, and Esenboğa airport. The other 10 fire brigades are responsible from the fires that take place in their fire responsibility zones of Sincan, Batıkent, Keçiören, Altınpark, Siteler, Kurtuluş, Kayaş, Esat, Gölbaşı, and İskitler (head office) as shown in Figure 4.5.

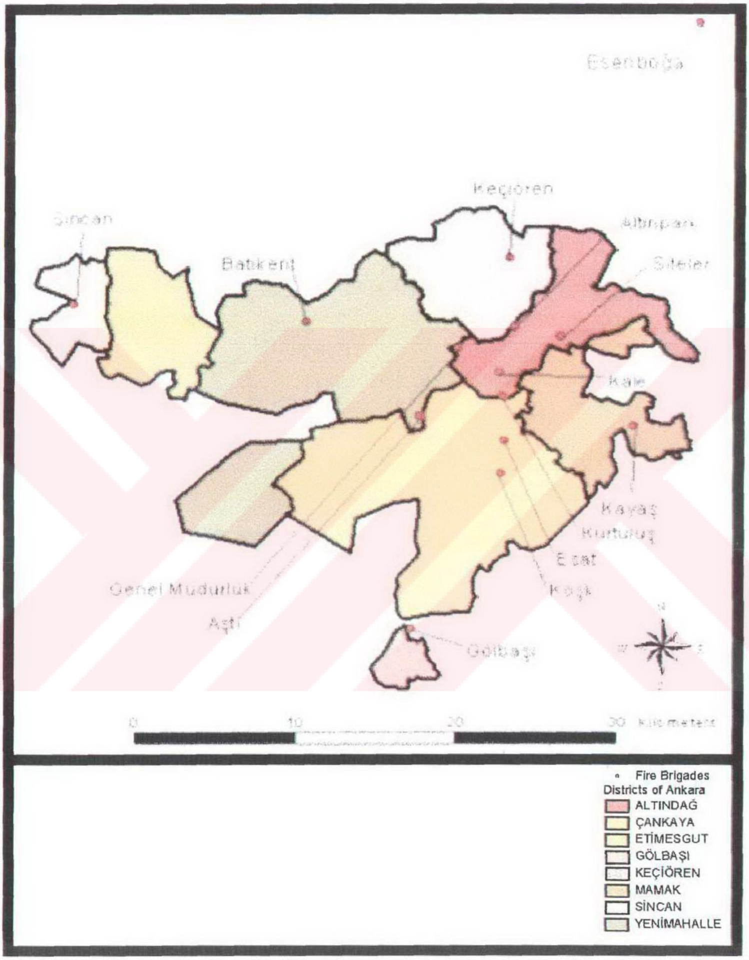


Figure 4.4: Fire Brigades of Ankara

Source: Ankara Metropolitan Municipality Office of Water and Infrastructure, 2002

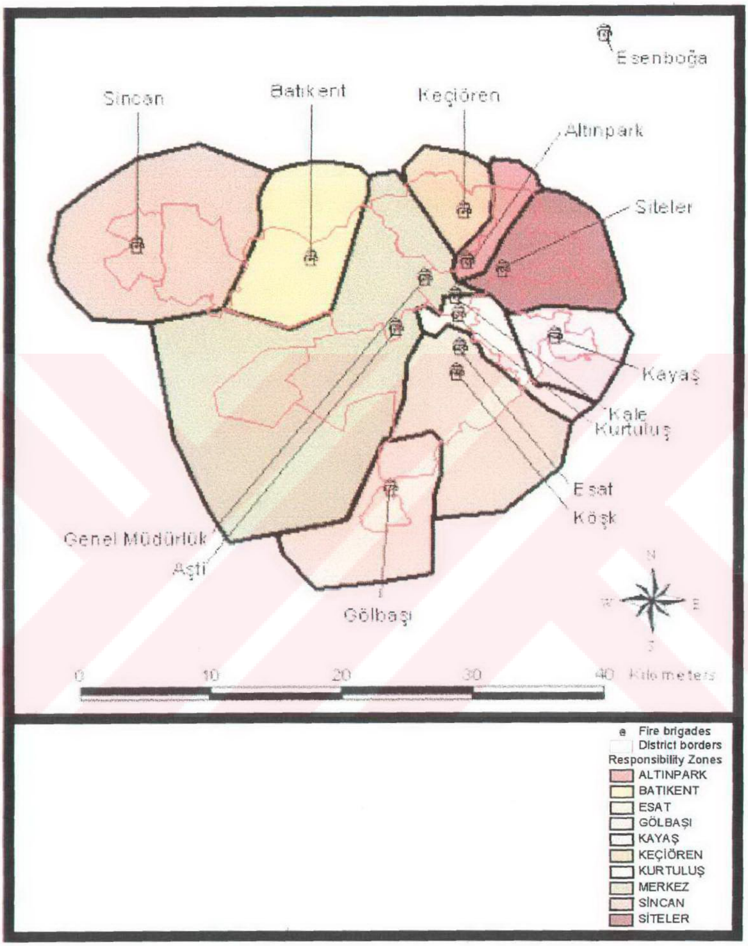


Figure 4.5: Fire Responsibility Zones in Ankara

Source: Ankara Metropolitan Municipality Office of Water and Infrastructure, 2002

When Çankaya district is focused, the district is under the responsibility of 6 different fire brigade services which are İskitler (head office), Kurtuluş, Esat, Gölbaşı, Aşti, and Köşk fire brigades (Figure 4.6). İskitler, Kurtuluş, Esat and Gölbaşı fire brigades are the main units that serve Çankaya district and the other two brigades of Aşti and Köşk have special responsibilities as described above. It can also be observed that fire responsibility zones don't overlap with the district borders and have their special forms based on transportation network of Ankara.

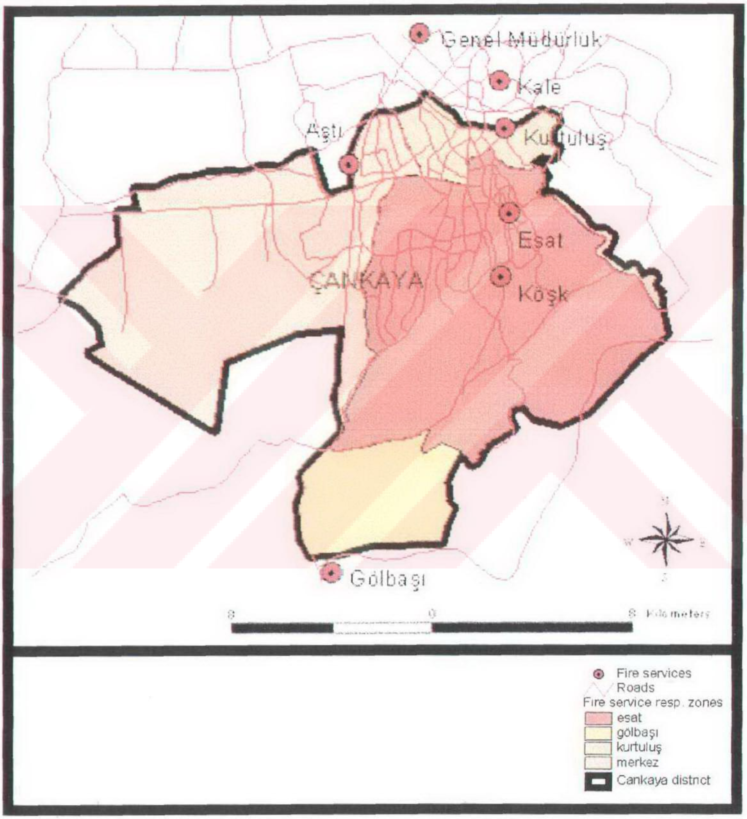


Figure 4.6: Fire Responsibility Zones in Çankaya District

Source: Ankara Metropolitan Municipality Office of Water and Infrastructure, 2002

4.3. Case Study Flowchart

The flowchart below shows the steps of the study:

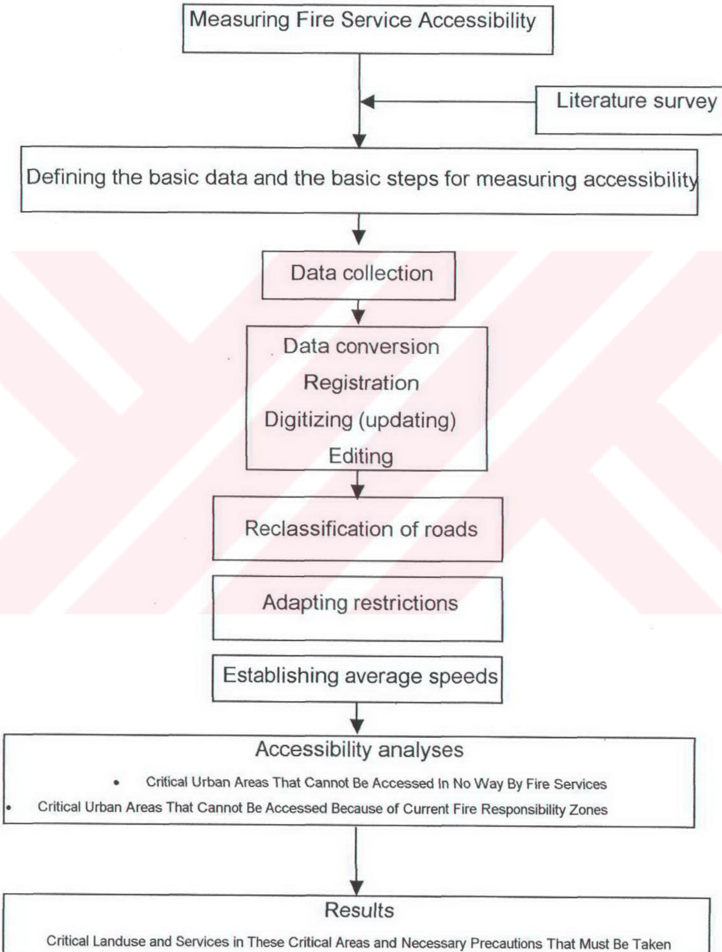


Figure 4.7: Case study flowchart

4.4. Data Collection and the Basic Steps in the Study

As described in Section 2.7, most of the effort required for an accessibility analysis is associated with data collection and processing, rather than the analysis. The basic steps and database components of measuring accessibility by isochronal technique in GIS are studied in the review of literature on accessibility and can be summarized as follows:

- Collection of the street data as transportation element[1],
- Collection of land use data and location of critical services data as activity elements (fire brigades, hospitals, educational buildings residences etc.).
- Collection of legal borders of fire responsibility zones, districts and quarters,
- Classification of roads according to their types,
- Establishing average speeds according to the road classifications,
- Establishing traffic restrictions and,
- Defining critical time thresholds regarding fire service accessibility (5 minutes,10 minutes, 15 minutes etc.).

At the end of these phases, measuring fire service accessibility in isochronal technique can be performed.

---

[1] Transportation and activity elements are the two main database components of measuring accessibility.

4.4.1. Data Collection: The General Spatial and Non-Spatial Raw Data Contents in the Study

After the definition of the basic data and the basic steps for measuring accessibility in isochronal technique, the next step is data collection. By the help of the "Ankara Metropolitan Municipality Office of Information Systems", "Ankara Metropolitan Municipality Head office of Ankara Fire Department" and "Ankara Metropolitan Municipality Office of Water And Infrastructure", the raw data needed for this study are compiled and listed below in Table 4.2.

Table 4.2: Raw Data About The Study

Name	Scale	Year	Format/Type	Content	Source
Transportation network_1 All roads	1/25000	2000	Digital mapinfo file-polyline	Name, Type,	Ankara Metropolitan Municipality Office of Water and Infrastructure
Transportation network_2 Main roads	1/25000	2000	Digital mapinfo file-polyline	Average speed, Name.	Ankara Metropolitan Municipality Office of Information Systems
Fire service location	1/25000	2002	Digital mapinfo file-point	Fire service Name.	Ankara Metropolitan Municipality Office of Water and Infrastructure
Fire responsibility zones	1/25000	2002	Digital mapinfo file-polygon	Fire service resp. zone name.	Ankara Metropolitan Municipality Office of Water and Infrastructure
Landuse Map of Çankaya district	1/50000	2002	Digital mapinfo file-polygon	Landuse type.	Ankara Metropolitan Municipality Office of Information Systems
Health Services (hospitals, health centers)	1/25000	2002	Digital mapinfo file-point	Name, Quarter.	Ankara Metropolitan Municipality Office of Water and Infrastructure

Table 4.2: Raw Data About The Study (continues)

Name	Scale	Year	Format/Type	Content	Source
Security services (police stations)	1/25000	2002	Digital mapinfo file-point	Name, Quarter.	Ankara Metropolitan Municipality Office of Water and Infrastructure
Education services (schools, colleges, universities)	1/25000	2002	Digital mapinfo file-point	Name, Quarter.	Ankara Metropolitan Municipality Office of Water and Infrastructure
Buildings (public buildings residences, industrial buildings)	1/1000	2002	Digital mapinfo file-poly	Usage.	Ankara Metropolitan Municipality Office of Water and Infrastructure
Border of Districts and quarters	1/25000	2002	Digital mapinfo file-poly	District name, Quarter name.	Ankara Metropolitan Municipality Office of Information Systems
Restrictions on main roads	-	2003	(paper format)	Oneway restrictions on main roads.	Ankara Metropolitan Municipality Head office of Ankara Fire Department
Avarage speeds based on fire brigade driver experiences	-	2003	(paper format)	Average speeds on roads by fire truck.	Ankara Metropolitan Municipality Head office of Ankara Fire Department
Ankara transportation map	1/25000	2000	(paper format)	All roads and their types.	Ankara Metropolitan Municipality Office of electric, gas and public transport

4.4.2. Data Conversion

In the beginning of the study, most of the data obtained from "Ankara Metropolitan Municipality Office of Water and Infrastructure (ASKİ)" and "Ankara Metropolitan Municipality Office of Information Systems" were on map-info file format and had extensions of "map" and "tab". These data on map-info file format had to be converted to Arcview shape file format (.shp) in order to be able to measure fire service accessibility by using Arcview Network Analyst extension of Arcview 3.1 software.

All data in map-info file format were exported to mif format (map info interchange file format) and then converted to Arcview 3.1. shape file format by using "mif to shape conversion tool" of Arc Toolbox software (Figure 4.8).

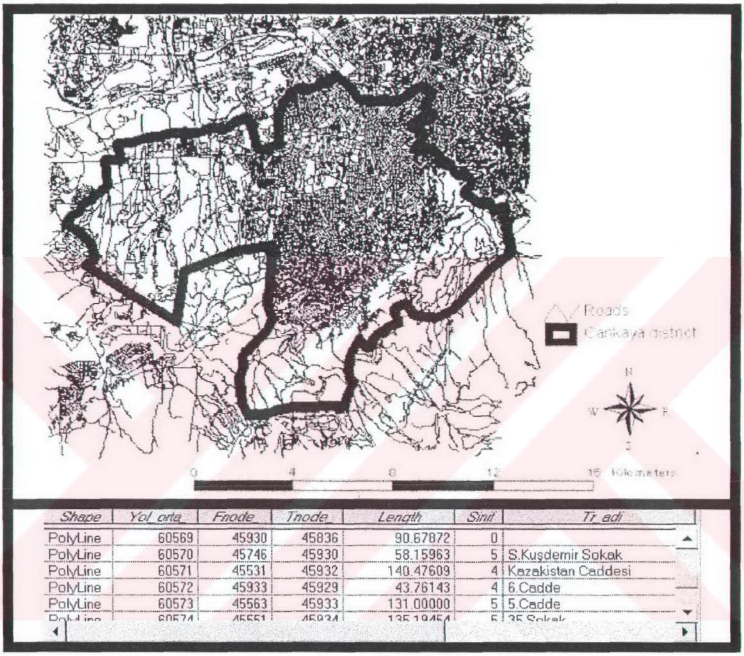


Figure 4.8: Transportation Network data_1 after mif to shape conversion (all roads)

4.4.3. Registration and Digitizing

After data conversion process from map-info tab file to arcview shape file, most of the work was about the transportation data, which can be considered as the main data in accessibility studies.

The transportation data including all roads needed to be updated and corrected in order to be used in accessibility measurement process. In this respect, two Ankara transportation maps in paper format showing the road connections and classifications, were scanned in 24 bit true color, in 200 dpi resolution by A0 scanner, saved in jpeg raster file format in order to be used as background objects for updating process of transportation data (Figure 4.9).

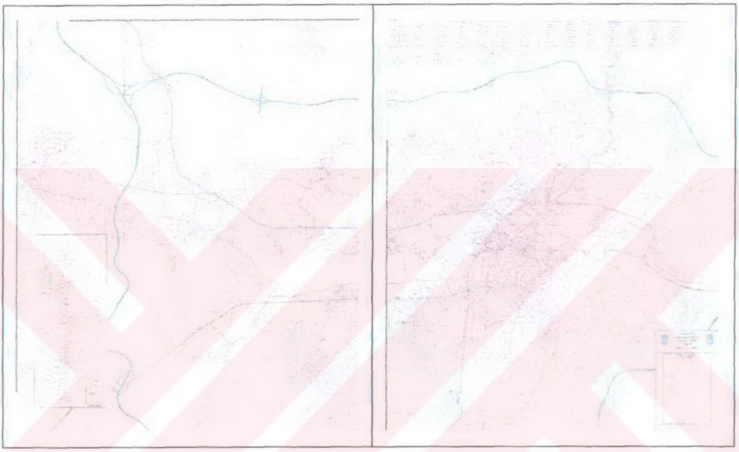


Figure 4.9: Two Ankara transportation maps in paper format

Before using the scanned Ankara transportation maps as background raster object in Arcview environment, registration process was made and scanner coordinates of the raster images were transformed to their real UTM coordinates by using "imagewarp extension" of arcview software which is a useful tool for registration of raster objects by using vector objects (Figure 4.10).

For each raster transportation map, eight intersection points of roads are defined by the help of the vector transportation network data and used as registration reference points. Three pairs of the reference points were selected from the external corners of the raster maps and the remaining points were selected from the internal parts of the raster maps in order to obtain homogeneous distribution of reference points (Figure 4.11; Figure 4.12).

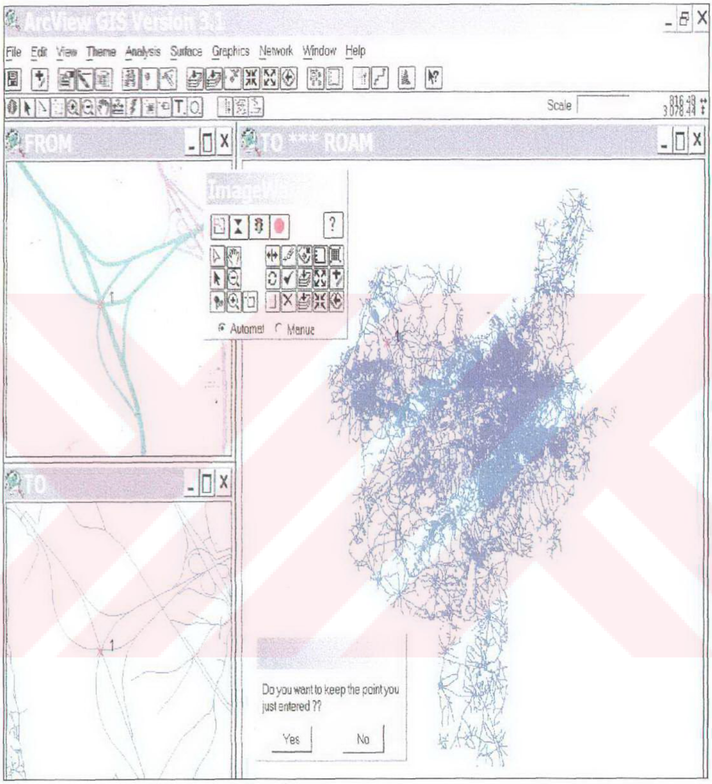


Figure 4.10: Imagewarp 2.0 extension of Arcview 3.1 software in registration process

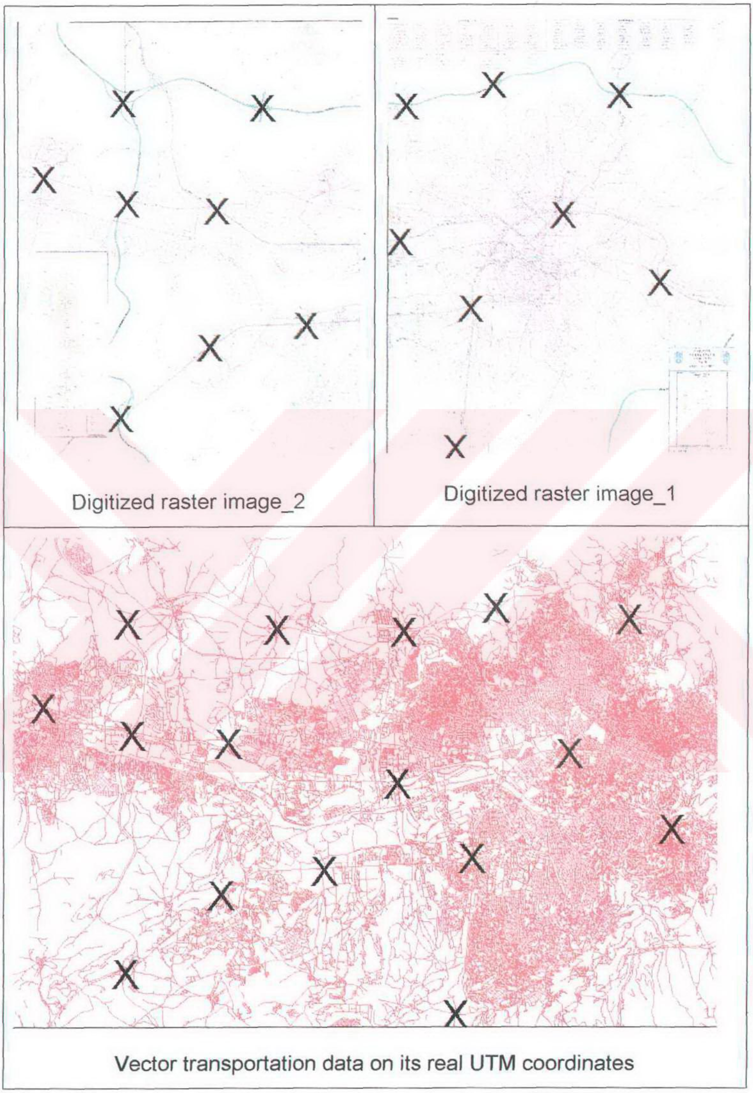


Figure 4.11: The distribution of reference points on raster maps for registration process

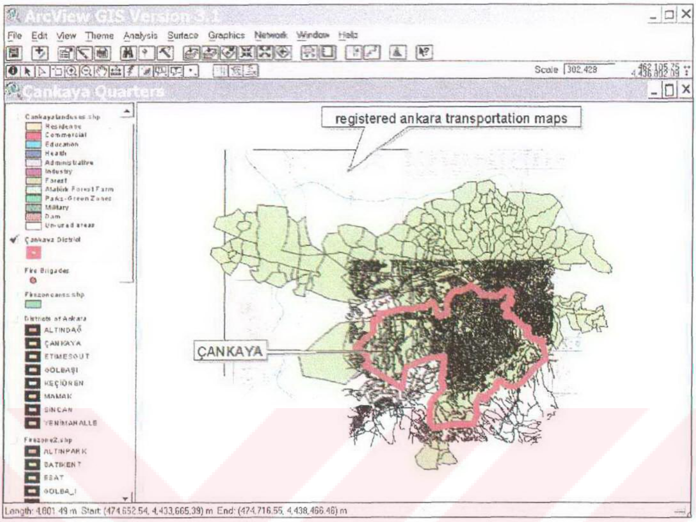


Figure 4.12: Raster Ankara transportation maps after registration process

After the registration process, Arcmap 8.1 software of ESRI is used in digitization process. At the end of the digitization, polyline topology was rebuilt by Arc toolbox software in order to obtain "record number", "from_junction", "to_junction" information of transportation data which were necessary data for measuring accessibility (Figure 4.13).

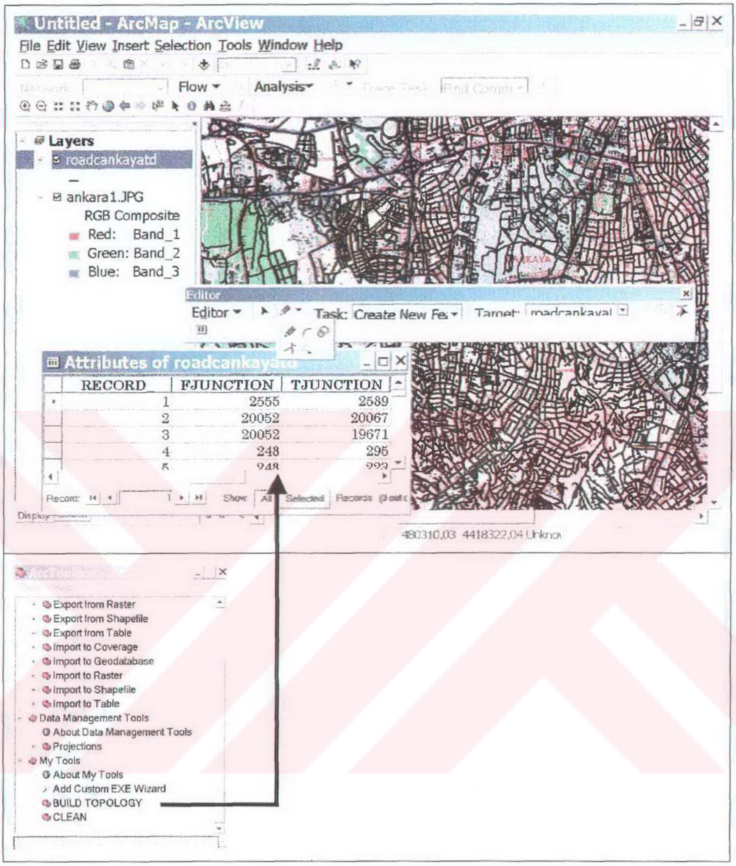


Figure 4.13: Digitization process by Arcmap 8.1 and the use of Arc Toolbox software for rebuilding polyline topology

4.4.4. Editing and Building the Database

The next three steps after updating process of transportation data, are reclassification of roads according to their types, adaptation of traffic restrictions to transportation data and establishing average speeds for roads according to the road classifications in the database.

4.4.4.1.Reclassification of Roads According to Their Types

The initial data obtained from Ankara Metropolitan Municipality Office of Information Systems had classification information of the roads according to their types but it was not for the whole region of Çankaya district and there were some mistakes about it.

Therefore, a new field "type" was added to transportation database and transportation data was reclassified according to types of roads as below by the help of the pre-registered raster background object of Ankara transportation maps (Figure 4.14; Figure 4.15). The database codes of "0", "1", "2", "3", "4" and "5" were entered to database to represent "crossroads", "highways", "state roads", "boulevards", "avenues" and "streets" respectively as in Table 4.3.

Table 4.3: Records of the "type" field in the transportation network database

Road type	**Database code**
Highways	1
State roads	2
Boulevards	3
Avenues	4
Streets	5
Crossroads	0

Attributes of Roadcankayatd.shp

Shape	Length	Tr_adi	Type	Record_	Fjunction	Tjunction
PolyLine	39.13150024414	Sile Sokak	5	4355	20798	207
PolyLine	138.90400695801	Sile Sokak	5	3928	19785	195
PolyLine	66.09649658203	Sile Sokak	5	3697	19464	193
PolyLine	25.08460044861	Sile Sokak	5	3733	19506	194
PolyLine	68.75119781494	Sile Sokak	5	4324	20721	205
PolyLine	72.01509857178	Simon Bolivar Caddesi	3	24713	15460	155
PolyLine	99.41570281982	Simon Bolivar Caddesi	3	25271	15902	160
PolyLine	28.80500030518	Simon Bolivar Caddesi	3	24985	15754	157
PolyLine	147.34599304199	Simon Bolivar Caddesi	3	25596	16214	164
PolyLine	8.90225028992	Simon Bolivar Caddesi	3	24932	15746	157
PolyLine	22.08189964294	Simon Bolivar Caddesi	3	25132	15874	159
PolyLine	5.86310005188	Simon Bolivar Caddesi	3	24912	15740	157
PolyLine	69.53569793701	Simon Bolivar Caddesi	3	25343	16070	161
PolyLine	69.12860107422	Simon Bolivar Caddesi	3	24566	15390	154
PolyLine	28.43440055847	Simon Bolivar Caddesi	3	25043	15793	158
PolyLine	104.89099884033	Simon Bolivar Caddesi	3	24896	15542	157
PolyLine	29.32609939575	Simon Bolivar Caddesi	3	25650	16415	164
PolyLine	77.86889648438	Simon Bolivar Caddesi	3	25790	16464	165
PolyLine	7.75963020325	Simon Bolivar Caddesi	3	25351	16195	162
PolyLine	26.98710060120	Simon Bolivar Caddesi	3	25094	15827	158
PolyLine	36.01369857788	Simon Bolivar Caddesi	3	24288	15295	153
PolyLine	221.83700561523	Simon Bolivar Caddesi	3	26146	16568	168
PolyLine	41.28530120850	Simon Bolivar Caddesi	3	24195	15295	152
PolyLine	66.46720123291	Simon Bolivar Caddesi	3	24440	15326	153
PolyLine	54.57410049438	Sinan Caddesi	4	26009	13444	134
PolyLine	80.57119750977	Sinan Caddesi	4	27279	13450	135
PolyLine	34.59329986572	Sinan Caddesi	4	26155	13451	134
PolyLine	6.84830999374	Sinan Caddesi	4	27211	13573	135

Figure 4.14: The newly added “type” field and its records in transportation network_1 database

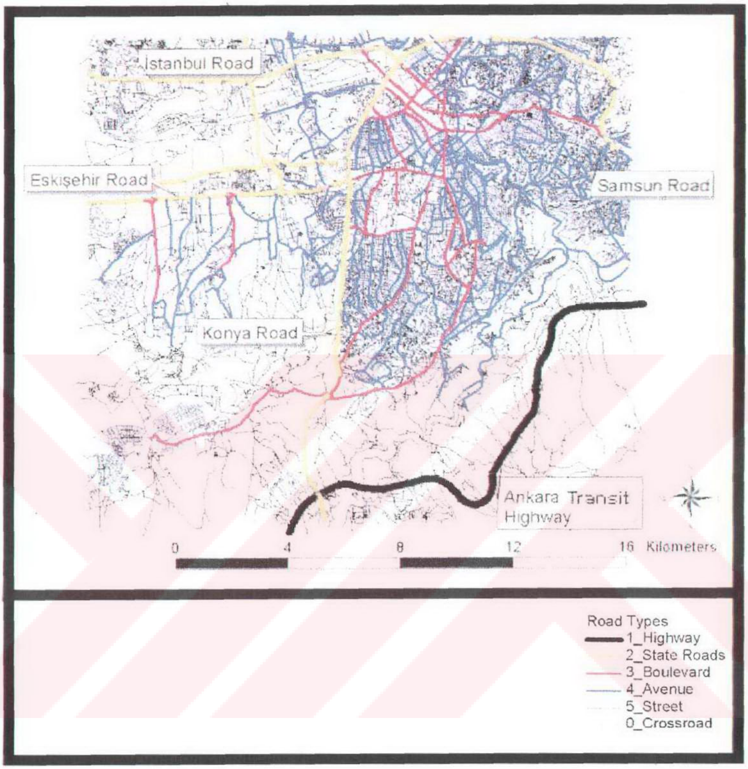


Figure 4.15: The Query of Road Types after Final Classification

Source: Ankara Metropolitan Municipality Office of Information Systems, 2002

4.4.4.2.Adapting Main Restrictions to Transportation Database

After reclassification of roads according to their types, oneway streets which were obtained from Ankara Governership Traffic Commision Of Administrative Province" on 31.01.2003 (Table 4.4) and turn restrictions on separated state roads were adapted to the transportation network database.

4.4.4.2.1.Adapting one-way restrictions to the database

A new string field "oneway" was added to transportation network attribute table and oneway restrictions (see Table 4.4) were represented by the string values of "FT", "TF", "N" and " " in order to restrict travel to certain directions as in Table 4.5; Figure 4.16.

Table 4.4: Oneway restrictions on main streets based on "Ankara Governership Traffic Commision of Administrative Province" on 31.01.2003

Oneway Restrictions On Main Streets
Esat Street Oneway To Çankaya Direction
Reşit Galip Street Oneway To Ulus Direction
Nenehatun Street Oneway To Çankaya Direction
Tunali Hilmi Street Oneway To Esat Intersection On Both Side
Bülbülderesi Oneway To Çankaya Direction
Kenedy Street Oneway To Kizilay Direction
Bağlar Caddesi Oneway From Esat Intersection To Ulus Direction And Oneway From Esat Intersection To Çankaya Direction
Başçavuş Street Oneway To Ulus Direction
Tahran Street Oneway From Nenehatun To Kavaklidere Direction
Billur Street (Abanvay Street) Oneway From Kuğulupark To Esat Direction
Büklüm Street Oneway From Tahran To Tunali And Oneway From Akay To Tunali Direction
Ballibaba Street Oneway To Çankaya Direction
Portakal Çiçeği Street Oneway From Hoşdere To Ulus Direction
Paris Street Oneway To Ulus Direction
Kuveyt Street Oneway From Ayranci To Ulus Direction
Ahmet Mithat Efendi Street Oneway From Çankaya To Vali Konaği Direction(Not Found In Street Database)
Ahmet Rasim Street Oneway From Çankaya To Dikmen Direction
Güleryüz Street Oneway From Ulus To Çankaya Direction
Meşrutiyet Street Oneway From Kizilay To Esat Direction
Mithatpaşa Street Oneway From Kocatepe To Ulus Direction
Bankalar Street Oneway From Esat To Ulus Direction
Kizilirmak Street Oneway From Kocatepe To Dedeman Direction

Table 4.4: Oneway restrictions on main streets based on "Ankara Governership Traffic Commision of Administrative Province" on 31.01.2003 (continues)

Karanfil Street Oneway From Meşrutiyet To Dedeman Direction
Konur Street Oneway From Çankaya To Meşrutiyet Direction
Hatay Street Oneway From Meşrutiyet To Ulus Direction
Selanik1 Street Oneway To Çankaya Direction
Doktor Mediha Erdem Street Oneway To Çankaya Direction
Haci Road Oneway From Bülbüldere To Bağlar Direction
Bağlayan Street Oneway From Bülbülderesi To Bağlar Direction
Dalkiran Sokak Oneway To Meşrutiyet(Not Found In Street Database)
Aşkabat Street Oneway From 7th Street To Beşevler Direction
Azerbeycan Street Oneway From Beşevler To Ismet Inönü Direction

Table 4.5: Records of the "oneway" field in the transportation network database

Restriction type	Database code
Travel is permitted from the start to the end of the line only, which is the same as the digitized direction	FT, ft
Travel is permitted from the end of the line to the start of the line only, which is opposite the digitized direction	TF, tf
Travel is permitted in neither direction; the line is closed to travel	N, n
Travel is permitted in both directions	Any other value or no data

Attributes of Roadcankayatd.shp

Shape	Length	Tr_adi	Type	Oneway	Record	Fjunction	Tjunction
PolyLine	225.26499938965	John F.Cannedy Caddesi	4	tf	17851	16487	168
PolyLine	222.16200256348	John F.Kenedi Caddesi	4	ft	20289	17254	172
PolyLine	173.66700744629	John F.Kenedi Caddesi	4	ft	18958	17214	171
PolyLine	128.01300048828	John F.Kenedi Caddesi	4	ft	19725	17278	172
PolyLine	170.49299621582	John F.Kenedi Caddesi	4	ft	19398	17245	172
PolyLine	167.61700439453	Karanfil Caddesi	5	ft	13990	15202	152
PolyLine	158.93600463867	Karanfil Caddesi	5	ft	15315	15290	153
PolyLine	182.59199523926	Karanfil Caddesi	5	ft	14453	15214	152
PolyLine	185.51800537109	Karanfil Caddesi	5	ft	15924	15321	153
PolyLine	137.73500061035	Karanfil Caddesi	5	ft	14842	15253	152
PolyLine	77.75920104980	Kızılırmak Caddesi	4	ft	14505	16198	160
PolyLine	67.51640319824	Kızılırmak Caddesi	4	tf	14375	16198	163
PolyLine	107.67800140381	Kızılırmak Caddesi	4	ft	14960	15979	158
PolyLine	8.12427997589	Kızılırmak Caddesi	4	tf	14312	16336	163
PolyLine	74.43379974365	Kızılırmak Caddesi	4	ft	14673	16067	159
PolyLine	191.64300537109	Kızılırmak Sokak	4	ft	15911	15817	157
PolyLine	113.37999725342	Kızılırmak Sokak	4	ft	15295	15884	158
PolyLine	44.02610015869	Kızılırmak Sokak	4	tf	14308	16356	164
PolyLine	188.53300476074	Konur Sokak	5	tf	15919	15557	155
PolyLine	315.16299438477	Konur Sokak	5	tf	15304	15440	155
PolyLine	178.09399414063	Konur Sokak	5	tf	14394	15344	154
PolyLine	91.98930358887	Kuveyt Caddesi	4	ft	20182	14793	149
PolyLine	128.57000732422	Kuveyt Caddesi	4	ft	20161	14950	151
PolyLine	74.51760101318	Kuveyt Caddesi	4	ft	20209	14642	147
PolyLine	89.62599945068	Kuveyt Caddesi	4	ft	20243	14520	146
PolyLine	101.22699737549	Kuvvet Caddesi	4	ft	20062	15396	156
PolyLine	79.82569885254	Kuvvet Caddesi	4	ft	20050	15643	158
PolyLine	103.59500122070	Kuvvet Caddesi	4	ft	19961	15815	160
PolyLine	31.42499923706	Kuvvet Caddesi	4	ft	20109	15161	152
PolyLine	81.27709960938	Kuvvet Caddesi	4	ft	20100	15231	153
PolyLine	91.03859710693	Meşrutiyet Caddesi	4	ft	14452	15253	154
PolyLine	101.24500274658	Meşrutiyet Caddesi	4	ft	14485	15047	152
PolyLine	69.11799621582	Meşrutiyet Caddesi	4	ft	14328	15678	158
PolyLine	93.58740234375	Meşrutiyet Caddesi	4	ft	14393	15440	156
PolyLine	71.65859985352	Meşrutiyet Caddesi	4	ft	14190	15971	161

Figure 4.16: The newly added "oneway" field and its records in Transportation network_1 database

4.4.4.2.2. Adapting turn restrictions to the database

After adaptation of oneway restrictions to transportation database, turn restrictions on separated state roads (Table 4.6) were adapted to the transportation network database. A new database table named "turntable.dbf" was created and the fields "node_", "f_edge", "t_edge" and "seconds" were added to this database in order to set turn restrictions on separated state roads (Figure 4.17).

Table 4.6: Turn restrictions on separated state roads

Roads	Turn restrictions on separated state roads
Eskişehir State Road	Turn to all directions is possible on 5 intersection points on Eskişehir State Road within borders of Çankaya district which are Konya, Söğütözü, Metu, Bilkent, Hacettepe intersections. Only right turn is possible according to traffic direction because of traffic separation.
Konya State Road	Turn to all directions is possible on 9 intersection points on Konya State Road within borders of Çankaya district which are Akköprü, Celal Bayar, Incitaşı, Bahçelievler, Hipodrom, Eskişehir, Çetin Emeç, Karakusunlar, Turan Güneş intersections. Only right turn is possible according to traffic direction because of traffic separation.
Ankara Transit Highway	Turn to all directions is possible on 4 intersection points on Ankara Transit Highway within borders of Çankaya district.

turntable43.dbf

Node_	F_edge	T_edge	Seconds
3036	13030	18183	-1
3161	13017	18214	-1
3502	17961	18370	-1
3564	17961	17944	-1
3474	17981	17966	-1
3397	17985	17982	-1
3249	18017	18003	-1
3023	18110	18032	-1
3696	17943	17916	-1
3707	17915	17913	-1
4278	17817	17809	-2
4504	17765	18392	-2
4906	17765	17706	-1
4935	17705	17701	-1
5080	17699	17679	-1
5256	17650	17626	-1
5340	17625	17609	-1
6146	17513	17462	-1
6223	17440	18703	-1
6257	17424	17719	-1
6392	17424	17382	-1
6537	17381	17337	-1
6537	17381	17338	-1
6537	17336	17596	-1
12365	2925	3317	-1
11812	4534	4479	-1
11768	4824	4631	-1
11695	4897	4825	-1
11660	34607	4898	-1
11660	4897	6441	-1
10858	7114	7079	-1
10798	7698	7286	-1
10638	7698	7697	-1
10638	7698	7851	-1
10335	8387	8585	-1

Figure 4.17: Newly created turntable database file to set turn restrictions on separated state roads

F_node, t_node and record_id information were refreshed by a built-in script in Figure 4.18 to use in the Arcview 3.1 environment. Related junctions and line segments, where the turn is prohibited, were selected one by one and entered to the database of transportation network's turntable as explained below;

- The field "node_", includes the topological f_node or t_node records of the transportation network database.

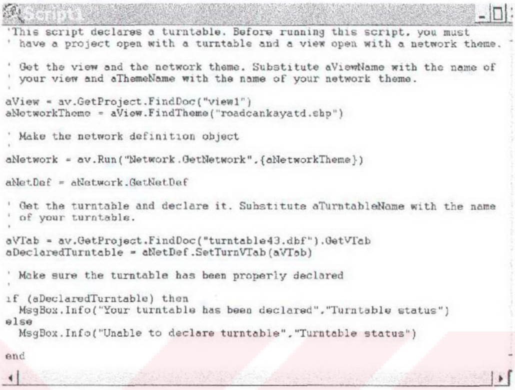
- The fields "f_edge" and "t_edge" includes the record_id values of transportation network database and represents the record_id of line segments where prohibited turn would be set and;

- The field "seconds" is the turntable's cost field and represents if the turn is prohibited or not. The numeric records of any value less than zero (<0), zero (0) or any value equal to or greater than zero (>0) can be used in "seconds" field. If the value is zero or under zero, it means that, turn is prohibited for that turn and if the value is above zero, it means that, turn is not prohibited for that turn, but there is a turn cost represented by that value.

```
' This script copies over node numbers from nodes.dbf and adds record
' numbers to the line theme feature table. It adds fields called RECORD#,
' FJUNCTION, and TJUNCTION to the line theme feature table. A network
' index directory must exist for the network theme before running this
' script.

' Get the view and the network theme. Substitute aViewName for the name
' of your view, and aThemeName for the name of your network theme.
'
aView = av.GetProject.FindDoc("view1")

aNetworkTheme = aView.FindTheme("roadcankayat.shp")
aNetworkThemeFTab = aNetworkTheme.GetFTab

' Get the nodes.dbf file, make the VTab object, and get its fields
'
aNetworkIndexDir = aNetworkTheme.AsString.Substitute("shp","nws")
aNodeFile = FN.Merge(aNetworkIndexDir, "nodes.dbf")
aNodeVTab = VTab.Make(aNodeFile, false, false)
aFjunction = aNodeVTab.FindField("Fjunction")
aTjunction = aNodeVTab.FindField("Tjunction")

' Add Record#, Fjunction, Tjunction fields to network theme FTab

'
aRecordField = Field.Make("Record#",#FIELD_LONG,12,0)
aFjunctionField = Field.Make("Fjunction",#FIELD_LONG,12,0)
aTjunctionField = Field.Make("Tjunction",#FIELD_LONG,12,0)
aFieldList = {aRecordField,aFjunctionField,aTjunctionField}
aNetworkThemeFTab.SetEditable(True)
aNetworkThemeFTab.AddFields(aFieldList)

' Use nodes.dbf to populate Rec#, Fjunction, Tjunction
'
Count = 0
for each r in aNetworkThemeFTab
  aFromNodeNumber = aNodeVTab.ReturnValueNumber(aFjunction,Count)

  aToNodeNumber = aNodeVTab.ReturnValueNumber(aTjunction,Count)
  aNetworkThemeFTab.SetValueNumber(aFjunctionField,r,aFromNodeNumber)
  aNetworkThemeFTab.SetValueNumber(aTjunctionField,r,aToNodeNumber)
  Count = Count + 1
  aNetworkThemeFTab.SetValueNumber(aRecordField,r,Count)
end

aNetworkThemeFTab.SetEditable(False)
```

Figure 4.18: The built-in script, used to produce "record_id" "from_node" "to_node" information for the turntable

Lastly, the built-in script shown below was ran, in order to adapt this newly produced turntable to the main transportation network data.



```
'This script declares a turntable. Before running this script, you must
' have a project open with a turntable and a view open with a network theme.

' Get the view and the network theme. Substitute aViewName with the name of
' your view and aThemeName with the name of your network theme.

aView = av.GetProject.FindDoc("view1")
aNetworkTheme = aView.FindTheme("roadcankayatd.shp")

' Make the network definition object

aNetwork = av.Run("Network.GetNetwork",{aNetworkTheme})

aNetDef = aNetwork.GetNetDef

' Get the turntable and declare it. Substitute aTurntableName with the name
' of your turntable.

aVTab = av.GetProject.FindDoc("turntable43.dbf").GetVTab
aDeclaredTurntable = aNetDef.SetTurnVTab(aVTab)

' Make sure the turntable has been properly declared

if (aDeclaredTurntable) then
  MsgBox.Info("Your turntable has been declared","Turntable status")
else
  MsgBox.Info("Unable to declare turntable","Turntable status")
end
```

Figure 4.19: The built-in script used to declare the turntable to network database

4.4.4.3. Establishing Average Speeds According To Road Classifications

In editing phase of the study, the next step was the establishment of average speeds according to the road classifications. There were two data about the average network speeds, one of which is the transportation network data of Ankara Metropolitan Municipality Office of Information Systems (Transportation network data_2) (Figure 4.20) and includes the average speeds for the main roads, and the other one is the average speed data based on fire driver experiences obtained from İskitler Fire Brigade.

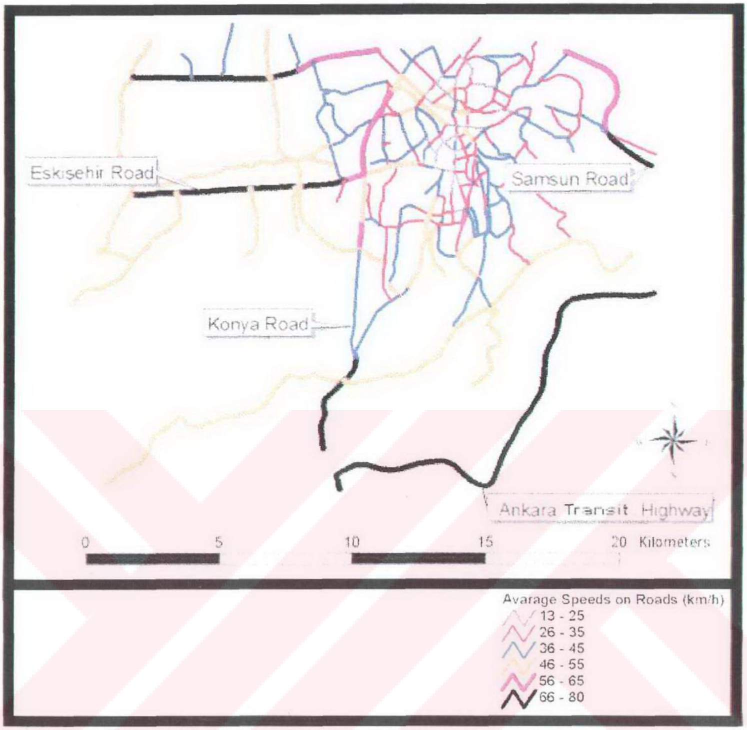
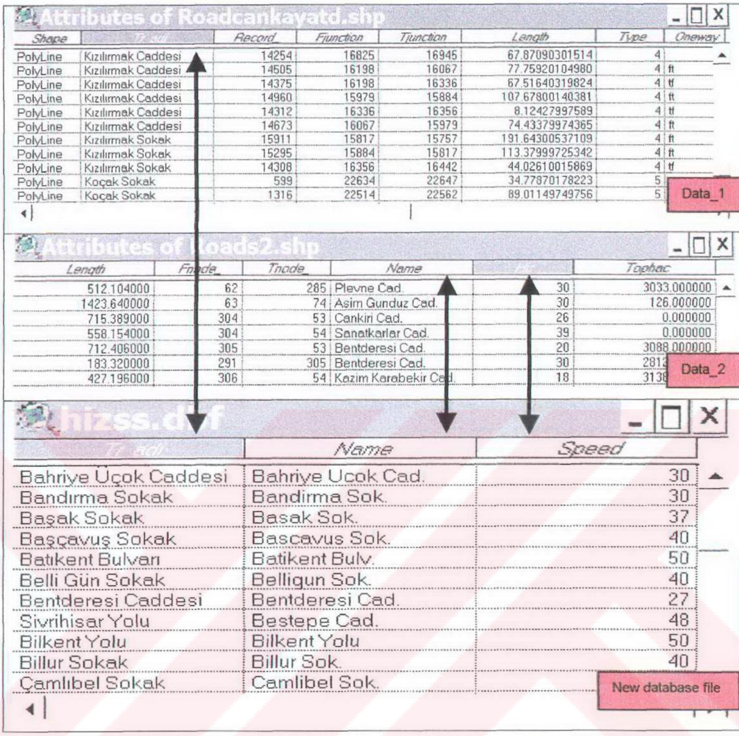


Figure 4.20: Transportation network data_2 of Ankara Metropolitan Municipality Office of Information Systems

However, the transportation network data_2, including the average speeds, was not the main transportation network data and had to be connected with the main transportation network data_1. Therefore, a new database file was created with "the name fields of the both transportation data" and "the average speeds calculated from transportation data_2" and it was linked to the main transportation network data, data_1, by the name field "tr_adi" which is the only unique common field between attribute tables. An important step in this linkage process was the correction of the name fields in order to be the same with each other (Figure 4.21).



Attributes of Roadcankayatd.shp

Shape		Record	Fjunction	Tjunction	Length	Type	Oneway
PolyLine	Kızılırmak Caddesi	14254	16825	16945	67.87090301514	4	
PolyLine	Kızılırmak Caddesi	14505	16198	16067	77.75920104980	4	ft
PolyLine	Kızılırmak Caddesi	14375	16198	16336	67.51640319824	4	tf
PolyLine	Kızılırmak Caddesi	14960	15979	15884	107.67800140381	4	ft
PolyLine	Kızılırmak Caddesi	14312	16336	16356	8.12427997589	4	tf
PolyLine	Kızılırmak Caddesi	14673	16067	15979	74.43379974365	4	ft
PolyLine	Kızılırmak Sokak	15911	15817	15757	191.64300537109	4	ft
PolyLine	Kızılırmak Sokak	15295	15884	15817	113.37999725342	4	ft
PolyLine	Kızılırmak Sokak	14308	16356	16442	44.02610015869	4	tf
PolyLine	Koçak Sokak	599	22634	22647	34.77870178223	5	
PolyLine	Koçak Sokak	1316	22514	22562	89.01149749756	5	

Data_1

Attributes of Roads2.shp

Length	Fnode_	Tnode_	Name		Tophac
512.104000	62	285	Plevne Cad.	30	3033.000000
1423.640000	63	74	Asim Gunduz Cad.	30	126.000000
715.389000	304	53	Cankiri Cad.	26	0.000000
558.154000	304	54	Sanatkarlar Cad.	39	0.000000
712.406000	305	53	Bentderesi Cad.	20	3088.000000
183.320000	291	305	Bentderesi Cad.	30	281
427.196000	306	54	Kazim Karabekir Cad.	18	313

Data_2

hizss.dbf

	Name	Speed
Bahriye Üçok Caddesi	Bahriye Ucok Cad.	30
Bandırma Sokak	Bandirma Sok.	30
Başak Sokak	Basak Sok.	37
Başçavuş Sokak	Bascavus Sok.	40
Batıkent Bulvarı	Batikent Bulv.	50
Belli Gün Sokak	Belligun Sok.	40
Bentderesi Caddesi	Bentderesi Cad.	27
Sivrihisar Yolu	Bestepe Cad.	48
Bilkent Yolu	Bilkent Yolu	50
Billur Sokak	Billur Sok.	40
Çamlıbel Sokak	Camlibel Sok.	

New database file

Figure 4.21: The new database file, created to supply the connection between the transportation data_1 and the average speeds on main roads

When the average speeds according to classification of roads are compared, "the average speeds obtained from transportation network data_2" were nearly the same with "the average speeds obtained by an interview with İskitler fire brigade drivers" as shown in Table 4.7 and Table 4.8. Therefore, the average speeds based on both sources were accepted as final average speeds to use in measuring accessibility (Table 4.9).

Table 4.7: Average speeds on normal traffic conditions based on the study of Ankara Metropolitan Municipality Office of Information Systems

Road types	**Average Speeds In Normal Traffic Conditions**
Highways	80 km/h
State roads	55 km/h
Boulevards	38 km/h
Avenues	31 km/h
Streets	21 km/h

Table 4.8: Average speeds based on an interview with İskitler fire brigade drivers

Road types	**Average Speed In Heavy Traffic Conditions**	**Average Speed In Normal Traffic Conditions**	**Average Speed In Light Traffic Conditions**
Highways	65-75 km/h	80 km/h	85-95 km/h
State roads	40-50 km/h	50-60 km/h	60-70 km/h
Boulevards	30 km/h	35-40 km/h	45-55 km/h
Avenues	20 km/h	30 km/h	40 km/h
Streets	10-15 km/h	15-25 km/h	30 km/h

Source: Interview with fire-fighters Mustafa Irmak and Nevzat Kaleli, Chiefs of the İskitler, Head office of Ankara Fire Department on February 2003.

Table 4.9: Final accepted average speeds based on fire driver experiences and the study of Ankara Metropolitan Municipality Office of Information Systems

Road types	**Average Speed In Heavy Traffic Conditions**	**Average Speed In Normal Traffic Conditions**	**Average Speed In Light Traffic Conditions**
Highways	70 km/h	80 km/h	90 km/h
State roads	45 km/h	55 km/h	65 km/h
Boulevards	28 km/h	38 km/h	48 km/h
Avenues	21 km/h	31 km/h	41 km/h
Streets	11 km/h	21 km/h	31 km/h

Finally, three new database fields called “speed_ht” (speed in heavy traffic conditions), “speed_nt” (speed in normal traffic conditions) and “speed_lt” (speed in light traffic conditions) were added to the database and these average speeds were entered to the database of the transportation network data as shown in Figure 4.22.

Attributes of Roadcankayatd.shp

Shape	Tr_adi	Record	Fjunction	Tjunction	Length	Type	Oneway	Speed_ht	Speed_nt	Speed_lt
PolyLine	Meşrutiyet Cadde	14328	15678	15829	69.11799621582	4	ft	20	30	40
PolyLine	Bentderesi Cadd	7609	18175	18462	164.71299743652	4		17	27	37
PolyLine	Bentderesi Cadd	7632	18462	18500	16.08550071716	4		17	27	37
PolyLine	Nenehatun Cadd	19373	17390	17403	199.05799865723	4	ft	29	39	49
PolyLine	17.Cadde	19361	8677	8724	39.75699996948	4		21	31	41
PolyLine	Hoşdere Caddes	19357	14458	14448	240.61799621582	4		28	38	48
PolyLine	Öğretmenler Cad	19355	7108	7041	53.96760177612	4		21	31	41
PolyLine	5.Cadde	19351	26089	26101	52.89599990845	4		21	31	41
PolyLine	2.Cadde	19324	22079	22270	218.99899291992	4		21	31	41
PolyLine	Paris Caddesi	19322	15523	15532	20.97220039368	4	tf	21	31	41
PolyLine	6.Cadde	19314	25664	25688	58.25590133667	4		21	31	41

Figure 4.22: The database of the main transportation network after the creation of speed fields “speed_ht”, “speed_nt” and “speed_lt”

4.4.4.4.Calculation of cost values as transportation network impedance values

After the establishment of the average speeds in the database, the last step to measure isochronal accessibility in GIS environment is the calculation of the transportation network cost values for light, normal and heavy traffic conditions.

Three new fields called “seconds_ht” (cost of traveling in heavy traffic), “seconds_nt” (cost of traveling in normal traffic) and “seconds_lt” (cost of traveling in light traffic) were added to the main transportation database and the field calculator of the Arcview 3.1 software was used to calculate the cost value (time) in seconds, for traveling from one point to another on transportation network as in Figure 4.23.

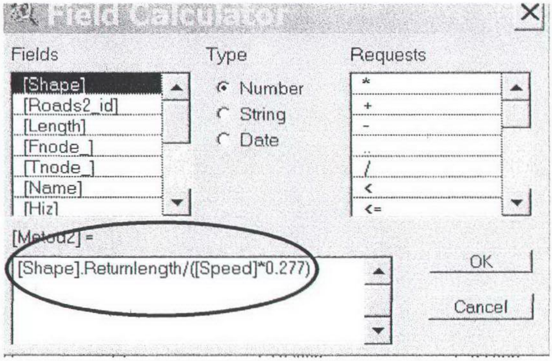


Figure 4.23: Calculation of the cost values in seconds in Arcview field calculator

The formula of [Shape].Returnlength / ((speed value) * 0.277) was calculated for the cost fields, where "[Shape].Returnlength" is the length of each network segment in the network database, "speed value" is the average traveling speed in km/h for each network segment and 0.277 is a constant to turn the speed values in kilometer per hour (km/h) to meter per seconds (m/s).

The final cost values in the main transportation network database after the calculations are shown in seconds unit in Figure 4.24.

Attributes of Roadcankayatc shp

Oneway	Speed_ht	Speed_nt	Speed_lt	Seconds_ht	Seconds_nt	Seconds_lt
	10	20	30	14.89	7.44	4.96
	10	20	30	21.87	10.93	7.29
	21	31	41	19.00	12.87	9.73
	10	20	30	46.98	23.49	15.66
tf	21	31	41	11.79	7.99	6.04
	10	20	30	16.94	8.47	5.65
	10	20	30	14.71	7.35	4.90
	10	20	30	25.87	12.93	8.62
	24	34	44	11.05	7.80	6.03
ft	21	31	41	19.78	13.40	10.13
	10	20	30	14.54	7.27	4.85

Figure 4.24: The final cost values of "seconds_ht", "seconds_nt" and "seconds_lt" in the main transportation network database

CHAPTER 5

THE RESULTS: MAPPING ACCESSIBILITY

In this chapter, fire service accessibility is measured and evaluated by isochronal technique, using GIS technology on a case study of Çankaya district of Ankara and inaccessible areas according to critical time thresholds are discussed.

As described in the previous sections, most of the effort required for an accessibility analysis is associated with data collection and processing, not simply with the analysis. After completing all prepatory steps for measuring fire service accessibility in isochronal technique, the final step is to measure and evaluate fire service accessibility for critical time thresholds of 5, 10, 15, 20 and 20+ minutes for three traffic conditions of heavy, normal and light traffic.

Therefore, this section includes the fire service accessibility analyses, their results and precautions in Çankaya district of Ankara including;

- critical urban areas and facilities that cannot be accessed in no way by fire services within critical time thresholds,
- critical urban areas and facilities that cannot be accessed within critical time thresholds because of current fire responsibility zones of fire services and proposals for fire service responsibility borders.

Two important points to be considered for the accessibility analyses are that;

- the critical urban areas and facilities that cannot be accessed in no way, are obtained by the accessibility analysis with no consideration of fire responsibility zones, and

- the critical urban areas and facilities that cannot be accessed because of fire responsibility zones are obtained by accessibility analyses with consideration of fire responsibility zones as described below.

5.1. Accessibility Analyses with No Consideration of Fire Responsibility Zones

In this part of the study, critical urban areas that cannot be accessed in no way by fire services within critical time thresholds are analysed without considering fire responsibility zones.

Fire service accessibility is measured for critical time thresholds of 5, 10, 15, 20 and 20+ minutes for three traffic conditions of heavy, normal and light traffic (see Figure 5.1, Figure 5.2, Figure 5.3) and critical quarters, landuse and services are evaluated for the threshold of 10 minutes in normal traffic conditions as an example.

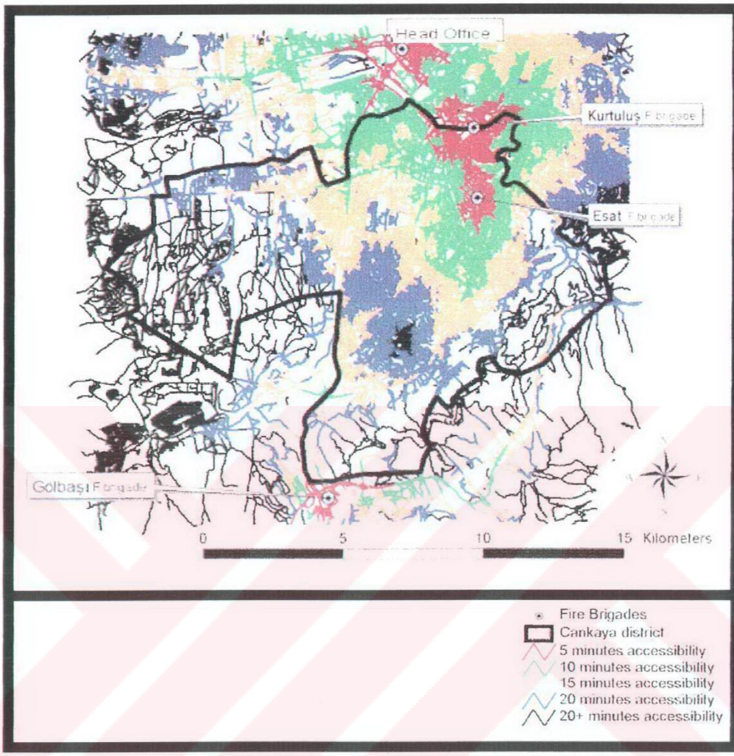


Figure 5.1: Fire service accessibility in heavy traffic conditions

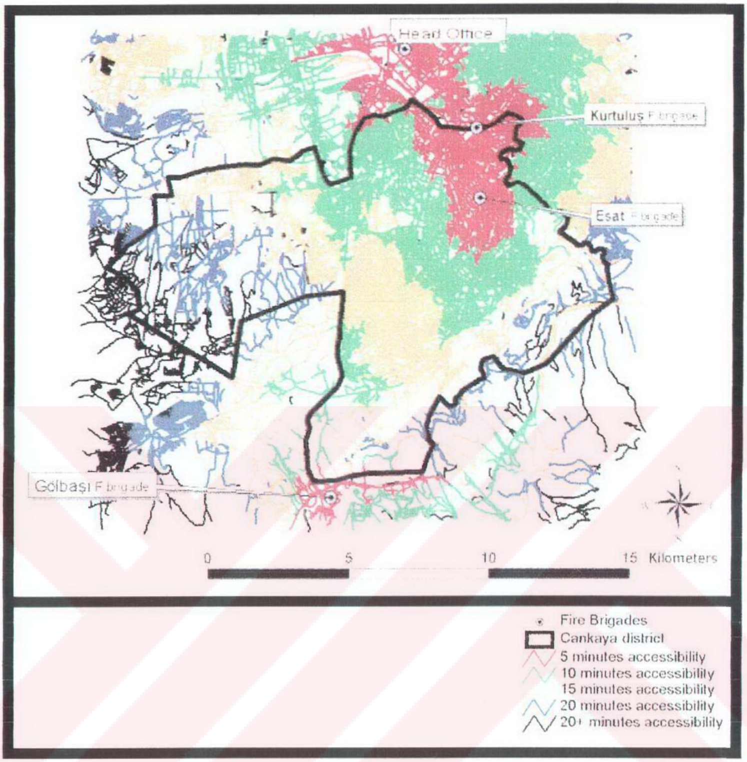


Figure 5.2: Fire service accessibility in normal traffic conditions

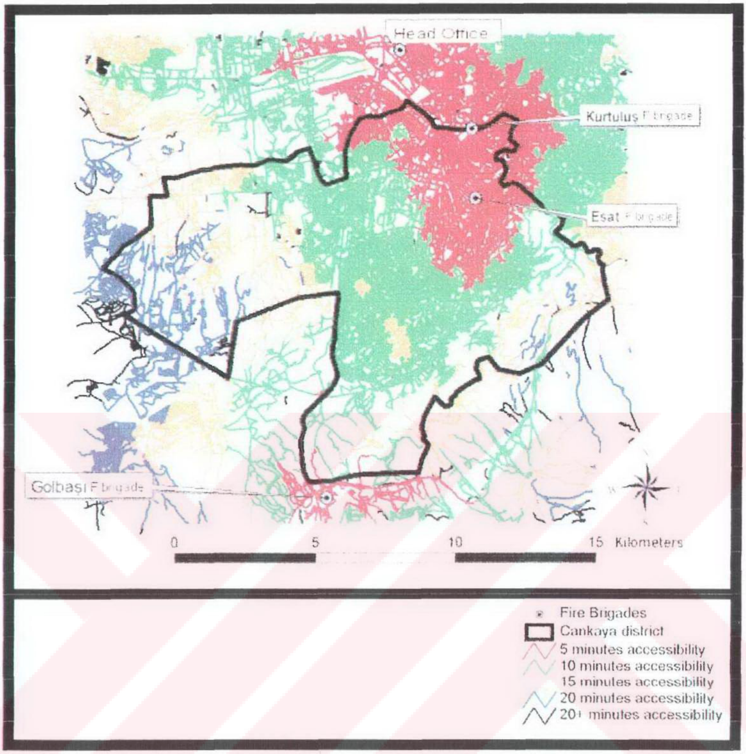


Figure 5.3: Fire service accessibility in light traffic conditions

In order to obtain critical area and facilities from the accessibility maps by overlay analysis, the accessibility maps in polyline format are converted to polygon format as in Figure 5.4 by "create contours" command in the "surface menu" of Arcview 3.1 software.

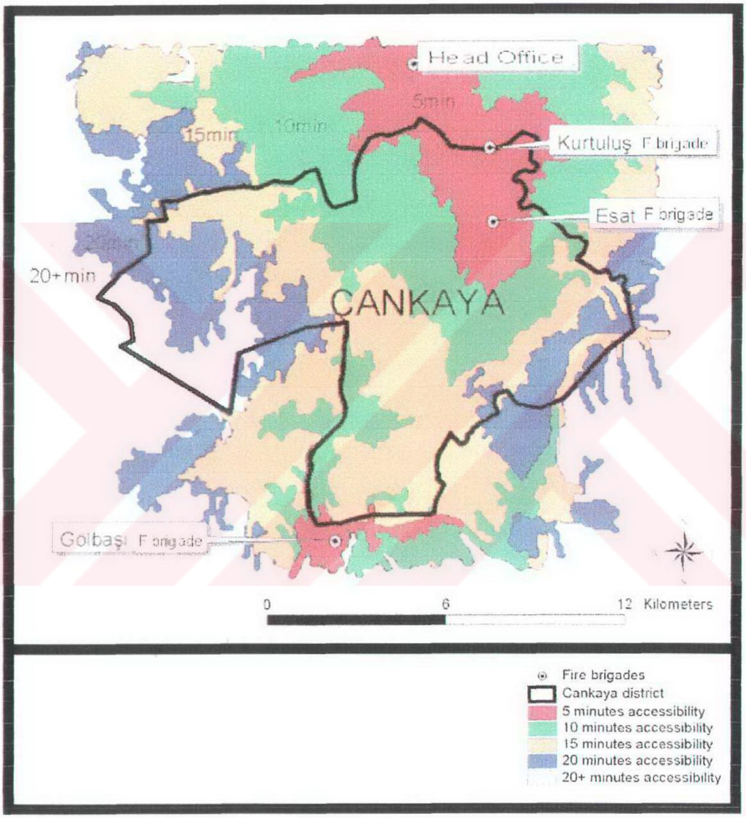


Figure 5.4: Fire service accessibility for normal traffic conditions in polygon format

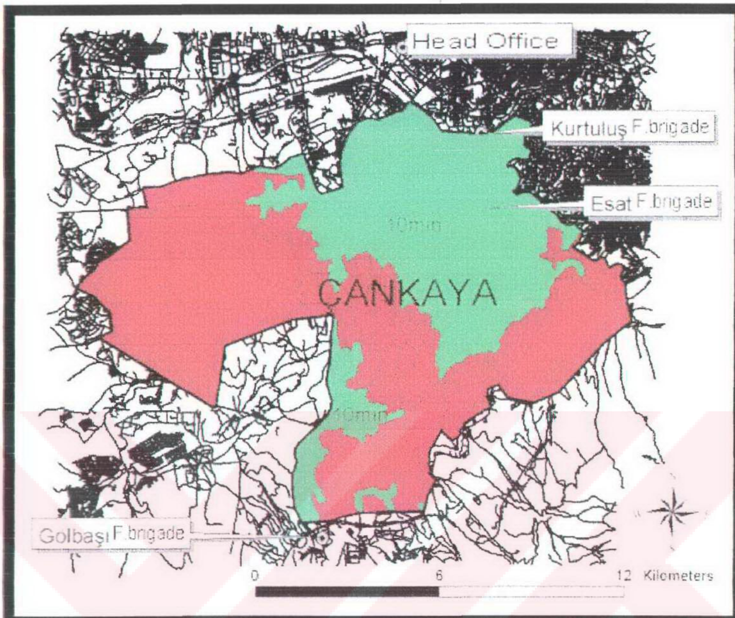
When the accessibility maps of heavy, normal and light traffic conditions are examined, 20,46% of the district can be accessed within 10 minutes in heavy traffic conditions, 40,77% of the district can be accessed within 10 minutes in normal traffic conditions and 62,75% of the district can be accessed within 10 minutes in light traffic conditions (Table 5.1). Even in light traffic conditions, the whole district of Çankaya cannot be accessed by fire brigades within National Fire Response Time standards of 10 minutes.

Table 5.1: Total accessed area by fire brigades in Çankaya district under different traffic conditions

Time	In Heavy traffic	%	In Normal traffic	%	In Light traffic	%
5 minutes	710 ha	5,61	1498 ha	11,83	2385 ha	18,84
10 minutes	2590 ha	20,46	5162 ha	40,77	7944 ha	62,75
15 minutes	5665 ha	44,75	9699 ha	76,61	11244 ha	88,82
20 minutes	8570 ha	67,69	11594 ha	91,58	12644 ha	99,87
Çankaya district total plane area: 12660 ha						

When normal traffic conditions are taken into consideration and the areas that have 10 minutes and above fire service accessibility are considered as critical areas in respect of fire response, the critical quarters, landuse and services in these critical areas can be analysed by the help of the GIS technology.

When critical quarters, obtained by selection of central points of quarters that are not within 10 minutes accessibility polygons, are analysed, 29 of 102 quarters have more than 10 minutes accessibility by fire services. Some of the widely known quarters in the critical zone are Dikmen, Öveçler, Söğütözü, Oran, Ortadoğu, Keklikpınarı, Karakusunlar, Ilker, Ata and Çukurambar quarters as shown in Figure 5.5.



Critical quarters:

[illegible]	Karapınar Mah	Osman Temiz Mah
Asağı Dikmen Mah	Keklikpınarı Mah	Öveçler Mah
Asağı Öveçler Mah	Malazgirt Mah	S. Mevlut Meriç Mah
Ata Mah	Metin Akkuş Mah	S.cengiz Karaca Mah
Cevizlidere Mah	Mustafa Kemal Mah	S.cevdet Özdemir Mah
Çukuranbar Mah	Mürsel Uluç Mah	Sancak Mah
Gökkuşağı Mah	Naci Çakır Mah	Söğütözü Mah
Huzur Mah	Oran Mah	Yeşilkent (muhye) Mah
İlker Mah	Orta imrahor	Yukarı Dikmen Mah
Karakusunlar Mah	Ortadoğu Mah	Yukarı Öveçler Mah

Figure 5.5: Critical quarters in respect of fire response in Çankaya district

The critical landuse types, obtained by intersection of landuse data and 10 minutes accessibility polygon data, mainly comprises forest areas with 2988 hectar (39,55%), and residential areas with 1366 hectar (17,88%). The other critical landuse types in the district are administrative usages with 795 hectar, educational usages with 507 hectar, military usages with 246 hectar, and etc. (Table 5.2; Figure 5.6).

Table 5.2: Total area of critical landuse types in Çankaya district

LAYER	SUM_HECTAR (Hectar)	PERCENTAGE (%)
Forest	2988,90	39,55
Vacant areas	1366,43	18,08
Residence	1351,13	17,88
Administrative	795,25	10,52
Education	507,04	6,71
Military	246,60	3,26
Dam	142,60	1,89
Industry	64,71	0,86
Commercial	40,22	0,53
Atatürk Forest Farm	39,73	0,53
Parks-Green Zones	14,65	0,19
TOTAL	**7557,24**	**100**

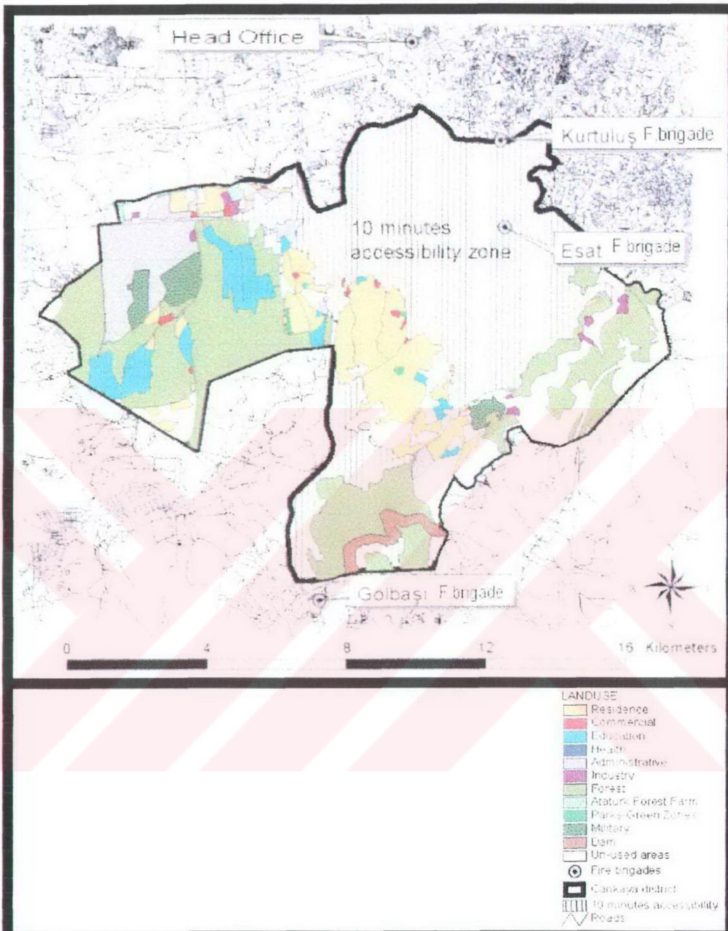


Figure 5.6: Critical landuse types in respect of fire response in Çankaya district

It is also possible to analyse the critical areas in building detail by selection of buildings that are not completely within 10 minutes accessibility polygons (Figure 5.7). Nearly %37 of residential buildings, %36 of public buildings and %70 of industrial buildings in Çankaya district cannot be accessed by fire brigades within NFRTS of 10 minutes (Table 5.3).

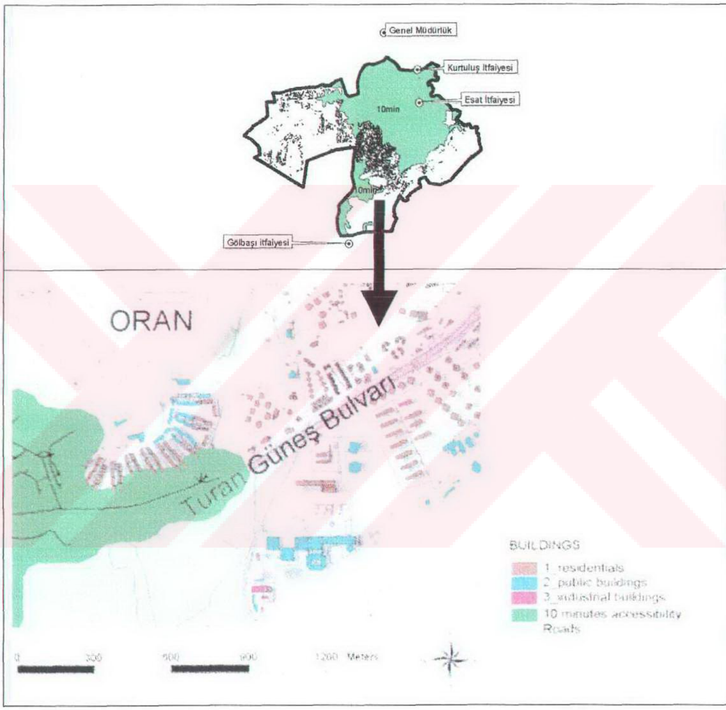


Figure 5.7: Buildings in critical areas

Table 5.3: Number of buildings in critical areas

Building type	In Çankaya district	In critical areas	Percentage (%)
Residential buildings	61862	23048	37,25
Public buildings	8038	2965	36,88
Industrial buildings	779	550	70,60
Other (un-known)	1353	575	42,49
Total	**72032**	**27138**	**37,67**

When critical education, health and security services are analysed; it can be said that there are some critical services, as compiled below, which cannot be accessed by fire brigades within NFRTS of 10 minutes (Figure 5.8).

- 3 of 8 universities, which include Middle East Technical University, Bilkent University and Hacettepe University

- 44 of 150 schools, which include among others, Tevfik Fikret Primary School in Mustafa Kemal quarter, Bilkent High School in Ortadoğu quarter, Balgat Technical High School in Öveçler quarter, ODTU Private High School in Ortadoğu quarter, Bilim Private High School and Ayşeabla Private High School in Karakusunlar, Sevgi Private High School in Dikmen quarter, Arı Private High School in Çukurambar, (Figure 5.9)

- 3 of 16 health centres, which include Mustafa Kemal health center in Mustafa Kemal quarter, Yüzüncüyıl health center in Ortadoğu quarter and Cevizlidere health center in Cevizlidere quarter (Figure 5.10) and

- 1 of 11 police department which includes Dikmen Police Station in Osman Temiz quarter (Figure 5.11).

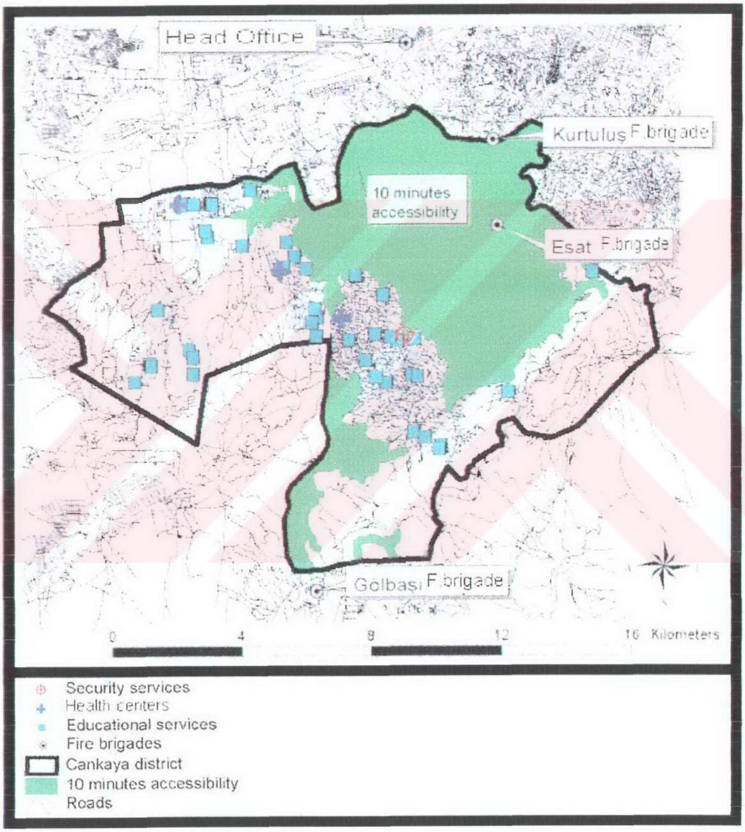


Figure 5.8: Security, health and educational services in critical areas

Attributes of Education_c.shp

Shape	Adi	Tür	Mahalle
Point	Fen L.	Fen L.	ORTADOGU MAH
Point	Yasemin Karakaya I.O.	Ilköğretim	MUSTAFA KEMAL MAH
Point	Bayraktar	Ilköğretim	KARAKUSUNLAR
Point	Özel Tevfik Fikret I.O.	Ilköğretim	MUSTAFA KEMAL MAH
Point	Özel Kent Ilkokulu	Ilköğretim	ORTADOGU MAH
Point	Odtü Özel Ilkokulu	Ilköğretim	ORTADOGU MAH
Point	Emlak Bankası I.O.	Ilköğretim	ORTADOGU MAH
Point	Ülkü Akın I.O.	Ilköğretim	100.YIL ISÇI BLOKLARI
Point	Ahmet Bahadır Ilhan I.O.	Ilköğretim	ORTADOGU MAH
Point	Türk-iş I.O.	Ilköğretim	100.YIL ISÇI BLOKLARI
Point	Talatpaşa I.O.	Ilköğretim	GÖKKUSAGI MAH
Point	Reşatbey I.O.	Ilköğretim	ÖVEÇLER MAH
Point	Turhan Feyzioğlu Ilköğretim Okulu	Ilköğretim	NACI ÇAKIR MAH
Point	Izciler I.O.	Ilköğretim	KEKLIKPINARI MAH
Point	Bilgi Ilkokulu	Ilköğretim	S. MEVLÜT MERIÇ MAH
Point	Kemal Atatürk I.O.	Ilköğretim	S.CENGIZ KARACA MAH
Point	Imrahor Ilkokulu	Ilköğretim	ORTA IMRAHOR
Point	Yasemin Karakaya Ilköğretim Ok	Ilköğretim	MUSTAFA KEMAL MAH
Point	Ahmet Yesevi I.O.	Ilköğretim	HUZUR MAH
Point	Yenilkil I.O.	Ilköğretim	MÜRSEL ULUÇ MAH
Point	Kıymet Nacip Tesal Ilköğretim	Ilköğretim	YUKARI DIKMEN MAH
Point	Akşemsettin I.O.	Ilköğretim	METIN AKKUS MAH
Point	Dsİ Ilköğretim Ilkokulu	Ilköğretim	MUSTAFA KEMAL MAH
Point	Rauf Orbay I.O.	Ilköğretim	ASAGI DIKMEN MAH
Point	Yeşilkent Ilkokulu	Ilköğretim	
Point	Kılıçarslan L.	Lise	100.YIL ISÇI BLOKLARI
Point	Tınaztepe L.	Lise	ASAGI DIKMEN MAH
Point	Bilkent L.	Lise	ORTADOGU MAH
Point	Tevfik Fikret L.	Lise	MUSTAFA KEMAL MAH
Point	Dikmen Pratik Kız Sanat Okulu	Meslek L.	S. MEVLÜT MERIÇ MAH
Point	Ingilizce Dili Meslek Yüksek Okulu	Meslek L.	ORTADOGU MAH
Point	Balgat Teknik L.	Meslek L.	YUKARI ÖVEÇLER MAH
Point	Balgat E. L.	Meslek L.	YUKARI ÖVEÇLER MAH
Point	Dikmen E. M.L.	Meslek L.	METIN AKKUS MAH
Point	Odtü Özel L.	Özel Lise / Kolej	ORTADOGU MAH
Point	Özel Bilim Koleji	Özel Lise / Kolej	KARAKUSUNLAR MAH
Point	Sevgi Koleji	Özel Lise / Kolej	YUKARI DIKMEN MAH
Point	Ayşe Abla Koleji	Özel Lise / Kolej	KARAKUSUNLAR MAH
Point	Özel Arı L.	Özel Lise / Kolej	ÇUKURANBAR MAH
Point	Yabancı Diller Yüksek Okulu	Yüksek Okul	ORTADOGU MAH
Point	Meslek Yüksek Okulu	Yüksek Okul	ORTADOGU MAH
Point	Uygulamalı Yabancı Diller Yüksek Okulu	Yüksek Okul	ORTADOGU MAH
Point	Bilkent Üniversitesi Hazırlık	Yüksek Okul	ORTADOGU MAH
Point	Bilgisayar Teknolojisi Ve Büro	Yüksek Okul	ORTADOGU MAH

Figure 5.9: Educational services in critical areas

Attributes of Healthcenter_c.shp

Shape	Adi	Mahalle
Point	MUSTAFA KEMAL MAHALLESI	MUSTAFA KEMAL MAH
Point	YÜZÜNCÜYIL	ORTADOGU MAH
Point	CEVIZLIDERE	CEVIZLIDERE MAH

Figure 5.10: Health centers in critical areas

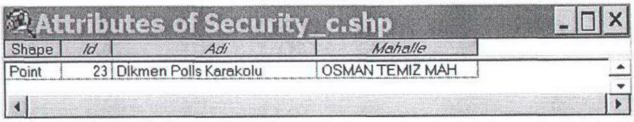


Figure 5.11: Security services in critical areas

5.2. Accessibility Analyses with Consideration of Fire Responsibility Zones

After the accessibility analysis which fire responsibility zones were not taken to consideration, in this part of the study, critical urban areas that cannot be accessed within critical time thresholds because of fire responsibility zones are analyzed.

Firstly, fire service accessibility is measured for critical time thresholds of 5, 10, 15, 20 and 20+ minutes for normal traffic conditions for each of the fire brigades separately (see Figure 5.12, Figure 5.13, Figure 5.14, Figure 5.15). Then, critical zones that cannot be accessed because of current fire responsibility zones are analyzed and new fire service responsibility borders are proposed for Çankaya district of Ankara.

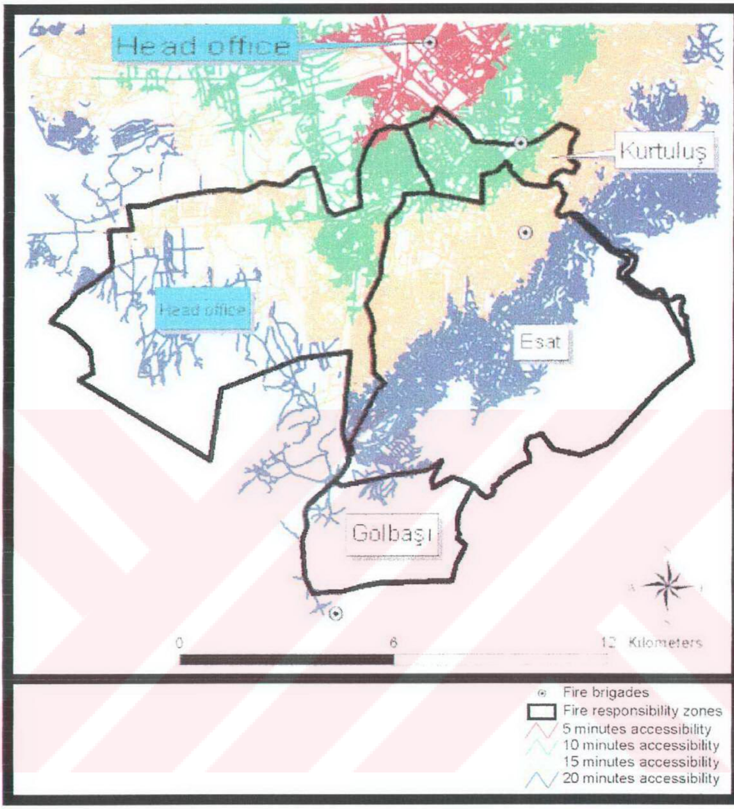


Figure 5.12: Fire service accessibility of Head office fire brigade

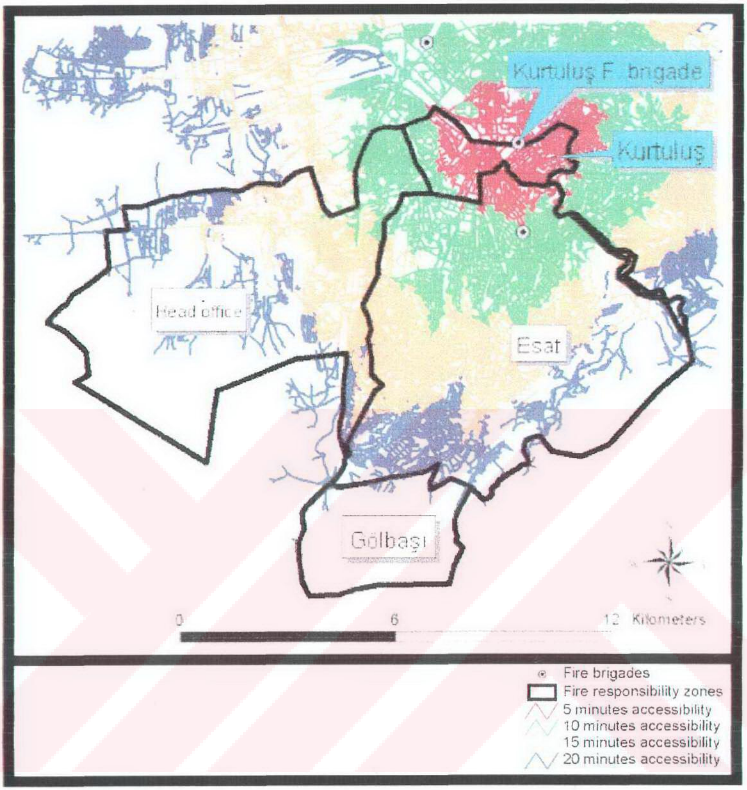


Figure 5.13: Fire service accessibility of Kurtuluş fire brigade

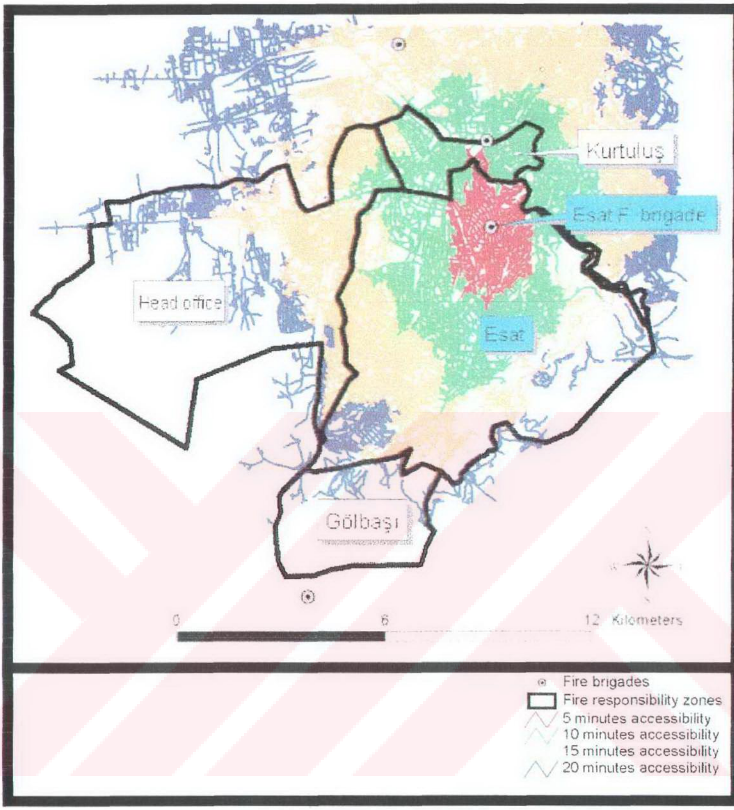


Figure 5.14: Fire service accessibility of Esat fire brigade

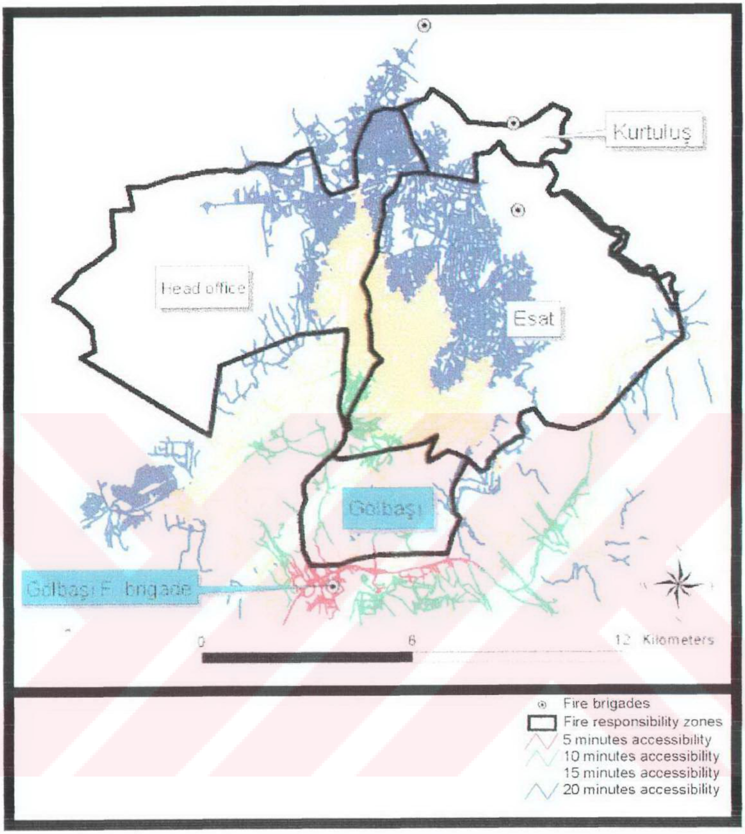


Figure 5.15: Fire service accessibility of Gölbaşı fire brigade

When the accessibility of each fire brigade are examined separately in their responsibility zones (Table 5.4), 20,11% of the total area of head office fire responsibility zone are in accessed part of the responsibility zone. The rest of the area consisting Ortadoğu, Mustafa Kemal, Gökkuşağı Karapınar and Akpınar quarters cannot be accessed by head office fire brigade within thresholds.

91,94% of Kurtuluş fire responsibility zone are in accessed part of the responsibility zone and only a total part of 8% of Boztepe, Aşağı Imrahor, and Orta Imrahor quarters, cannot be accessed by Kurtuluş fire brigade within thresholds.

46,92% of Esat fire responsibility zone are in accessed part of the responsibility zone. The rest of the area consisting north part of Oran quarter, Dikmen, Ilker, Ata Huzur and Keklikpınarı quarters etc., cannot be accessed by head office fire brigade within thresholds.

26,96% of Gölbaşı fire responsibility zone are in accessed part of the responsibility zone and the rest part of the zone, Oran and Aşağı Dikmen, quarters, cannot be accessed by Gölbaşı fire brigade within thresholds. However the results in Gölbaşı responsibility zone shows difference from the other responsibility zones and mostly depends on the the restrictions on south Ankara transit highway.

When the total accessed area within thresholds in Çankaya district is analysed, 37,09% of the total area can be accessed within 10 minutes in normal traffic conditions. However it was 40,77% of the total area in accessibility analysis considering fire responsibility zones (Table 5.6) and it means that nearly 4% of the Çankaya district can be within NFRTS of 10 minutes, by small changes in fire responsibility zones.

Table 5.4: Total accessed area by fire brigades in normal traffic conditions by considering fire responsibility zones in Çankaya district

Fire responsibility zones	Total responsibility area (hectar)	%	Total Accessed area within 10 minutes	%
Head office service area	4901,94	38,72	986,14	20,11
Kurtuluş service area	727,58	5,75	668,96	91,94
Esat service area	5740,04	45,34	2693,29	46,92
Gölbaşı service area	1290,13	10,19	347,86	26,96
Total	**12659,69**	**100**	**4696,25**	**37,10**

By the help of the overlay analysis between fire response zones and accessibility analyses, the regions that cannot be accessed because of current fire responsibility zones can be extracted as in Figure 5.16 and Figure 5.17.

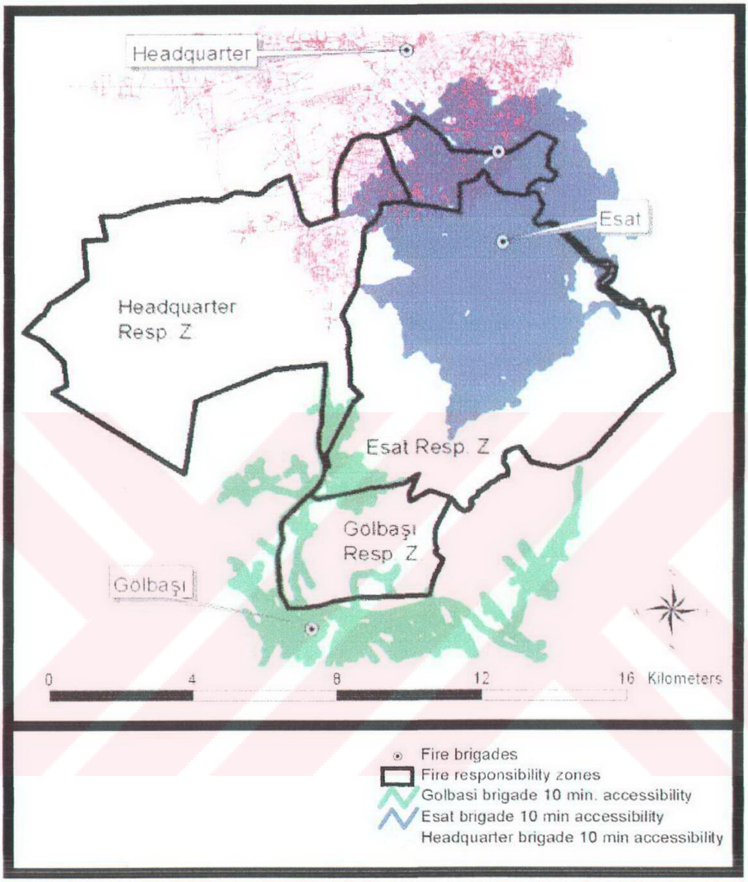


Figure 5.16: Fire service accessibility of Head office, Esat and Gölbaşı fire brigades within 10 minutes

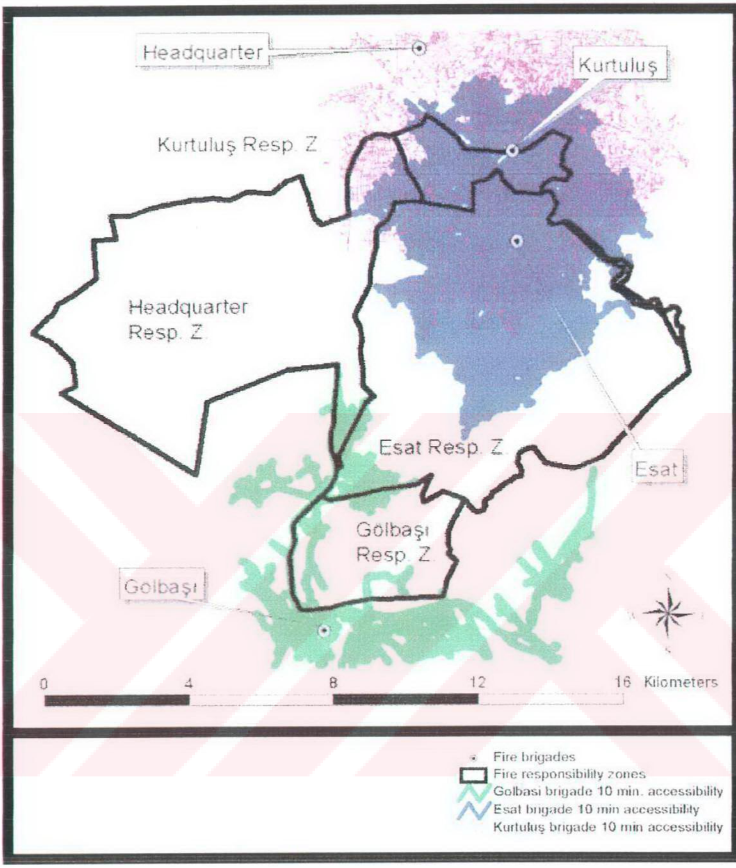
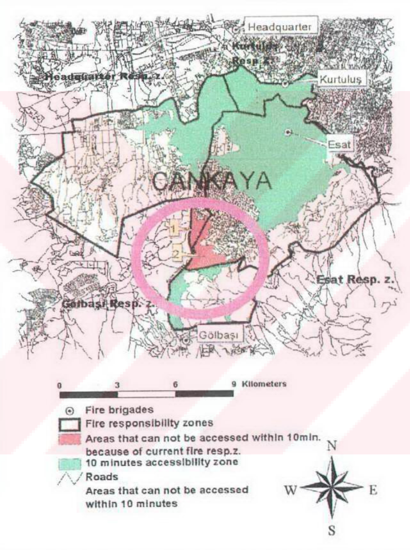
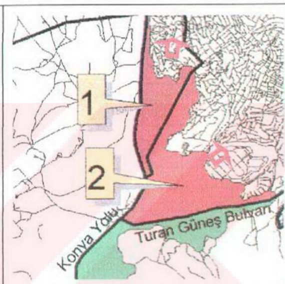


Figure 5.17: Fire service accessibility of Kurtuluş, Esat and Gölbaşı fire brigade within 10 minutes

According to the results, a total of 314,81 hectars which 95,76 hectars in Head office fire responsibility zone (Region1) and 219,10 hectars in Esat fire responsibility zone (Region2) can be more quickly accessed by Gölbaşı fire brigade (see Figure 5.18). An enlargement in fire responsibility zone of Gölbaşı fire brigade in a way that contain these areas, can open a road to increase the total amount of areas within NFRTS of 10 minutes.

Inaccessible areas because of current fire responsibility zones





Region1: Areas in Head office fire responsibility zone but accessed by Gölbaşı fire brigade within 10 minutes

Region2: Areas in Esat fire responsibility zone but accessed by Gölbaşı fire brigade within 10 minutes

Figure 5.18: Inaccessible areas because of current fire responsibility zones

When the districts, more quickly accessed by Gölbaşı fire brigade are analysed; Oran, Dikmen, Keklikpınarı Gökkuşağı Akpınar and Karapınar quarters are not within Gölbaşı fire responsibility zone but can be accessed more quickly by Gölbaşı fire brigade as seen in Figure 5.19.

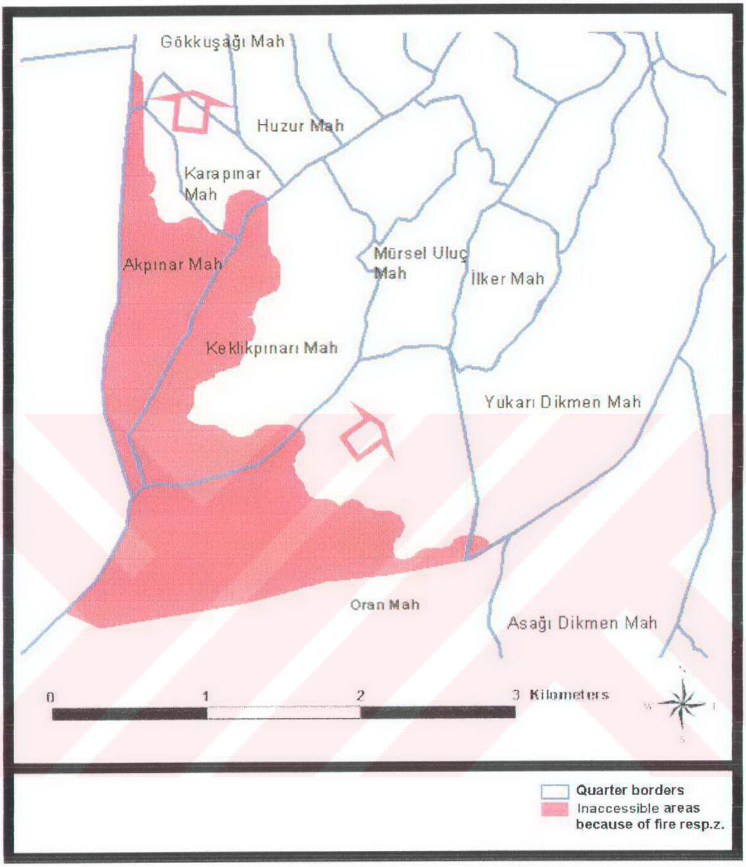


Figure 5.19: Inaccessible districts because of current fire responsibility zones

It is also possible to analyse inaccessible areas in building detail (Figure 5.20). Nearly 900 residential buildings, 1 industrial building and 35 public buildings could be accessed within 10 minutes, if Gölbası fire responsibility zone is enlarged in a way that contain the inaccessible areas.

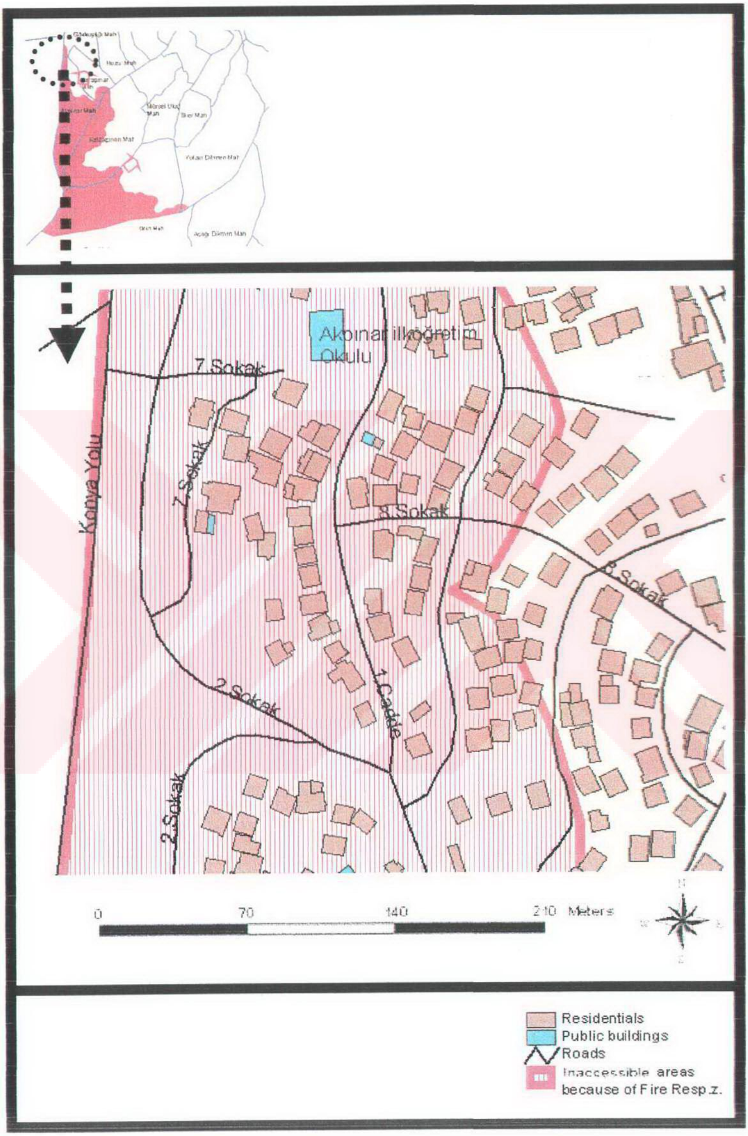


Figure 5.20: Inaccessible buildings

When the landuse types which are inaccessible according to current fire responsibility zones but can be accessed within 10 minutes by Gölbaşı fire brigade are analysed; there are 78,61 hectares forest area, 161,5 hectares residential area, 3.26 hectares administrative area, 1,55 hectares parks and green zones and 70 hectares vacant area as in Figure 5.21; Table 5.5.

Figure 5.21: Inaccessible landuse types because of current fire responsibility zones

Table 5.5: Total area of inaccessible landuse types because of current fire responsibility zones

Landuse type	Total area (Hectar)
Forest	78,61
Vacant areas	69,89
Residence	161,5
Administrative	3,26
Parks-Green Zones	1,55
TOTAL	**314,81**

When the educational, health and security services which are inaccessible according to current fire responsibility zones but can be accessed within 10 minutes by Gölbaşı fire brigade are analysed; there are 5 primary education schools; Akpınar, Fatih Çalda, Mehmet Içkale, Süleyman Uyar and Oran, 1 health center; Akpınar health center and 1 police station; Mustafa Düzgün Police Station as in Figure 5.22.

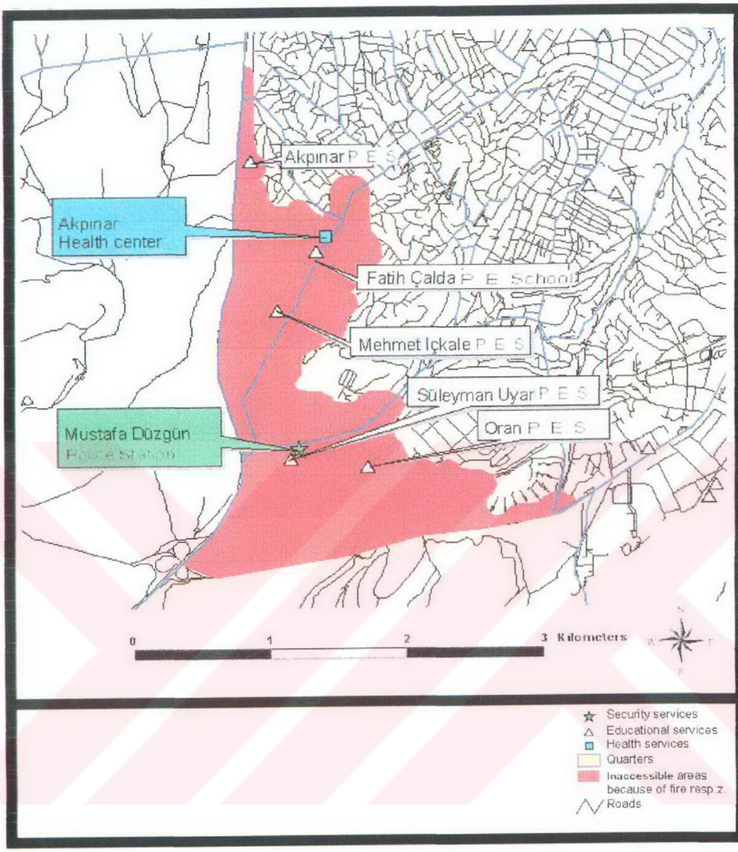


Figure 5.22: Inaccessible health, education and security services because of current fire responsibility zones

CHAPTER 6

CONCLUSIONS

The aim of this thesis was to measure the fire service accessibility in Çankaya district of Ankara by using GIS technology. Measuring fire service accessibility would enable the decision makers, who are local authorities including civil defence, fire service providers, department of planning, to understand the ability of response units to provide timely response, would open a road for the estimation of critical zones according to critical response time thresholds, determination of critical buildings, landuse and services in critical zones and would enable responders to take effective precautions in order to minimise the possible loses. That is why fire service accessibility is a vital concept in fire preparedness and has a leading role in reducing casualties.

The study mainly tried to find out the answers for the following questions in order to be able to take necessary precautions for fire preparedness;

- Which parts of the Çankaya district could not be accessed by fire brigades within critical time thresholds?

- Which critical urban services (education, health etc.) are found in these critical areas?

In this respect, the study consisted of a review of literature on accessibility and preparedness. The review of the literature about accessibility in second chapter was used to understand and define the accessibility measures, measurement techniques and database components of accessibility. The main focus in the study was on fire service accessibility concept; therefore, the review of the literature about fire preparedness in third chapter was handled generally, in order to understand the critical fire response time thresholds. The review of the literature about fire preparedness also helped to understand what extent the accessibility results could be used as a baseline to take precautions and to reduce the probable losses in inaccessible areas according to critical response time thresholds.

When fire process is investigated, approximately the first 20 or 30 minutes can be accepted as the most effective threshold time to respond to a fire and initiate an interior attack. However one third of this 20 or 30 minutes (5 – 10 minutes) is the time that generally passes for the report of fire to the fire department and fire alarm. In this case there is only maximum 20 minutes time left to intervene a fire. Furthermore the used materials in many buildings necessitate to be responded in less than 20 minutes (10-15minutes). In the light of the above-mentioned facts; the critical threshold for fire response was accepted as 10 minutes which is also maximum NFRTS, suggested by NFPA.

Chapter five presented the final fire service accessibility analyses and their results in Çankaya district of Ankara including;

- critical urban areas and facilities that can not be accessed in no way by fire services within critical time thresholds, (these areas were extracted by accessibility analyses without considering fire responsibility zones) and

- critical urban areas and facilities can not be accessed within critical time thresholds because of current fire responsibility zones of fire services (these areas were extracted with considering fire responsibility zones) and proposals for fire responsibility zones

When accessibility analyses with no consideration of fire responsibility zones are considered, main findings of the study, extracted from the accessibility analyses can be gathered under 7 headings;

i. When the accessibility maps of heavy, normal and light traffic conditions are examined, 20,46% of the district can be accessed within 10 minutes in heavy traffic conditions, 40,77% of the district can be accessed within 10 minutes in normal traffic conditions and 62,75% of the district can be accessed within 10 minutes in light traffic conditions. Even in light traffic conditions, the whole district of Çankaya can not be accessed by fire brigades within NFRTS of 10 minutes.

In normal traffic conditions;

ii. 29 of 102 quarters have more than 10 minutes accessibility by fire services. Some of the widely known quarters in the critical zone are Dikmen, Öveçler, Söğütözü, Oran, Ortadoğu, Keklikpınarı, Karakusunlar, Ilker, Ata and Çukurambar quarters,

iii. The critical landuse types which have more than 10 minutes accessibility by fire services are mainly formed by forest areas with 2988 hectar, 39,55% and residential areas with 1366 hectar, 17,88%, administrative usages with 795 hectar, educational usages with 507 hectar, military usages with 246 hectar, and etc. in Çankaya district,

iv. 3 of 8 universities, which include Middle East Technical University, Bilkent University and Hacettepe University can not be accessed in no way by fire brigades within NFRTS of 10 minutes.

v. 44 of 150 schools which include among others are, Tevfik Fikret Primary School in Mustafa Kemal quarter, Bilkent High School in Ortadoğu quarter, Balgat Technical High School in Öveçler quarter, ODTU Private High School in Ortadoğu quarter, Bilim Private High School and Ayşeabla Private High School in Karakusunlar, Sevgi Private High School in Dikmen quarter, Arı Private High School in Çukurambar can not be accessed in no way by fire brigades within NFRTS of 10 minutes.

vi. 3 of 16 health centres, which are Mustafa Kemal health center in Mustafa Kemal quarter, Yüzüncüyıl health center in Ortadoğu quarter and Cevizlidere health center in Cevizlidere can not be accessed in no way by fire brigades within NFRTS of 10 minutes and

vii. 1 of 11 police department which is Dikmen Police Station in Osman Temiz quarter can not be accessed in no way by fire brigades within NFRTS of 10 minutes.

When accessibility analyses with consideration of fire responsibility zones are analyzed in normal traffic conditions, main findings of the study, extracted from the accessibility analyses can be gathered under 4 headings;

i. A total of 314,81 hectares of which 95,76 hectares in headquarter fire responsibility zone and 219,10 hectars in Esat fire responsibility zone, can be more quickly accessed by Gölbaşı fire brigades within NFRTS of 10 minutes,

ii. Oran, Dikmen, Keklikpınarı Gökkuşağı Akpınar and Karapınar quarters can be accessed more quickly by Gölbaşı fire brigade,

iii. 78,61 hectar forest area, 161,5 hectar residential area, 3,26 hectar administrative area, 1,55 hectar parks and green zones and 70 hectar vacant area can be accessed more quickly by Gölbaşı fire brigade by an enlargement in fire responsibility zone of Gölbaşı fire brigade,

iv. 5 primary education school Akpınar, Fatih Çalda, Mehmet Içkale, Süleyman Uyar and Oran, 1 health center, Akpınar health center and 1 police station Mustafa Düzgün Police Station can be accessed more quickly by Gölbaşı fire brigade by an enlargement in fire responsibility zone of Gölbaşı fire brigade.

Throughout the study the objectives of the research are achieved. The main findings of the study that gained from the evaluation of accessibility maps can be useful for fire departments for focusing on areas or zones that are inaccessible within critical time thresholds and can be used by decision makers to take effective precautions in order to minimise the possible loses in fire case. These precautions can be summarized as:

- Strengthening or building new fire stations closer to inaccessible areas,

- Deployment of fire stations in order to minimize inaccessible areas (Distribution of current fire staff and equipment into smaller and widespread stations considering critical areas),

- Replacement or deployment of critical facilities if necessary,

- Improving transportation network from fire stations to inaccessible areas (new traffic arrangements for example organizing emergency bands on roads to speed up response),

- Improving the fire resistance of buildings and physical structures,

- Improving fire communication opportunities,

- Legislative obligations for improving fire resistance of buildings by using fire resistant materials in constructions,

- Legislative obligations for building fire warning systems (alarm) and fire sprinkler systems (automatic fire extinguishment systems) in constructions (especially for inaccessible areas),

- Legislative obligations for fire insurance in critical areas.

The results of accessibility analyses created for Çankaya district of Ankara was site specific. Because it was built with the local values and inputs of the district. However the measures, measuring techniques, data and the general steps for measuring accessibility can be adapted to elsewhere for different aims and studies.

This thesis can be improved by several further studies gathered under five headings:

i. In this study, only restrictions on main roads could be taken into consideration because of the size of the data. The further step can be editing of the database for traffic restrictions of all roads.

ii. In this study, the average speeds obtained from Ankara Metropolitan Municipality Office of Information Systems and from the interview with fire truck drivers from Head Office of Fire Brigades (İskitler) were used. It would increase the reliability of the study to use more detailed average speeds based on local traffic analyses for all roads in different time periods of the day.

iii. In this study, separated roads had to be represented by single lines and turntables were used to adapt turn restrictions to the database because of the structure of the road data, obtained from Ankara Metropolitan Municipality Office of Water and Infrastructure. In further studies it would be better to represent separated roads by double lines in the database. Because representation of separated roads by double lines in the network can enable more realistic network analysis.

iv. The comparison of the accessibility maps with the actual response time recordings of fire brigades would be useful to understand the reliability of the results in further studies (for example, the response time record of İskitler fire brigade for a fire in mechanical engineering department of METU was 15 minutes on 13.10.1998 at 09:15pm and this result overlaps with İskitler fire brigade isochronal accessibility map in normal traffic conditions as in Figure 5.12).

v. In this study, only Çankaya district could be taken into consideration and analysed because of time and data size restrictions. It would be better and more meaningful to analyse accessibility for the whole of Ankara city, including all districts and by comparing all fire responsibility zones.

I believe that; this study can be accepted as a first step for building a more comprehensive fire management system and can be developed by further database improvements. For example; the developed study can be used as a part of a decision support system and help local authorities to manage fire related resources (human, vehicle etc.), to make prequeries for nearby places of the fire area, to analyse the fire service responsibility borders, to analyse the location of new fire brigades (for example the question of "What would change if one of the locations of fire brigade was changed?" or " What would change if another fire brigade was added?" can be answered). It can also provide a basis for an interactive route finding system that will allow fire services to assess, compare and select routes through urban areas (for example the question of "From which route in the city do fire service units have to travel to reach fire incident area?" can be answered easily).

As a final finding of the study, it can be easily pointed out that the contributions of GIS_based factors to the accessibility analyses were considerably great and essential. Using GIS in measuring accessibility will contribute to decision makers, responsible for planning, with the ability to visualize, organize and manipulate large volumes of spatially referenced data, and understand geographic patterns and trends that would otherwise be difficult to comprehend. GIS has a lot of strong capabilities in calculating the distances or costs in the spatially referenced transportation data, building regulations of streets such as one-way streets, closed streets, overpasses and underpasses, estimating driving times based on actual speeds of vehicles and the delays in intersections, extracting spatially referenced accessibility information from the databases, presenting accessibility results with opportunity of different scales and resourceful colour and figure choices.

It must never be forgotten that the success in all professional branches, related with geography, relies heavily on the success in collecting, structuring, evaluating and presenting the geographical information.

REFERENCES

Badri, Masood A., Mortagy, Amr K., Alsayed, Colonel Ali., (1996) "A Multi-Objective Model For Locating Fire Stations" *European Journal of Operational Research*, 110, 243-260

Chen, Qinglin., Weng, Wei., (1999) "Urban Accessibility Evaluation In Gis" http://mather.ar.utexas.edu/Courses/parmenter/gis/fall/index.html visited on 5.11.2001

Chen, Qinglin., (2000) "Measuring Accessibility in GIS" http://mather.ar.utexas.edu/students/cadlab/chen/measuring_accessibility_in_gis.htm visited on 7.01.2002

Çankaya municipality web page, http://www.cankaya-bld.gov.tr/cankaya_rakamlar.asp visited on 31.03.2003

Dong, Ben-Akiva., Bowman, John L., Walker, Joan., (1998) "Analysis of Activity-Based Accessibility" http://web.mit.edu/jwalker/www/JW_ABA.pdf visited on 21.12.2001

Emelinda, M. Parentela., Shashi K. Sathisan., (1995) "Gis-Based Allocation of Emergency Response Units Along A Transportation Route" *Aggricultural And Biological Engineering Purdue University* http://abe.www.ecn.purdue.edu/~aggrass/esri95/to200/p161.html visited on 12.10.2001

Englefield, Peter., Lee, Bryan., Suddaby,Rod., (2000) "Spatial Fire Management System" http://fms.nofc.cfs.nrcan.gc.ca/sfms/docs/cffdrs_e.html visited on 12.11.2001

Esri public safety literature "GIS for Fire Planning and response" http://www.esri.com/industries/public_safety/fire.html visited on 11.10.01

Esri, (1997) "Arcview Network Analyst", Environmental Systems Research Institute Inc., USA

Esri, (2000) "What GIS Can Do" http://www.esri.com/library/whitepapers/pdfs/fire_ems.pdf visited on 10.1.2002

Heritage Collections Council (2000) "Guidelines for Writing a Disaster Preparedness Plan" Australia, http://amol.org.au/craft/publications/hcc/beprepared/beprepared.ppt visited on 15.10.02

Halden, Derek., Mcguigan, David., Nisbet, Andrew., Mckinnon, Alan., (2000) "Guidance On Accessibility Measuring Techniques And Their Application", Scottish Executive Central Research Unit, http://www.scotland.gov.uk/cru/kd01/blue/guidance.pdf visited on 11.11.2001

Howard, Steve., (1997), "The City of Glendale Fire Map Book Database Development", Esri User Conference, Emergency Management and Public Safety

Gould, P., (1969), "Spatial Diffusion", Resource Paper No. 17, Washington, DC: Association of American Geographers

Joly, O., (1999), "Anexe 5, Part II : Recent Overview of Spatial Accessibility Indicators Applied In France: 1st Synthesis of The French Research Network Contributions", Study Program on European Spatial Development (SPESD) SDEC – France

Juliao, Rui Pedro., (1999) "Measuring Accessibility Using Gis" Geo-computation-99, http://www.geovista.psu.edu/sites/geocomp99/Gc99/010/gc010.ppt visited on 17.12.2001

Lake County Indiana Local Emergency Planning Commission "Emergency Management Glossary And Acronyms" http://www.lepc.co.lake.in.us/empglos.pdf visited on 1.12.02

Los Osos South Bay Fire Department, "Fire Response and Medical Response" "http://www.losososcsd.org/firedept.html#Response" visited on 11.9.02

Kemeç, S.,(2001), "Kavramsal Ve Kuramsal Boyutlarıyla Erişilebilirlik" Şbp482-Bitirme Ödevi, Şehir ve Bölge Planlama Bölümü, Gazi Üniversitesi

Kuntay, Orhan., (1990), "Erişilebilirlik Kesin Bir Öncelik" Planlama Dergisi, Journal of The Chamber of City Planners, 90/1-2, 7

Kuntay, Orhan., (1976a), "Planlama Kontrol Aracı Olarak Fiziksel Erişilebilirlik Ve Çekim Gücü", Şehircilik Enstitüsü Dergisi, 33-47, İTÜ, İstanbul.

Kuntay, Orhan., (1976b), "Mekanda Fiziksel Erişilebilirlik Ve Çekim Gücü", Basılmamış Doçentlik Tezi, K.T.Ü., Trabzon

Kwan, Mei-Po., (1998), "Space-Time And Integral Measures of Individual Accessibility: A Comparative Analyses Using A Point-Based Framework", Geographical Analysis,30/3, Ohio State University Press

Makrí, Maria Brodde., (2001) "Accessibility Indices. A Tool for Comprehensive Land-Use Planning" http://www.infra.kth.se/tlenet/meet5/papers/Makri.PDF

Makrí, Maria-Christina., Folkesson, Carolin., (1999) "Accessibility Measures for Analyses of Land Use and Travelling with Geographical Information Systems" Department of Technology and Society, Lund Institute of Technology, Lund University & Department of Spatial Planning, University of Karlskrona/Ronneby, Sweden

Meşhur M., C. (1997) "Fire Brigade Organization As An Urban Service" Unpublished Report, METU, Ankara

National Fire Protection Association NFPA "Codes and Standards" http://www.nfpa.org /Codes/index.asp visited on 12.08.02

National Fire Protection Association NFPA "about nfpa" http://www.nfpa.org/Home/AboutNFPA/index.asp visited on 12.08.02

National Public Employer Labor Relations Association "*Fire Group Abandons Minimum Response Time Standards for Now*" http://www.npelra.org/articles/nfpa.asp visited on 15.10.02

Peters, Jeremy., Hall,G. Brent., (1999) "Assessment of Ambulance Response Performance Using A Geographic Information System", *Social Science & Medicine*, 49, 1551-1566

Radke, J., Cova, T., Sheridan M., Troy, A., Mu, L., Johnson R. (2000), "Application challenges for geographic information science: implications for research, education and policy for emergency preparedness and response", Journal of the Urban and Regional Information Systems Association, 1 2(2), 1 5-30

Sarıkaya, Yasemin., (2001), "Defining Urban Fire Risk: Explatory Analysis of Fire Incidents With Socioeconomic Characteristics For Altındağ And Çankaya Districts, Ankara", Unpublished Master Thesis in Department of City And Regional Planning, Middle East Technical University, Ankara

Shields, T. J.; Silcock, G. W. H. (1987) Buildings and Fire, Longman Scientific And Technical, Newyork

Transportation Statistics Annual Report, (1997), "Mobility, Access And Transportation" http://www.bts.gov/transtu/tsar/tsar97/chap06.pdf visited on 23.12.2001

Xin, Han., Jie Li., Zuyan, Shen., (2000) "Non-autonomous coloured Petri net-based methodology for the dispatching process of urban fire-fighting" Fire Safety Journal, 35, 299-325

University of California Davis, Emergency Information "Glossary of Terms", http://planit.ucdavis.edu/howto/GLOSSARY.html visited on 15.12.02

University of Wisconsin Disaster Management Center "Aim and Scope of Disaster Management" http://dmc.engr.wisc.edu/courses/aimscope/AA02-intro.html visited on 7.11.02

University of Wisconsin Disaster Management Center "Disaster Preparedness" http://dmc.engr.wisc.edu/courses/preparedness/BB04-intro.htm visited on 7.11.02

United Nations Department of Humanitarian Affairs, "Internationally agreed glossary of basic terms related to Disaster Management" http://www.unisdr.org/unisdr/glossaire.htm visited on 1.12.02

U.S.Fire Administration Topical Fire Research Series, (2001),Volume 2,Issue 11 http://www.usfa.fema.gov/downloads/pdf/tfrs/v2i11-508.pdf visited on 15.10.02

Yalazı, Bülent., (1998) "Yangına Karşı Hazırlık", Unpublished Article.